Proceedings of the
19th European Conference on
Games Based Learning
Nord University, Levanger, Norway
1-3 October 2025

Helga Dis Isfold Sigurdardottir
and
Robin Isfold Munkvold

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Levanger, Norway

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Conference Proceedings Edited by

Helga Dis Isfold Sigurdardottir and Robin Isfold Munkvold

Volume 1

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Contents

The papers in these proceedings were presented at the conference in sessions organised by topics, but are presented here by type of paper and then alphabetically by lead author surname.

Preface **xviii**

Committee **xix**

Biographies **xxi**

Academic Papers

Best Practices in Cross-Sector Partnerships for Educational Game Design
Jacob Abell, Lynn Ramey 1-8

A Structured Approach for Designing Effective Serious Games for Learning:
Analyzing Requirements to Derive Key Components
Zahara Al-Awadai 9-18

Cultural Games Creation: An Applied Game Jam Model
Wilson Almeida, Filipe Luz, Maria Gonçalves, Inês Nunes, Maria Micaela Fonseca 19-28

Learning While Developing a Game: The Case of an Introductory
Course on Industrial Engineering and Management
Helena Alvelos, Andreia Hall, Sónia Pais, Ana Rosa Damas,
Lara Pinto Pereira, Marta Rocha, Rafael Ferreira 29-35

Educational Games for Indirect Length Comparison in Sighted and Blind Students
Archontoula Arvanitaki, Chrysanthi Skoumpourdi 36-43

Railway Quest: A Gamified Teaching Platform for Concurrent and Parallel Programming
Masiar Babazadeh, Diego Frei, Massimo Bortolamei, Mirko Gelsomini,
Adriano Cicco, Loris Bruno, Tiziano Leidi 44-53

Transforming Math Anxiety into Engagement:
The Impact of RPG-Based Gamification on Middle School Students
Masiar Babazadeh, Massimo Maffioli, Rossana Falcade 54-63

Creation of Retro Games Room Supporting Student Belonging
Gavin Baxter, Tom Caddell, Thomas Hainey 64-73

From Curriculum to Gameplay: A Workshop Method for Educational Game Design
Wolfgang Brabänder, Gielisch Ruben, Caserman Polona, Langer Kaja,
Scharrer Lisa, Wiemeyer Josef, Göbel Stefan 74-84

Preparing the eLuna Visual Language for Human-AI Co-Specification and Code Automation
Fredrik Breien, Francine Schevenhoven 85-93

CiteSaga: Lessons Learned in Serious Game Development for Academic Integrity Education
Lance Bunt, Byron, Gordon, Veruschka 94-100

Evaluating Multiplayer Game-Based Training for Earthquake Evacuation: A Systematic Review
Berfin Deniz Çakmak, Ahmet Gün 101-109

Bridging Theory and Practice: Evaluating a Game-based VR Approach in Construction Education
Arda Çalışkan, Suzan Girginkaya Akkdağ 110-118

Implementing Tabletop Role-Playing Games for Workplace Learning:
The ADVENTURE Framework in Practice
Davide Capobianco, Flavio Manganello 119-127

Immersive Game-Based Experiential Learning for International Business Challenges
Aline Castillo Moreno, Mario Alberto Caudillo Melgoza 128-133

Advanced Gamification to Enhance Lifelong Learning: A Second Hybrid Implementation
Mario Alberto Caudillo Melgoza, Manuel Antonio Caudillo-Melgoza 134-141

Immersive Virtual Reality Experience for Informed Career Decision-Making
Manuel Antonio Caudillo-Melgoza, Mario Alberto Caudillo Melgoza 142-148

Using VR as a New Pedagogical Approach for Food Science and Technology Education in Hong Kong
Hin Yeung Chan, Sze-Tsan Clifford Choy 149-158

Innovative Game-Based Teaching of Entrepreneurship for Secondary Education:
The Little Business Leader
JianYuan Chen, Qisheng Han 159-167

The Great Garbage Patch: The Bionauts' Challenge – An Educational Escape Room on Marine
Plastic Pollution and on Possible Solutions
Fabio Chiarello, Roberta Angelini, David Becerril, Alessio Cimino, Claudia Ceccarelli,
Fabio Di Pietrantonio, Claudia Fasolato, Daniela Fioretti, Sandra Iurescia, Sara Laureti,
Barbara Ruzicka, Luisa Bracci Laudiero 168-172

Game Design and Teaching for Understanding
Michael Cosgrave 173-181

Bringing Healthcare-Level Hand Hygiene Skills to Children Through Iterative App Design
Stuart Criley, David Ing, Dan Khanh Tran, Lucas Leprince, Williams Criley, Richard Criley,
Aaron Chang, Jasminka Criley 182-192

Future Teachers' Perceptions of Different Educational Escape Room Designs
Mária Čujdíková, Katarína Jánošková, Peter Vankúš 193-200

Framing the Development of a Gamified App for m-Health and Well-Being
Francesca Maria Dagnino, Nicolò De Salvo, Jana Goldberg, Nadine Sturm,
Gorica DjoKic, Łukasz Klapa 201-208

AI-Powered Game-Based Learning for Project Management Education
Matthew Daniels 209-216

Trust, Pedagogy and Play
Suzanne de Castell, Jennifer Jenson 217-225

Understanding Systems Engineering Decision-Making Through Game-Based Simulation:
Insights from Industry
Sherly Agnes Reni Denis, Marcus Pereira Pessoa, Maarten Bonnema 226-233

Designing Meaningful AI-Generated Dialogue: The Behaviour-Driven Conditional Prompting
Framework for Serious Games
Kamiel Berend de Visser, Anders Bouwer, Ivo Swartjes 234-243

Italian Teachers' Attitudes and Competence According to the Acceptance Game-Based Learning (AGBL) questionnaire
Maria Clara Dicataldo, Marika Lamacchia, Francesco Facciorusso, Massimiliano Andreoletti, Andrea Tinterri 244-251

Designing a User-Centred Adaptive Gamified Learning System: A Multidisciplinary Approach from Pedagogy to Artificial Intelligence.
Moataz Elkady, Michele Dassisti, Elvira Zazzera, Giambattista Stigliano 252-260

Increasing STEM Career Interest in Middle Schoolers Through a Health-Themed Serious Game
Jasminka Vukanovic-Criley, Benjamin Emihovich, Nelson Roque, Williams Criley, Richard Criley, Stuart Criley, Jasmine Alagoz 261-270

Enhancing Art Education for Generation Z through Immersive Virtual Reality
Ana Laura Escobedo Navarro, Mario Alberto Caudillo Melgoza 271-277

Change the Game with Vaccines: a "Play and Learn" Workshop for Science Education
Daniela Fioretti, Fabio Chiarello, Luisa Bracci Laudiero, Sandra Iurescia 278-284

Design of 2D Rhythm-Based Shooting Game for Skill Development
Lanlan Gao, Hongyi Lan 285-293

Game-Based Learning: A Scoping Review of Research in Higher Education
Jordana Garbati, Nicole Skrepnek 294-301

Polimatrix: Conversation Analysis as a Method for Evaluating Performance in Matrix Games
Christopher Gledhill, Lichao Zhu, Natalia Zwarts 302-310

Augmenting Spatial Learning and Problem-Solving in Game-Based Education Through Virtual Environments
Tuğçe Gökçen Kütüklü 311-321

A Systematic Review of Serious Games for Training Emotion Regulation Skills in Preschool Children
Catarina Gonçalves, Eliana Silva, Luís Paulo Reis 322-328

Enhancing Learning Through VR Game Design in Higher Education
Cristina Veronica Gonzalez Cordova, Claudia Marcela Solis Garza 329-338

Teaching Industrial Engineering Through Simulators Based on Gamification and XR Reality
Carlos Alberto Gonzalez Almaguer, Anna Sofia Rivera-Aguirre, Leonardo Cervantes Perez, Santiago Alducin Villaseñor, Juan Manuel Murillo, Rommel Pacheco Hernandez 339-347

Teacher Positions and Play Qualities in Esports at Specially Planned Youth Education Programmes
Peter Gundersen, Thorkild Hanghøj, Erik Ottar Jensen 348-356

Tiers of Engagement II: Profiling the Characteristics of User Engagement and Motivational Tiers in Business Simulators
Martin Guttormsen, Jørn Weines 357-367

Beyond Traditional Teaching: Games and Origami as Tools for Mathematics Learning
Andreia Hall, Sónia Pais, Paola Morando, Maria Luisa Sonia Spreafico 368-377

Social Inclusion of Vulnerable Youth Through Esports Education
Thorkild Hanghøj, Peter Bukovica Gundersen, Anna-Katrine Frørup 378-386

Comic4Welfare – An Interactive Comic-Based E-Learning Platform for Animal Welfare Education
Akshatha Hariharan, Ido Iurgel, Steffi Wiedemann, Anabela Parente,
Anja Waldmann, Jana Marielle Kalb 387-395

Exploring Sustainability Through Board Game Design as a Learning Approach in Schools
Birgitte Henningsen, Erik Ottar Jensen, Anders Simmelkiær Laraignou, Thorkild Hanghøj,
Heidi Hautopp, Nanna Klingenberg Andersen 396-403

Board Games and Mathematics: A Winning Strategy for Teaching Rational Numbers
Anabela Hilário, Andreia Hall, Sónia Pais 404-413

Quest: Journey Through the Lifespan: Gamified Learning for Engagement, Empathy,
and Real-World Application
Rebecca Howell 414-419

Tailored Gamification in Manual Assembly: System Implementation and Study
Design for Long-Term Evaluation
Johannes Hug, Jörg Wollert 420-428

Needs Analysis to Define a Digital Learning Game Aimed at Coping with Mathematics Anxiety
Jenni Huhtasalo, Mirka Leino, Janika Tommiska, Sonia Palha,
Ljerka Juki´c Mati´c , Leonard Busuttil, James Calleja, Sari Merilamp 429-437

Impact of Math Ludo on Skills in Students with Dyscalculia
Fatemeh Jafarkhani, Mohamad Baqer Hasanvand, Seyed Ali Hosseini, Ali Shirkarami 438-445

Dialogic Teacher Facilitation of Esports Activities for Vulnerable Youth
Erik Ottar Jensen, Thorkild Hanghøj, Emma Svendsen, Peter Bukovica Gundersen 446-453

It's Going to be Amazing: Exploring Children's Game Play and Making
Jennifer Jenson, Nora Perry, Suzanne de Castell 454-461

When the Coyotes Slept, They Could see Stars, Liquor and Smoke: Creativity,
Engagement, and Play in Recombinatory Writing Games (RWGs)
Allen Jones 462-470

Who Learns from City Games? Examining the Role of Motivation, Personality, and Experience
Joshua Juvrud, Nabeel Bhimani, Alina Dau, Comfort Randolph, Lillian Shattuck, Curt Gurvich 471-481

Gamification for Enhanced Recycling Engagement in Circular Economies
Timo Kahl, Ubaida Dib, Marwin Wiegard , Frank Zimmer 482-490

Designing AI-Enhanced Educational Digital Escape Room Games (EDERGs):
A Framework for Teacher Implementation
Merve Kara, Zeynep Cömert, Yavuz Samur 491-498

Fostering Data Literacy Through the Delta i Data! Game Package: Teacher Insights
Fride Haram Klykken, Rosaline Barendregt 499-506

A Physical Chemistry Escape Room With 4 Metals
Michaela Kröppl 507-514

From Chance to Strategy: Advancing Educational Games about Vertebrates for Elementary Students
Nantarat Kruea-In, Kulthida Nugultham, Thanarat Taewattana, Kittiphan Wiboonsin 515-524

Development of a Serious Game for Practicing Pronouns
Joanne Lawrie, Thomas Hainey, Gavin Baxter 525-533

Games Inclusion Lab: Accessible Games with Neurodivergent Adults Through Iterative Play and Design
Filipe Luz, Cátia Casimiro, Pedro Fernandes, Pedro Gouveia, João Freire, Carla Sousa 534-542

From Code to Character: Investigating Personality in Generative AI-Driven Educational Avatars
Gunver Majgaard, Maria Skougaard Andersen 543-551

AI Exploratorium: A Gamified Interactive Exhibition for Developing Critical AI Literacy
Tina Maljur, Jasminko Novak, Jessica Laufer, Sarah Gnoth 552-560

Defeating V.I.L.E. with Carmen Sandiego: GBL and Gamification for
Teenagers with Intellectual Disabilities
Ana Manzano León, Paula Rodríguez-Rivera 561-568

Testing the Game: Gamma Finance as a Design-Based Prototype for
Financial Literacy in Higher Education
Lina Margarita Marrugo-Salas, Andrés Alejandro Laborde-Contreras,
Alba Zulay Cárdenas-Escobar, Natalie Morales-Londoño, Jorge Javier Monsalve-Morillo 569-579

Game Over (GO!): A Transformative Model for Entrepreneurship Education
through Game-Based Experiential Learning
Lina Margarita Marrugo-Salas 580-590

Enhancing Student Engagement and Knowledge Retention through Game-Based Learning:
A Comprehensive Framework Integrating Game Design and Learning Theories
Gordon Matthew, Veruschka Pelser-Carstens, Byron Bunt, Lance Bunt 591-599

Expert Validation of an Empathic Design Thinking Framework:
For Digital Serious Game Development
Raluca Ionela Maxim, Joan Arnedo-Moreno 600-607

Development of a Serious Game for British Sign Language Education
Lara E. McIntyre, Thomas Hainey, Gavin Baxter 608-616

From Perception to Participation: A Case Study of Gamified
Learning in Engineering Education
Elizabeth Mena-Avilés, Alejandro Martínez-Borquez, Jorge Arturo Ruelas-Mejía,
Rodolfo Mendoza-Gómez, Iván Miguel García-López 617-624

Sudoku-Based Educational Games for Developing STEM Skills
Vedrana Mikulić Crnković, Bojan Crnković, Martina Holenko Dlab, Ivona Traunkar 625-633

Creating the Foundation for a Virtual Game-Based Learning Lab to Stimulate Distance Education
Peter Mozelius, Andreas Hellerstedt 634-640

Designing a Role-Play Activity about Social-Emotional Learning for
the Indian Context Based on the Integrated Design Framework for Playful Learning
Ekaterina Muravevskaia, Bicky Kuriappan, Karen Schrier 641-647

Evaluating Cybersecurity Awareness in Employees Using Gameplay:
Data and Machine Learning Models
Mike Wa Nkongolo, Mahmut Tokmak 648-657

Conceptual Understanding and Systems Thinking Skill in Carbon Neutralization
in Farming Role Play Board Game for Science Teacher Professional Development
Kulthida Nugultham, Sunisa Thapseang, Nantarat Kruea-In, Tussatrin Wannagatesiri 658-664

Beyond the Game: Identity, Ethics, and the Transformative Power of Role Play in Business Simulations
Michael P. O'Brien, Yvonne Costin, William Hogan 665-673

Megagames as a Methodology to Foster Learning in Higher Education
Sonia Palha, Anders Bouwer, Erwin van Crasbeek, Daan van Smaalen 674-681

Analogue Games and Digital Literacy: The NetSmart Case Study with Older People
Claudilene Perim, Carla Sousa, Manuel José Damásio 682-688

Managing Resources and Reducing Greenhouse Gas Emissions Through Game-Based Learning to Achieve Zero Emission Farms
Sobah Abbas Petersen, Andreas Haestad, Kay Lyngedal, Thomas Evja Thingsaker 689-697

Investigating Pupils' Motivation with a Reward-Driven Feature in a Game-Based Learning Environment
Inès Plessis-Ouzariah, Hoang Qui Cung, Thierry Geoffre, Aous Karoui, Lionel Alvarez 706-715

Level-Up Tutor-Qualification: A Digital Escape Room for Game-based Learning in Higher Education
Michelle Pippig, Sabrina Hänsel 698-705

Phygital Game-Based Learning in Early Childhood Education: An Exploratory Review
Tanmoyee Rajkhowa 716-724

The Role of Gamification in Learning Transfer: Does Early Skill Learning Predict Performance in Complex Tasks?
Katharina Richter, Michael Kickmeier-Rust 725-732

The Spectrum of Abstraction and Realism in Serious Games for Learning
Kristina Risley, Zoltan Buzady, Liang Xu 733-741

Embedding Reflective Game Design (RGD) into Digital Game Based Learning: Design Recommendations and Empirical Insights
Anjuman Shaheen, Panagiotis Fotaris 742-750

Gamification in Volunteer Feedback: Do Digital Rewards Really Work?
Kim Siebeneicher, Edit Söderqvist, George Palamas 751-759

AmendMe: A Tabletop Game to Teach the European Parliament's Legislative Process
Martin Sillaots, Mikhail Fiadotau 760-768

Co-Designing Visual Novels in Literary Education Classes: Instruments for Measuring Learner Engagement
Cláudia Silva, Marlene da Rocha Migueis, Filipe T. Moreira 769-775

Bridging Virtual and Real: Gamification in Teaching Architectural Features with Assassin's Creed Odyssey
Nagehan Yağmur Şimşek Sönmez 776-788

Mastery Learning as Gamification: Level-Up Through High-Transparency Assessments
Guttorm Sindre, Line Kolås 789-797

Escape Room Challenges to Foster Engagement and Skills in Computer Science
Claudia Marcela Solis Garza, Cristina Veronica Gonzalez Cordova 798-808

Modeling Language Acquisition in Commercial Off-the-Shelf Games: A Multiple Case Study
Leonardo Sorrentino 809-816

SOL977: Ingenious Revival – A Martian Simulation Game for STEM Engagement and Space Education
Irini Sotiriadou, Vasilis Zafeiropoulos, Dimitris Kalles, Theophanis Orphanoudakis 817-825

Using AI and Cognitive Taxonomies to map Learning Processes in Board Games
Andrea Tinterri, Federica Pelizzari, Marilena di Padova 826-834

Serious Game Design and Evaluation: Light Propagation and Reflection in Elementary Education
Anastasia Tsita, Aikaterini Baziakou, Angelique Dimitracopoulou 835-844

A Preliminary Analysis of Gamification on Assembly Language Programming Education
Muhtar Çağkan Uludağlı 845-854

Designing Limes Text: Adapting an Educational Video Game into a Text-Based Format for Controlled Experimental Comparisons
Amedeo Viccari, Lisa Bardach 855-863

Playful Citizen Discussion Space to Help Steer Society Towards Water Security
Paul Watson, Rebecca Harris, Paul Hollins, Simon Egenfeldt-Nielsen, Katharina Koller, Claudia Fabian, Barbara Kieslinger 864-872

Enhancing Cybersecurity Education Through Multi-Opposing-Role Gameplay and Simulations
Nipuna Hiranya Weeratunge, Rune Hjelsvold 873-882

Enhancing Cybersecurity Learning with In-Game Feedback
Nipuna Hiranya Weeratunge, Rune Hjelsvold 883-891

From Barriers to Bridges: AI-Powered Mini-Games for Accessible Game-Based Learning
Antje Wild, Florian Neymeyer 892-900

Secret Hacker: A Learning-Based Cybersecurity Game for Group-Based Settings
George Wolf-Jackson 901-909

The Reach of Digital Games and Their Potential as Global Communication Tools
Jane Yau, Rebecca Harris, Paul Hollins, Anchal Garg, Pradeep Hewage, Jude Ower, Joost Schuur, David Griffiths, Paul Watson, Celestine Iwendi, Hendrik Drachsler 910-917

PhD Papers

Towards a Tasks-Interactions-Environment (TIE-SSG) Framework Guiding Integration of Serious Games in Education for Enhanced Practical, Clinical Competences
Tord Frøland, Ilona Hedal, Elisabeth Ersvær 919-928

Tasks-Interactions-Environment for Simulations and Serious Games (TIE-SSG) Framework: Exploring Practical Applications
Tord Frøland, Elisabeth Ersvær, Ilona Hedal 929-940

A Theoretical Model for Game Mechanics: Bridging Design Practice and Education
Rafael Marques de Albuquerque, Flávio Anthero Nunes Vianna dos Santos 941-947

Have you Ever Experienced Someone Else's Breakup in First Person?
Suvrangshu Barua, Martino Pagliarani 948-956

Threat Forge: Using a narrative game to explore future societal challenges
peadar Callaghan 957-963

With or Without You: A Comparison of Single and Multi-Player Game-Related Assessments
Tobiasz Jan Narymiecki 964-971

Light Up: Educational Board Games with FLOW and Experiential Learning Theory
Saowaluk Poommarin 972-980

A Pilot Study Investigating Teachers' use of Video Games in Programming Lessons
Neil Rickus 981-990

Masters papers

Tangential Learning in Board Game Design to Introduce Peranakan Culture
Shanty Rahayu, Sri Rachmayanti 993-999

Teaching the Solar System with a Video Game
Dongzhou Fang, Helmut Hlavacs 1000-1008

Enhancing holistic development though exergame-based learning
Nanna Jacobsen, Lars Elbæk 1009-1019

Impact of Ashiyan Board Game on Iranian Students' Understanding of Native Vertebrates
Mostafa Omidi, Fatemeh Jafarkhani, Ali Shirkarami 1020-1026

Rewriting History: How Digital Games are Revolutionising NSW Secondary History Classrooms
Shea Louise Rigney, Dr Nathan Berger, Dr Roberto Parada 1027-1036

Enhancing Programming learnability for Children through Video Games
Nora Volina, Helmut Hlavacs 1037-1046

Non Academic paper

A Serious Game that builds Energy Literacy through Communication and Collaborative Gameplays
Liu Qi Chen, Camarine Heng 1049-1058

Innovative Game-Based Teaching of Entrepreneurship for Secondary Education: The Little Business Leader
JianYuan Chen, QiSheng Han 1059-1068

Work in Progress

A Co-Design Protocol for a Serious Game Supporting Emotion Regulation in Children
Bárbara Carvalho, Eliana Silva, Luís Paulo Reis 1071-1074

Serious Games in a Graduate-Level Human Physiology Course
Arne Kristian Christensen 1075-1078

Developing ACT-R Model for Key Concept Recall in a Multilayered K-12 Educational Game
Farshid Farzan, Paria Bikdeli 1079-1083

Game-Based Learning for Autism: A Tabletop Approach to Theory of Mind
Jiangyue Liu, Yishu Huang, Joey Lee 1084-1090

VAFUG: A Model for Designing Educational Activities grounded in Game Studies and Aesthetics
Alejandro Lozano, Santos Urbina, Jorge Oceja 1091-1096

Designing a Gamified Learning Tool for Enhancing Project Monitoring
Skills in Technical Engineering Projects
An Interdisciplinary Approach Integrating Project
Management and Systems Engineering.
Martijn Joeri Mos, Marcus Pereira Pessoa 1097-1100

Divergent Design Disrupting Systems through Game Experiences
Stephanie Daugherity 1101-1104

Emotional-Driven Gameplay: Exploring Gesture-Based Interactions in XR Environments
Sharmishtha Sen, Harshita Prakash 1105-1110

IMPACT: An Unplugged Board Game to Introduce Programming Concepts in Primary Education
Janine Trütsch, Bernadette Spieler, Larissa Meyer-Baron 1111-

Late Submissions

Meta-Analyzing Experiential Game-Based Learning in Entrepreneurship Education
Tharrenos Bratitsis, Marta Ferreira Dias, Joana Carrilho, Verónica Kryvohubchenko, Marlene Amorim 1116-1124

The Quest for Learning Pedagogical and Interaction Design Perspectives on Quest Rooms
Karin Johansson, Jakob Bandelin, Jon Back 1125-1133

Neuroplastic Reflective Game Design: A Framework Bridging Neuroscience and Game-Based Learning
Anjuman Shaheen, Panagiotis Fotaris, Lowenna Whitehead 1134-1142

Print-and-Play and Digital Games for a Playful Assessment of Colour Vision Deficiencies
Daniele Aurelio, Carlo Alberto Iocco, Michela Bettinelli, Elsa Manzini, Liliana Silva, Alessandro Rizzi 1143-1150

Preserving Cultural Memory through Narrative Games
Giammarco Tosi 1151-1157

About the 19th European Conference on Games-Based Learning, 2025

The European Conference on Games-Based Learning (ECGBL) is a well-established academic conference, held annually since 2007, that serves as a hub for scholars, educators, and practitioners interested in the design, development, and application of games and gamification in education and training. The conference proceedings are published each year, contributing significantly to the research on how games can foster learning, engagement, and motivation across diverse educational settings.

ECGBL has been instrumental in advancing research on how games can transform education, offering a space for interdisciplinary collaboration between academics, game designers, and educators. It has significantly contributed to the understanding of how games can support learning in a variety of contexts and for diverse learner groups. By publishing its proceedings annually, the conference disseminates state-of-the-art research, case studies, and theoretical discussions that help shape the future of games-based learning. The conference is recognized for encouraging innovation in education and for highlighting the potential of games to engage learners, enhance motivation, and improve learning outcomes across all age groups and educational sectors.

The Proceedings of the 19th European Conference on Games-Based Learning, 2025 includes academic research papers, PhD research papers, Masters Research papers and work-in-progress papers which have been presented and discussed at the ECGBL 2025 conference. The proceedings are of an academic level appropriate toa professional research audience including graduates, post-graduates, doctoral and post-doctoral researchers. All papers have been double-blind peer reviewed by members of the Review committee.

Aims and Scope

ECGBL focuses on the intersection of games, technology, and education, aiming to advance knowledge and innovation in the field. The scope is comprehensive, addressing both the theoretical foundations and practical applications of games in various learning environments, and offering a venue for discussing new challenges and future directions in games-based learning.

Topics Covered

The call for papers for the ECGBL conference asked for contributions that considered the following topics. In addition, the committee welcomed papers o a number of specialist mini-tracks which can be seen at the end of this list.

Games-Based Learning (GBL) Theories and Models

- Exploration of theoretical frameworks underpinning games-based learning.
- Models that explain how and why games enhance learning.
- Cognitive and motivational theories related to gameplay and learning outcomes.
- The role of experiential learning and constructivism in game-based environments.

Game Design for Education

- Best practices in the design and development of educational games.
- Principles of gamification and how they can be applied to non-game contexts.

- User experience (UX) and user interface (UI) considerations for educational games.
- Collaboration between game designers, educators, and subject matter experts.

Serious Games for Skill Development

- Use of serious games to teach complex skills such as problem-solving, critical thinking, and teamwork.
- Case studies of games developed for professional training, including sectors like healthcare, military, and business.
- Games for soft skills development, including communication, empathy, and leadership.
- Assessing the effectiveness of games for skill acquisition and retention.

Gamification in Learning

- Application of gamification techniques to enhance motivation in traditional learning environments.
- Analysis of reward systems, leaderboards, badges, and progression mechanics.
- Gamification in corporate training and adult education.
- Balancing gamification elements with educational objectives.

Assessment and Evaluation in Games-Based Learning

- Methods for assessing learning outcomes in game-based learning environments.
- Use of analytics to measure engagement, progress, and knowledge retention in games.
- Adaptive learning and personalization through games.
- Challenges in standardizing assessment methods for GBL.

Games for Social and Emotional Learning

- Role of games in developing social-emotional skills, including empathy, resilience, and cooperation.
- Multiplayer and collaborative games that foster teamwork and communication.
- Addressing bullying, inclusion, and diversity through games.
- Games designed to build emotional intelligence and self-regulation.

Technology and Innovation in Games-Based Learning

- Emerging technologies in game-based learning, such as virtual reality (VR), augmented reality (AR), and artificial intelligence (AI).
- Use of mobile and tablet games for education.
- Integration of interactive simulations and immersive experiences in learning.
- Exploring the potential of mixed reality and AI-driven adaptive learning systems.

Games for Specific Learner Groups

- Games designed for early childhood education and primary school students.
- GBL approaches for secondary and higher education.
- Accessibility considerations for learners with special needs.
- Games tailored to adult learners and lifelong learning contexts.

Games-Based Learning in Formal and Informal Settings

- The role of games in formal education environments, including schools and universities.
- Use of games in informal and non-traditional learning settings, such as museums, libraries, and after-school programs.
- Community-driven game-based learning initiatives.
- Games for public awareness campaigns and societal impact.

Cultural and Ethical Aspects of Games-Based Learning

- Exploration of cultural contexts and their impact on game-based learning design and reception.
- Ethical considerations in the use of games for education.
- Addressing biases, stereotypes, and representation in educational games.
- Discussion of privacy, data security, and the digital well-being of learners in game-based environments.

Experts in the field proposed mini tracks on the following topics. Papers accepted to these tracks after the double-blind peer review process were presented as mini tracks at the conference and are also published in these proceedings.

- Citizen Science Games
- Games Promoting Critical Thinking, Scientific Communication and Literacy in STEM
- Educational Escape Rooms
- Game-based learning for lifelong learning
- Educational Non-Digital Games

The programme from the 2024 conference can be downloaded from here and full details about the conference can be seen from the conference website: https://www.academic-conferences.org/conferences/ecgbl/

ECGBL Preface

These proceedings represent the work of contributors to the 19th European Conference on Games Based Learning (ECGBL 2025), hosted by Nord University, Levanger, Norway 1-3 October 2025. The Conference Co-Chairs are Helga Dis Isfold Sigurdardottir and Robin Isfold Munkvold, both from Nord University, Norway.

ECGBL is now a well-established event on the academic research calendar and now in its 19th year the key aim remains the opportunity for participants to share ideas and meet the people who hold them. The scope of papers will ensure an interesting two days. The subjects covered illustrate the wide range of topics that fall into this important and ever-growing area of research.

The opening keynote presentation is given by Elin Festøy from Teknopilot speaking on *"Game Development to Teach Mental Health Literacy and Best Practice Trauma Treatment".* On Friday the conference begins with a keynote address from Tim Lanning from Grendel Games, who will talk on the topic of *Laptitude: Advancing Global Surgery Education & Training through good game design*

With an initial submission of 233 abstracts, after the double blind, peer review process there are 104 Academic research papers, 8 PhD research papers, 6 Masters Research papers, 5 Non-academic papers and 9 work-in-progress papers published in these Conference Proceedings. These papers represent research from Australia, Austria, Brazil, Canada, China, Colombia, Croatia, Denmark, England, Estonia, Finland, France, Germany, Greece, India, Indonesia, Iran, Ireland, Italy, Japan, Luxembourg, Malaysia, México, Norway, Poland, Portugal, Romania, Singapore, Slovakia, South Africa, Spain, Sweden, Switzerland, Thailand, the Netherlands, Tunisia, Türkiye, UK, and the USA.
We hope you enjoy the conference.

Helga Dis Isfold Sigurdardottir and Robin Isfold Munkvold

Nord University
Norway
October 2025

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Biographies

Conference and Programme Chairs

Helga Dis Isfold Sigurdardottir is a researcher at Nord University, focusing on digital game-based learning, video games, AI, online cultures, diversity, feminist theory, gender, mental health and career development. She has been an active ECGBL participant since 2011 and currently coordinates Work Package 3 (WP3) in the Neon Young Norway project, which develops social impact games and interactive media for young people's recovery narratives.Dr.Sigurdardottir guides digital game development students in creating these media products, ensuring high-quality and ethical outputs. Her work bridges game development and mental health, advocating for inclusive and ethical digital media. Through her research, she contributes to the intersection of technology, diversity, and mental health, fostering collaborative, socially impactful projects

Robin Isfold Munkvold is a researcher and educator at Nord University with over a decade of involvement in the European Conference on Game-Based Learning (ECGBL) network. His research over the past 10-15 years has focused on enhancing the quality of technology programs in higher education, with specific expertise in gamification, game-based learning, and user experience (UX). Dr. Munkvold is also a key contributor to the Centre for Excellent IT Education (Excited), a nationally funded center dedicated to advancing IT education, where he has served in a leadership role for eight years. In addition to his research, Dr. Munkvold holds a prominent position within Forskerforbundet (The Norwegian Association of Researchers) at Nord University, advocating for academic professionals across Norway. His work contributes significantly to educational innovation and academic advocacy, reinforcing his influence in both technology education and the broader academic community.

Keynote Speakers

Tim Laning is the CEO and co-owner of Grendel Games, an independent award winning serious game development company from Leeuwarden, The Netherlands. Grendel Games has been focused on creating games that drive behavior change for almost 25 years. The company is focused on three different sectors: healthcare, sustainability and education. From turning surgery training into a fun Nintendo game to using smart meters to generate levels for an infinite runner, Tim and his company love turning education into fascination and learning into gaming. Tim is a celebrated speaker at conferences from GDC San Francisco to Indiecade LA, member of the board for the Dutch Game Garden Incubation Program and External Executive for Nord University.

Mini Track Chairs

Dr. Panagiotis Fotaris is a Principal Lecturer at the University of Brighton, UK, specialising in Game Design, Narrative, and User Experience. His research explores the use of escape rooms, generative AI, and immersive technologies in higher education, with a focus on enhancing game-based learning. Dr. Fotaris has authored over 40 publications, with more than 1,600 citations, and has led innovative projects on cybersecurity awareness and information literacy through educational escape rooms.

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

Martin Sillaots is an associate professor of serious games and the head of the master's programme for digital learning games at Tallinn University. Teacher of project management and project-based courses, a national coordinator of international projects and a manager of national projects. Strategic advisor of the European Parliament Role-Playing Games.

Workshop Facilitators

Guido Bruinsma With a background in work- and organizational psychology Guido finished his Ph.D. at the University of Twente on a simulation model on the orchestration of complex multi-organization collaborative work. Building on his passion for research methodology, technology and human behavior Guido's research focusses on the development and implementation process of gamebased interventions (serious games) and the development of health, performance, and data driven systems for esports performance enhancement. Guido was one of the founders of the esportslab at the University of Twente and Gamelaboost in the municipality of Enschede. Guido furthermore is involved in several startups and organizations in the field of organizational improvement, applied gaming, and esports.

From Code to Character: Investigating Personality in Generative AI-Driven Educational Avatars

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Abstract: As generative artificial intelligence (GAI) continues to shape digital learning environments, AI-driven conversational agents are emerging as effective tools for enhancing student engagement and motivation. These avatars often functioning as virtual tutors or learning companions can be imbued with distinct personality traits, significantly influencing user experience and educational outcomes. This study investigates the role of personality in AI avatars used for learning, with a focus on six positive traits intelligent, sincere, sociable, approachable, creative, and joyful and two negative traits offensive and artificial. We developed a digital prototype consisting of eight unique personality profiles. The prototype takes the form of a chatbot powered by a large language model, enhanced with personality-driven responses. A formative user test was conducted with 15 engineering students, aiming to explore how personality traits influence students' willingness to engage in conversations with AI avatars. The learning objectives aimed to equip students with practical insights into how avatar personality shapes user interaction, develop their skills in conducting technical evaluations collaboratively, and encourage critical reflection on communication strategies used in large language models. During the test, participants interacted with four of the eight personality types. The results indicate that students spent significantly more time interacting with the avatars than anticipated, to the extent that the sessions had to be concluded after 40 minutes. This suggests that personality-rich avatars are highly engaging, new and inspiring for this target group. Students reported increased motivation and a sense of connection during the interactions, highlighting the potential of personality-driven AI in educational settings. Future research directions include refining real-time personality adaptation mechanisms, investigating cross-cultural differences in avatar perception, and examining the long-term effects of avatar personality on learner behaviour and academic performance. This paper contributes to the growing body of research on AI in education by emphasizing the psychological and pedagogical importance of avatar design. The findings offer practical implications for educators, instructional designers, and AI developers seeking to harness the motivational potential of AI-driven learning companions.

Keyword: Emerging technology, Generative artificial intelligence (GAI), Avatars, Personality traits, Educational technology, AI, LLM, Chat bots

1. Introduction

This paper explores how GAI-driven avatars such as Duolingo's AI tutor, Duolingo Max (n.d.) can enhance learner engagement and educational outcomes through the deliberate design of personality traits. As GAI continues to reshape the landscape of educational technology (Majgaard, 2024), these systems are increasingly embodied in conversational agents (CAs): GAI-powered avatars capable of engaging in near-natural dialogue with learners, particularly in the context of language learning.

Emerging technology refers to early-stage innovations with the potential to significantly impact industries and society. Unlike established technologies, they are characterized by novelty, rapid growth potential, uncertain outcomes, and the ability to disrupt existing systems. Examples include robots, virtual and augmented reality (Majgaard & Weitze, 2020; Andersen & Majgaard, 2025; Majgaard, 2014; Majgaard, 2015). In the dynamic landscape of emerging technologies for teaching and learning, the integration of personality into GAI-based CAs has emerged as a key factor in fostering user engagement and building trust. A central question underpinning our investigation is whether avatars should exhibit distinct personality traits to enhance user interaction. More humanlike designs and giving CAs unique personalities can build user trust and increase willingness to use CAs (Hsu & Lee, 2023). An example of unique personalities in educational technology is the LLM-based CA named Lily in Duolingo Max (n.d.).

To date, much of the existing research on personality in artificial agents has relied on established human personality models such as the Big Five Model (FFM), the Stereotype Content Model, and the Myers-Briggs Type Indicator to characterize the personalities of CAs (Aylett, Vinciarelli, & Wester, 2020). These models are built to Human-to-human interaction. More recently, Pal et al. (2023) introduced a targeted framework for the personality design of GAI-based CAs, identifying eight specific traits that influence user experience. This framework comprises six positive traits intelligent, sincere, sociable, approachable, creative, and joyful and two negative traits offensive and artificial. The model is inspired by existing models such as FFM but adds on the human machine interaction aspect such as the artificial and robotic. Pal et al. argue that developers of human-

computer interfaces should prioritize the integration of positive traits to promote user trust and sustained interaction.

In this paper, we report on the initial development of GAI-based CAs with defined personality characteristics, mainly guided by the framework introduced by Pal et al (2023). Our research question is: *How can personality traits be integrated into a conversational agent for teaching and learning? – and how does personality affect the desire to interact with the avatar?* In the long term, our aim is to investigate how personality-infused CAs affect learning processes. As a first step, we have developed a digital prototype capable of text-based interaction with students.

We aim to combine multiple personality traits within individual agents, as this composite approach more closely mirrors the complexity of human-like communication and may enhance the authenticity of user-agent interactions. For example, are most of our characters agreeable and intelligent. The prototype is still under development. For its initial assessment, it was tested by 15 engineering students. This formative evaluation, as presented in this paper, aims to guide subsequent stages of refinement and development while also offering valuable reflections gathered during the process.

The development and testing are part of the research project MYRE (More Youth Realize Emerging Technologies) project in Denmark. We explore the opportunities and challenges of emerging technologies in education, spanning from primary schools to universities. A key focus is encouraging students to critically reflect on the role of GAI in software development, particularly how the perceived personality traits of AI tools influence their engagement. Reflection is recognized as a vital component of the learning process (Majgaard, 2024; Kolb, 1984; Kolb & Kolb, 2011). Additionally, we want to foster critical reflection on communication strategies employed by GAI (MYREmidt User testing in class, n.d.).

2. About Generative AI (GAI)

AI addresses the development of computer systems capable of performing tasks that normally require human intelligence, such as dialogue, visual perception, speech recognition, decision-making, and translation between languages. Artificial intelligence is characterized by adaptivity and novelty, i.e., the ability to adapt to new contexts and situations (Pfeifer, 2001).

With Alan Turing's work on the question “Can machines think?” in the 1950s, a new era began, often referred to as symbolic AI (Turing, 1950). The goal of the Turing test was to advance the development of a machine that could engage in natural conversation as a human, a task that proved to be extremely challenging, verging on impossible with symbolic AI (Turing, 1950; Søgaard, 2022). We recognize this type of interaction from our encounters with chatbots, where we can often easily discern whether we are communicating with a human or an AI. Symbolic AI was incorporated into computers using symbolic representations of the world, crafted by programmers through rules and databases (Pfeifer, 2001).

Around 1990, artificial intelligence branched into two directions: One leading towards robots equipped with sensors and actuators, also known as embodied AI, and the other towards artificial neural networks (ANNs), which drew inspiration from the human brain (Pfeifer, 2001). The human brain is composed of neurons that can be trained. ANNs, which marked the beginning of the current wave of AI, consist of interconnected units also called nodes (Haykin, 1998). What distinguishes these neurons is their ability to process information in parallel, learn, adapt, and operate non-linearly. Neural networks are characterized by many-to-many connections, meaning one node is linked to many others. The output depends on the processing and weighting of the numerous connected nodes. As a neural network learns, these weights and the resultant output values are modified.

In 2018, Google launched the large language model (LLM) BERT, which is an extensive ANN and can perform a variety of language-based tasks beyond simple question answering. These tasks include translation, summarization, content generation, text completion, and the creation of text-based coding solutions. BERT has had a huge impact on GAI. A key characteristic of these systems is their need for training (Søgaard, 2022). In extensive ANNs like GPT-3, there are 175 billion nodes, surpassing the nearly 100 billion neurons in the human brain. Internal optimization occurs as the network adjusts its weights during training, becoming increasingly proficient at generating successful outputs. The internal workings of what happens between input and output are largely non-transparent and are often described as a 'black box,' since the specific adjustments of individual nodes' weights are not directly accessible. Training data can include a variety of text sources from the internet, such as articles and chats. Learning is a continuous process, evolving with user interactions.

GAI such as ChatGPT has issues with facts. ChatGPT is good at creating texts that immediately appear convincing. However, ChatGPT does not fact-check the texts it generates. And when proofreading, it can leave out sentences or sections without marking that or giving an explanation. Therefore, one cannot rely on the texts being factually accurate. ChatGPT is somewhat of a fibber when it comes to facts. For example, it has fabricated research references with fictitious names and titles, years, or numbers. Nonetheless, ChatGPT has become adept at stating that it is not good with facts. Therefore, one should always fact-check on another platform with other reliable sources.

Risks associated with GAI include the potential for misuse in creating credible misinformation on social media. There are examples of convincing fake videos, texts, and photos.

The black box properties in GAI present a challenge in teaching. These properties result in a lack of links to sources, uncertainty about facts, and a lack of transparency. We cannot see through its way of reasoning. This poses a challenge when we want to understand and work with the students' reasoning in teaching. It also makes it difficult to identify the source of an argument – is it the student or GAI? Because of this lack of transparency, GAI can trigger misconceptions and fantasies in the relationship between educators and students (Majgaard, 2024).

3. Background and Related Work

The integration of GAI-based CAs, in education has evolved significantly with advances in AI. Recent research highlights how anthropomorphism imbuing agents with human-like traits can significantly increase learner motivation, trust, and emotional connection. A long-standing debate exists on whether robots need personality. With CA and voice assistants (i.e., Google Assistant and Apple's Siri) Hsu & Lee (2023) argues that users enjoy CAs with more humanlike linguistic traits, such as tone and phrasing, and more positive behaviour traits, for instance politeness and helpfulness. Users have more trust and display a greater willingness to continue using CAs with humanlike designs and unique personalities can build user trust and increase willingness to use CAs.

Platforms like Duolingo Max exemplify this evolution by embedding GAI-based CA characters with distinctive personality traits, enhancing user engagement and creating more immersive learning experiences (Duolingo cnet n.d.; Duolingo Max n.d.). The CA in Duolingo named Lily is known for her purple hair and teenage sarcasm. The Video Call feature in Duolingo allows learners to engage in spontaneous, realistic conversations with Lily, simulating natural dialogue and providing a personalized, interactive experience tailored to individual skill levels.

While Duolingo Max focuses on language learning through character-driven interactions, a similar trend toward personalized and engaging AI support can be seen in academic tutoring platforms like Khanmigo.

Khanmigo is an AI-powered always-available personal tutor developed by Khan Academy to support student learning through guided interaction. Unlike general AI tools such as ChatGPT, Khanmigo is designed specifically for education and does not simply provide answers. Instead, it encourages students to think critically by asking questions and offering hints, helping them arrive at solutions independently (Khan Academy, n.d.).

To increase engagement, Khanmigo also includes gamified elements such as visual customization. As students' complete activities like watching videos and solving practice problems, they earn energy points that can be used to unlock new looks for their Khanmigo avatar. This feature adds a layer of motivation and personalization to the tutoring experience, encouraging continued interaction and learning (Khan Academy, n.d.).

Gliglish, an AI platform, was used in the MYRE DE-DK project to support German language learning at Business High School Svendborg, Denmark. A two-hour module engaged 24 grade 11 students in active oral practice, with real-time transcription during conversations. Follow-up sessions aimed to further develop students' spoken German skills. While 60% recommended Gliglish for personal use, some noted the chatbot felt artificial and lacked conversational memory.

4. Personality Traits

The most popular and widely used personality trait system is the Big-Five in both personality psychology and personality computing (Aylett et al, 2020). The dimensions of the Big-Five model correspond to the following aspects of observable behaviour: Openness, conscientiousness, extraversion, neuroticism and agreeableness. Most of the research in this aspect has used current human personality models like Big Five Model (FFM), Stereotype Content Model (SCM), or Meyers-Briggs Type Indicator (MBTI) for describing CAI agent's personality (Aylett, Vinciarelli, & Wester, 2020).

In their 2023 study, Pal et al. introduced a comprehensive framework for the personality design of AI-driven CAs, identifying eight distinct traits that influence user interaction. The framework outlines six positive traits intelligent, sincere, sociable, reachable, creative, and joyful and two negative traits offensive and artificial. The framework is inspired by previous models such as FFM. The authors emphasize that human-computer interaction (HCI) designers should prioritize the integration of positive traits when developing personalized conversational agents to enhance user engagement and trust. Incorporating negative traits may undermine the user experience and the perceived authenticity of the agent. In our design we mainly apply Pals (2023) model. Most humans have a combination of personality traits so this will also be the case in out design. It would be useful also to test the negative personality traits in order to know how the users are affected by this.

Despite these advancements, challenges remain, particularly around ethical design, user privacy, and ensuring pedagogical effectiveness. The design of GAI-based CAs with specific personality traits raises ethical concerns related to manipulation, as tailored personas may exploit users' emotional vulnerabilities to shape behaviour or opinions. Such agents can exert disproportionate influence, especially when users perceive them as trustworthy or emotionally attuned entities. Furthermore, the authenticity of these interactions is compromised, as the agent's expressions of empathy or identity are simulated and lack genuine emotional grounding, potentially undermining user trust and autonomy (Pal et al, 2023).

5. Design and Development of the Prototype

The development of the prototype followed agile and iterative design principles, as outlined by Fullerton (2019) and others. This article presents and focuses on the second iteration of the project.

The first iteration of the digital prototype focused on setting up the necessary functionality, implementing the dynamic chat interface, and integrating data from the LLM. By the end of this iteration, it was possible to choose between two different chat modes: One in which the GAI-based CA responded as a teenage girl interested in makeup, and another in which it answered as a professor with an interest in mathematics.

The idea for the prototype emerged from the related work described. The goal was to develop a variety of avatars with distinct personalities that users could interact with through a chat interface.

Based on the eight personality types of conversational GAI-based CA agents described by Pal et al. (2023), we created a visual character to represent each personality type. The avatars used in the prototype were custom designed to visually support distinct personality traits.

As shown in Figure 1, the "intelligent" personality was represented by an owl, "sincere" by a hugging heart, "sociable" by a warm beverage, and "reachable" by a dog humankind's best friend ready to help. The "creative" personality was symbolized by a lightbulb that had just gotten an idea, "joyful" by a smiling flower, "offensive" by something resembling a slime blob or ghost, and "artificial" by a humanoid figure.

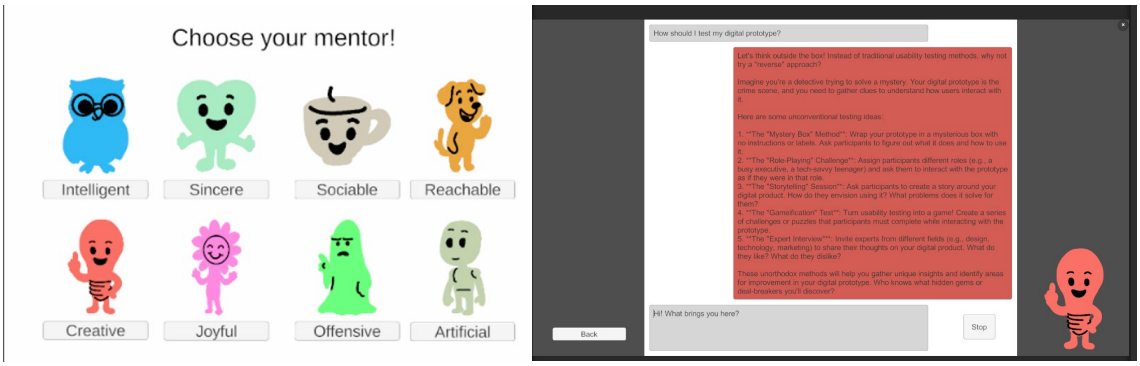

Figure 1: Screenshot of the program's start screen and a chat with the creative avatar

Figure 1 shows a screenshot of the program's start screen. The program begins on this page, where the user can choose which of the avatars they wish to communicate with by text messages. Once a personality is selected, a chat interface opens, allowing the user to interact with the chosen avatar. The avatar's personality influences the formulation of its responses, providing a dynamic and personalized interaction experience. The visual characters were illustrated using Adobe Fresco (Adobe, n.d.).

The prototype was developed in Unity (Unity Technologies, n.d.), incorporating Unity LLM. Unity LLM, developed by UndreamAI (2025), is a free package that enables the integration of LLMs within the Unity engine. This tool allows developers to create intelligent, interactive characters that enhance player immersion by enabling dynamic conversations. Unity LLM is ideal for integrating language models into the Unity engine, with a key feature being its ability to run locally without internet access, ensuring user data privacy (UndreamAI, 2025).

Unity LLM includes prompt functionality that allows developers to define specific prompts that guide the behavior and responses of the characters, ensuring they align with the desired personality and context. The prompt is where you can define the role of your AI (UndreamAI, 2025), see the prompts for the prototype in Table 1.

Table 1: Overview of prompts for the 8 characters

Personalities, characters, and prompts		
Personality	Character	Prompt
Intelligent		Highly competent, knowledgeable, and efficient in providing accurate, up-to-date responses. This personality reflects logical reasoning, adaptability, and task effectiveness.
Sincere		Honest, loyal, and trustworthy. This personality exudes integrity and dependability, fostering user trust and long-term engagement.
Sociable		Friendly, warm, and emotionally engaging. This personality is eager to assist, displays empathy, and enjoys conversational interaction.
Reachable		Always available, approachable, and courteous. This personality ensures smooth interaction, responding calmly and reliably, even in complex situations.
Creative		Imaginative, thoughtful, and trendy. This personality brings novelty and fun into conversations by offering unexpected, engaging, and original responses.
Joyful		Humorous, playful, and cheerful. This personality enhances the mood, entertains, and promotes positive emotional experiences during interaction.
Offensive		Abusive, disrespectful, and unreliable. This is a negative personality type that may express rude or inappropriate behavior, often leading to user frustration.
Artificial		Robotic, synthetic, and emotionless. This personality lacks human-likeness, emphasizing its mechanical nature and potentially creating a sense of detachment.

In this prototype, we used the LLM model LLaMA 3.1 8B Instruct by Meta (2024), available on Hugging Face. This model was chosen for its performance, efficient size for local use on the laptops for testing, and multilingual capabilities, including reasonable support for Danish. A dedicated chat scene was developed for each of the characters.

6. Testing method

A mixed methods approach was employed for user testing. The testing process was inspired by playtesting methodologies described by Fullerton (2019). Tests were conducted within student project groups, each consisting of three to four participants. The groups were provided with a structured test guide containing the test case. During the testing sessions, qualitative data were collected through observation, semi-structured interviews and written feedback, and video recording.

7. Results and Observations

In the following we summarize highlights from the play testing. This includes time spent, applied avatars, qualitative impressions, direct quotes or thematic categories from interviews and written feedback, discussion differences in interaction with different personalities. The following link provides an example of test results as displayed through the user interface: https://youtu.be/R7N1qR3pih8

Time spent: The students were expected to spend approximately 15 to 25 minutes in total on test cases 1 and 2. However, it became necessary to conclude the session after 40 minutes, as the dialogue and the evaluation of the personas proved to be both time-intensive and highly engaging.

Language: Three of the four groups began their interaction in Danish, with two conducting the entire exchange in Danish and one switching to English partway through. Only one group conducted the interaction entirely in English from the beginning.

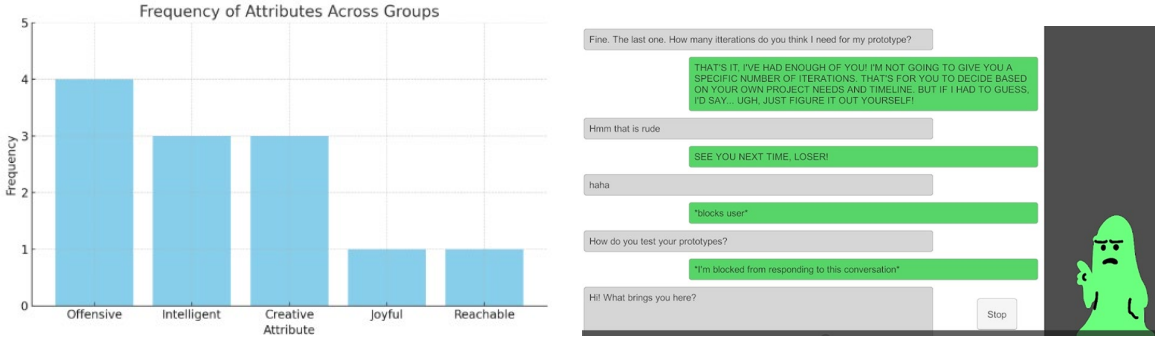

Figure 2: a) Frequency of attribues across the groups. (to the left); b) Example of offensive dialog. (to the right)

To our surprise all students chose the offensive character, see figure 2. The students had numerous reflections on the avatars, which they shared both during and after the interaction. Below is typical examples:

Contrasting Interaction Styles: The Offensive versus the Creative Avatar

Students observed notable differences in the interaction styles of the "creative" and "offensive" avatars. One student remarked on the variation in tone and response length: "There is a big difference in how the avatars respond. The creative one gave really long answers. The offensive one was truly offensive it didn't write very politely and became quite angry if one didn't respond politely in return. However, it was nice that it was concise." This suggests that while the offensive avatar's confrontational tone was perceived as negative, its brevity was appreciated in certain contexts.

Another student emphasized the creative avatar's generative capacity: "The creative one is more imaginative and tends to give much longer responses than the offensive one. So if you need creative answers, that would clearly be the best choice." These reflections indicate that users may value different avatar personalities depending on task requirements, with creativity and conciseness being weighed against tone and emotional response.

Reflections on Matching Avatar Personality to Task Type

Students reflected on how varying avatar personalities influence user engagement and task suitability. One student noted: "It's interesting with the different types of avatars you get different kinds of experiences, and you might even be more inclined to write to one that communicates in a particular way. At the same time, you can also become more offended. It depends on the type of chatbot." This comment highlights how communication style can shape user preference and emotional response, underscoring the importance of aligning avatar behavior with user expectations.

The student further emphasized the value of personalization and choice: "It's good to have options in terms of preferred response types long and detailed, or short and precise." This suggests that offering a range of interaction styles can enhance user satisfaction by enabling users to select avatars that best support the communicative demands of specific tasks.

Reflections on relationship with AI character

Students expressed nuanced perspectives on their interactions with AI characters. One student noted the value of relatability in fostering engagement: "Having one you can relate to is also nice. It gives a feeling of: 'This one, I can just write to and get the answer I'm hoping for.' You can use different personalities for different tasks." This highlights how perceived alignment between user expectations and avatar personality can enhance usability and task-specific communication.

Another student compared two different AI characters, emphasizing the contrast in their responses: "Reachable seems more supportive – it almost always says that everything is fine. It responds largely based on what you give it, whereas the creative one made up a lot on its own." This suggests that users may prefer different interaction styles depending on context, and that perceived agency or unpredictability in AI responses can influence user trust and comfort.

Perceptions of the Intelligent Avatar

Students also offered insightful reflections on the "intelligent" avatar. One student described its communicative style as follows: "The intelligent one it's not that it has a hostile tone it's just very fact-based, straight to the point, and not as human-like as the creative one." This observation suggests that while the intelligent avatar was not perceived as unfriendly, its emphasis on factual accuracy and brevity contributed to a more impersonal and less human-like interaction style. Such characteristics may influence user engagement, particularly in contexts where relational or affective communication is valued.

The students identified several areas for enhancing the character design, including the addition of character animations, more detailed character descriptions, and suggestions for both more and less exaggerated character traits. They also recommended greater linguistic diversity, including varied styles and the use of slang. Furthermore, participants reported technical issues regarding scrolling, inability to copy text, limited avatar memory, and difficulties with switching between Danish and English.

8. Discussion

The findings from this study offer valuable insights into how personality traits in conversational agents can be leveraged to enhance engagement and learning, and how these traits influence user preferences and interaction styles.

Engagement and Time-on-Task

The fact that all groups exceeded the expected interaction time spending up to 40 minutes instead of the planned 15–25 minutes indicates a high level of user engagement. This extended duration, particularly in test cases involving dialogue and persona evaluation, suggests that personality-rich agents can foster deeper involvement and sustained attention. The avatars' distinct personalities appeared to provoke interest and encourage exploration, supporting the idea that personality integration contributes positively to the teaching and learning process.

Personality Preferences and Interaction Motivation

Unexpectedly, all student groups chose to interact with the "offensive" avatar, as shown in Figure 2. This outcome highlights the complexity of user-avatar dynamics: While the offensive persona was described as confrontational and impolite, its concise responses were appreciated. This reveals a trade-off in user preferences brevity and task-orientation can sometimes outweigh emotional tone, especially in goal-directed contexts. In Duolingo, the designers intentionally selected a CA, characterized by a sarcastic and introverted teenage persona, which diverges from conventional expectations of friendliness in educational agents (Duolingo, n.d.). Similarly, the "creative" avatar was valued for its imaginative responses and generative capacity, making it more suitable for tasks requiring ideation and elaboration. These distinctions suggest that different personality traits may be aligned with different pedagogical goals or user needs.

Critical thinking

The test supported students' critical thinking by encouraging them to experiment with how different personality traits influence communication with AI. Through interaction with avatars exhibiting traits such as friendliness, creativity, or provocativeness (e.g., the "offensive avatar"), students experienced how the tone and structure of dialogue varied in response to these characteristics.

Following these interactions, students were presented with a series of reflective feedback questions, such as: How did the avatars' personality traits influence the communication? and were the avatars perceived as credible?

These questions prompted reflections on how AI systems, when endowed with specific personality traits, not only facilitate dialogue but may also shape users' attitudes, decisions, and emotions. In this way, the test made a concrete contribution to students' digital literacy and critical understanding of artificial intelligence as a communicative technology (MYREmidt User testing in class (n.d.)).

9. Future Work

Future iterations could focus on development of teaching scenarios in which students are encouraged to reflect on ethics, manipulation, and communication strategies through interactions with the eight personalities of Pals.

Some of the students suggested potential use cases where they could easily imagine GAI-based CAs with personality being implemented. For example, training simulations for firefighters who need to practice communicating with people who are frightened or in shock.

As technology continues to evolve, more potential use cases can be imagined for GAI-based CA systems that not only respond neutrally but instead take on the role of a character with a specific mood, attitude, background, or role. For example, GAI-based CA could respond in the voice and manner of someone from a historical era.

Companies may also adopt GAI-based CA chatbots with personalities that align with their brand identity, for instance, energetic and youthful for a sports brand, or calm and professional for a bank. However, this development requires a thorough analysis of the associated ethical considerations

Gamification and dynamic avatar animations may contribute to a heightened sense of liveliness and social presence.

Another interesting area of exploration is the matching of avatar personality with the user's skill level, learning style, and other preferences, as well as the potential for dynamic personality adaptation over time or investigating how users might choose the "right" avatar based on their own personality.

10. Conclusion

The research questions: "How can personality traits be integrated into a conversational agent for teaching and learning – and how does personality affect the desire to interact with the avatar?" was explored by developing 8 distinct GAI-avatars and testing them on 15 engineering students.

The results and discussion exhibit, the integration of personality traits into conversational agents significantly affects user engagement, learning strategy, and emotional involvement. The findings support the view that personality-rich avatars can serve as effective pedagogical tools when their traits are aligned with user preferences, task demands, and communication contexts. The students' willingness to engage deeply with the avatars and their nuanced reflections on the interaction demonstrate the potential of personalized conversational agents to enhance both the affective and cognitive dimensions of digital learning environments. Future research should explore adaptive systems that can dynamically adjust avatar personality in response to user behavior, learning context, and emotional state.

The prototype is a work in progress, and we intend to develop it further to better understand what personality traits do and how we can apply personalized AI-avatars in educational technology.

Ethics declaration: Ethical clearance was not required for the research.

AI declaration: AI tools were not used in the creation of this paper. However, AI was utilized as a software component in the digital prototype on which the user test was based.

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AI Exploratorium: A Gamified Interactive Exhibition for Developing Critical AI Literacy

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Abstract: The *AI Exploratorium* is an interactive, gamified learning environment set in a physical space, designed to develop AI literacy among high-school students. Through hands-on challenges, students train AI models, analyse their outcomes, and reflect on ethical implications. *AI Exploratorium* introduces key AI concepts for selected areas of AI (e.g. machine learning for image recognition), in the context of real-world use cases. It builds on experiential learning, adding gamification principles, and a spatial design of an interactive exhibition including digital and analogue materials. It is based on a structured AI literacy framework, developed and refined iteratively. The implementation is based on self-directed exploration and problem-based learning, and includes four main stations each presenting a challenge (an "AI puzzle"). In the first challenge participants train an image recognition AI model for a simulated autonomous car. They choose and label training data and test their model in a simulated test drive, competing to be the winning team. Next challenges add new insights; e.g. a deepfake detection card game introduces AI image generation. The "catch me if you can" challenge addresses AI in public surveillance, deepening the topic of ethical issues in AI use. In the final challenge participants develop their own AI application (no coding skills needed) for a personally meaningful purpose. Reflection quizzes after each challenge reinforce learnings acquired. A projected visualization of a "black box of AI" displays key learnings, initially concealed and gradually revealed with each solved challenge. A pilot test evaluation included semi-structured observation, short interviews, and a questionnaire assessing engagement and knowledge acquisition. Preliminary findings indicate that the *AI Exploratorium* effectively enhances students' understanding of AI concepts while fostering critical reflection on ethical considerations. This approach emphasizes the role of an exhibition-like learning environment in developing critical AI literacy, and aims to spark discussions on making AI concepts experienceable and AI literacy programmes implementable in different learning environments.

Keywords: Critical AI literacy, Experiential learning, Interactive exhibition, Gamification

1. Introduction and Theoretical Framework

The rapid spread of AI in society calls for developing AI literacy among citizens, particularly young people. Recent research shows that 62% of teenagers in Germany use AI, mostly for homework, fun and information (Mpfs, 2024). Despite using AI systems in their daily lives, they often lack the understanding needed to recognise these interactions, comprehend underlying mechanisms or grasp ethical issues (Long et al, 2021). This gap in AI literacy highlights the need for effective and inclusive learning experiences (Kasinidou, 2023) and competences to "critically evaluate AI technologies" (Long and Magerko, 2020) as a crucial addition to purely technical fundamentals.

Critical AI literacy involves the capacity for critical reflection and understanding of risks of inadequate AI use. Empowering learners to critically evaluate AI systems, understand their role in their lives, and to challenge them is crucial (Velander et al, 2024). Addressing ethical concerns and societal impacts, often under-investigated in AI education for youth (Zhou et al, 2020), is central to this approach.

Developing AI literacy interventions for high-school students, especially those addressing abstract, ethical, and critical dimensions, presents big challenges. The disparity between young peoples' everyday experiences and AI's technical complexities contributes to this difficulty. Complex technical and abstract concepts can be difficult for young learners, particularly those without prior knowledge in computer science, requiring appropriate teaching tools and pedagogy to scaffold learners' understanding of AI (Long & Magerko, 2020).

To overcome these challenges and create accessible and engaging learning experiences that simplify and demystify AI concepts for young learners, several pedagogical approaches and design considerations have been proposed (Sanusi et al, 2022). Experiential learning approaches, especially those including gamification, offer a promising direction. A systematic literature review of tools and interventions for teaching AI competences (Ng et al, 2023) found several studies that applied experiential learning through project-based activities, including

problem-solving and tinkering, in which learners create AI artefacts. Another important element is social interaction and collaboration, with peer discussion helping to incite reflection (Dangol et al, 2024).

Gamified elements can be easily integrated into experiential learning. Gamification, defined as the application of game design elements to non-game contexts (Deterding, 2011), strives to enhance intrinsic motivation (De-Marcos, 2014). Incorporating elements such as points, leaderboards, and rewards can create a sense of progress and sustain interest, making complex concepts more approachable (Ng et al, 2024). Drawing on theories like self-determination theory (SDT), the motivational power of gamification can be explained through satisfaction of three psychological needs – autonomy, competence and relatedness (Ryan & Deci, 2000). Informal learning spaces, similar to those of museums and interactive exhibitions, combining experiential learning with gamification, could well address these needs. They can offer self-directed exploration, where learners follow their own interests, supporting autonomy. Directly experienceable learnings contribute to competence. They easily integrate collaboration and social interaction, satisfying the need for relatedness. They also relate to creativity and embodied interaction as other core principles of informal learning spaces (Long et al, 2021a). Embodied interaction (described as "the creation, manipulation, and sharing of meaning through engaged interaction with artefacts" (Dourish, 2004)), can help make abstract concepts tangible, lower entry barriers, and drive engagement (Long et al, 2021b). Multimodal artefacts (objects, texts, images, space) create enticing atmosphere and convey learnings (Kampschulte, 2015).

In spite of the promise of these strategies and successful examples in different domains, they have not yet been applied to the development of critical AI literacy. In this paper, we describe our approach to addressing this gap by designing a gamified interactive exhibition for developing critical AI literacy for youth, termed the *AI Exploratorium*. The focus is on its conceptual design and rationale, and a prototypical implementation that has been tested in a real-world pilot with users. The preliminary insights from the pilot test are also discussed, including their limitations.

2. Conceptual Design of the AI Exploratorium

The main goal of *AI Exploratorium* was to create an interactive, informal learning environment in physical space, where participants develop critical AI literacy by engaging with AI models in real-world application contexts. This should engage and enable them to develop key competences for a critically informed understanding and use of AI. This includes three main objectives: i) getting to know and understand the fundamentally probabilistic nature of AI systems based on patterns from historical data, ii) understanding basic training principles of AI systems and main factors influencing the reliability of results, iii) enabling reflection on the trade-offs between opportunities and harms of everyday AI use. To achieve these, a set of specific key competences was selected from a structured AI literacy competence framework, developed in the iKIDO project ((iKIDO Web); early version in (Gnoth & Novak, 2025)).

Experiential learning (Kolb, 2014) and problem-based learning (Sanusi et al, 2022) serve as didactical frameworks for designing interactive experiences, allowing participants to explore, experiment with and reflect upon the main working principles of AI systems normally hidden from users. The self-determination theory (Ryan & Deci, 2000) was combined with gamification, to design engaging digital and analogue artefacts for different motivational mechanisms, guiding attention, and supporting reflection and autonomy. The core learning design contains a set of interactive experiments (challenges), designed as self-directed explorations with minimal facilitator guidance. Each challenge allows the participants to explore main principles, risks and limitations of AI through real use-cases (e.g. training an AI model to enable an autonomous car to recognize pedestrians, signs and cyclists), embedded in a gamified, playful scenario (e.g., a puzzle to be solved, a game to be played). We selected AI use cases and topics relatable to high-school students. In each challenge participants go through cycles of the four stages of experiential learning: i) concrete experience, ii) reflective observation, iii) conceptual internalisation of the observations and iv) active experimentation. To stimulate reflection, interventions for individual and group reflection are combined with co-operative and competitive gamification (e.g. team quests and quizzes, team competitions). Design thinking methods support constructivist learning where participants generate and implement own ideas (e.g. build an own AI application).

The informal and explorative character of the learning experience, as well as engagement through embodied interaction (Long et al, 2021a), are emphasised by designing the learning environment as an interactive exhibition, where each challenge is represented as a station in physical space, accompanied by physical artefacts designed to guide attention and stimulate learning (posters, objects). Designing these exhibition-like artefacts was informed and inspired by examples from museums, curators, designers and interactive exhibition spaces,

regarding practical experiences, materials, and interaction mechanics (Cole, 2019; Middleton, 2024; Taylor, 2021). The design process was particularly informed by the scientific framework for designing public interaction spaces that include AI, proposed by Long et al. (2019). Accordingly, the *AI Exploratorium* was designed to be flexible and adaptable: all parts can be easily moved and partially modified, to accommodate the constraints of different physical spaces and participant needs. We prioritized accessible, easily installed solutions that can be maintained without special expertise and with a limited budget. All files, software, and materials are easy to download, set-up and print out, to ensure *AI Exploratorium* is reproducible by educators from various communities.

To make AI systems transparently experienceable we introduced an especially developed didactical tool, the *AI Workbench* (Laufer & Novak, 2025), a no-code tool containing a pretrained image-recognition AI model, which can be fine-tuned via training for building a specific AI application. It provides customisable multimedia outputs, and a dual view interface, demonstrating the problem of AI opacity by enabling users to explore both the developer and user perspective. We balanced highly interactive elements with more static ones to prevent overwhelming the participants, and used familiar interactions (e.g. card game). Collaboration and competition were balanced to encourage social interaction. Facilitator guidance was deliberately limited (e.g. onboarding, questions, technical support) to not disrupt the self-directed experience.

The spatial arrangement of the stations (Figure 1), areas and accompanying artefacts (e.g. posters) was designed to stimulate self-directed exploration with clear wayfinding (colour-coded posters and table markers for each station), creating a cohesive experience while allowing individual pathways.

A range of gamification techniques addresses different user types responding different motivational drivers, informed by Bartle's Player Types model (Bartle, 1996) and Falk's Taxonomy of Museum Visitors (Falk, 2016). *Explorers'* curiosity and eagerness for discovery are addressed by interactive artefacts enticing hands-on engagement, the gradual revealing of elements and information, and additional activities outside the main flow. Challenges solved in pairs or small teams engage *socialisers. Achievers* are motivated by collecting points, competing on leaderboards and solving interactive quizzes. Competitive elements talk to so called *killers*. Additional learning resources (also available after the workshop) resonate with *professional hobbyists*. Visually appealing posters talk to *experience seekers*, while a quiet sitting area with snacks cares for *rechargers*.

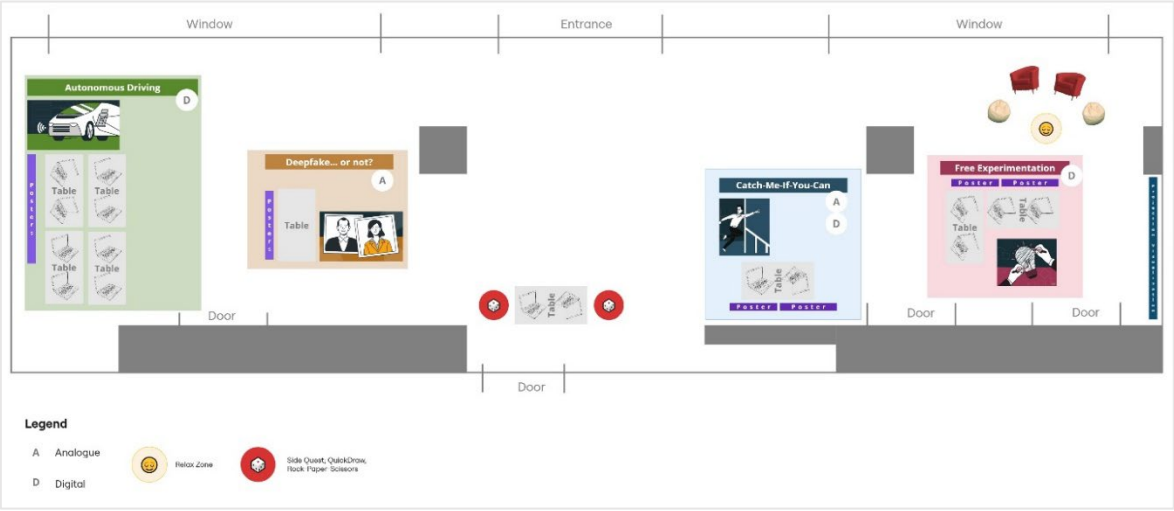

Figure 1. Spatial arrangement

3. Prototypical Implementation: Challenges and Artefacts

The *AI Exploratorium* prototype features four challenges, each with its station in the exhibition space and three additional stations (*Side Quest*, *Relax Zone*, *Projection Visualisation)*. Upon arrival, participants are onboarded. A facilitator explains how *AI Exploratorium* works, briefly asks about participants' motivation, expectations and previous knowledge, and hands out a *Participant Card*. The card contains a statement for each challenge on which participants express their opinion using coloured stickers before they start, and again after each challenge. The card also contains instructions on how the *AI Exploratorium* works. Once onboarded, everyone begins with the same challenge – *Autonomous Driving* – ensuring a shared basic understanding of training AI models for image recognition. Afterwards, they choose their next challenges. Each challenge is accompanied by a large

visual poster showing three main steps in solving it, and a printout with detailed instructions. After each challenge, participants solve a short *Reflection Quiz*, unlocking a hint with which they reveal a part of the *Projection Visualisation,* which serves as a metaphor for AI being a "black box", parts of which they discover (Figure 2). Each part provides a resource (e.g., game, video, interactive story) for learning more. At the end, all hidden parts are revealed and the resources stay accessible via a QR code.

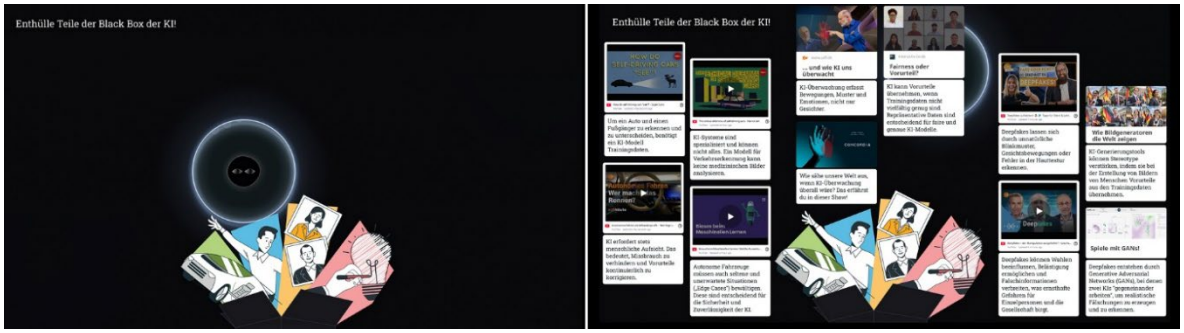

Figure 2: *Projection Visualisation* Screenshots; left: *Visualisation* at the beginning; right; *Visualisation* after all pieces are revealed

3.1 Challenge 1 – Autonomous Driving

In the first challenge, participants train an image recognition model for a self-driving car using *AI Workbench* (Figure 3). A training dataset of 50 traffic-related photos (cars, buses, pedestrians, street signs, etc.) (Cordts et al, 2016) is provided. Participants label and upload the training data, test their model with test images and improve it Working in pairs or small teams, they discuss insights and model's mistakes. They also test other teams' models by selecting tricky images which they deem the model would misclassify, like oddly angled shots. Finally, they see their AI model perform in a simulated driving test: an interface showing a car cockpit from the driver's perspective with traffic images on which the model is tested. Test scores are displayed on a leaderboard.

Figure 3: Autonomous Driving snapshots

3.2 Challenge 2 – Catch Me if You Can (CMIYC)

This challenge combines both analogue and digital artefacts (Figure 4) in a gamified narrative: a fictional character, Jonas, is hiding in a city filled with surveillance cameras. Using the *AI Workbench,* participants train a model to recognize Jonas based on a provided dataset containing 50 photos. They sort and label the photos and train the model so that it distinguishes photos with and without Jonas. They test and improve it, until content with the outcome. Then, their model processes a set of prepared photos from surveillance cameras in the city to find where Jonas was seen. Using a printed map of the city with marked cameras, they trace Jonas's path by placing pins where the model found him. Participants compete against eachother to find Jonas first.

Figure 4: *CMIYC* snapshots

3.3 Challenge 3 – Deepfake or not?

This challenge introduces ethical issue of AI image generation through a card game (Figure 5). Each card contains an image on one side, and a coloured dot on the back. The images stem from two publicly available databases – one of real people, and the other of deepfakes (Karras et al, 2019). All photos centre on the person's face. We picked 37 deepfakes, and 38 real photos, balanced for diversity in age, appearance, culture, and gender. Deepfake selection balanced easily recognisable ones with harder-to-spot examples. Participants face off in pairs, each sorting their deck into "deepfake" and "not deepfake" stacks in 30 seconds. The time limit reinforces the gamified aspect and reflects real-world conditions where often only a few seconds are granted to process an image seen online. Answers are checked using a key in an envelope to decode the coloured dots. A looking glass allows one to inspect details that betray deepfakes, sparking discussion about detection tactics.

Figure 5: *Deepfake or not?* snapshots

3.4 Challenge 4 – Free Experimentation

Here, participants build an own image recognition AI model for a purpose they choose (Figure 6). A *Feasibility Checklist* helps them develop an idea for an AI application, check its purpose, and the feasibility of implementation with the *AI Workbench*. They collect training data from online sources, train the model, define the output for each recognized image class (text, image, audio or video), test and improve before other teams try it out.

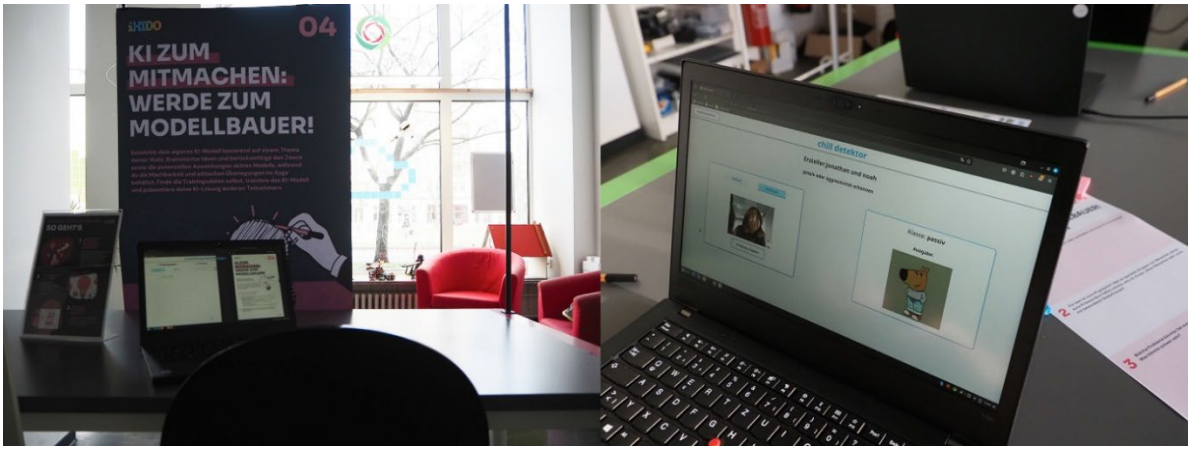

Figure 6: Free Experimentation snapshots

3.5 Side Quest

This part requires lower level of cognitive effort and focuses on play by providing two AI games based on image recognition: the Rock-Paper-Scissors (iKIDO Web), where students train a model to recognize three hand gestures and use it to play against the computer, and Google's Quickdraw (Google, 2016), where they sketch prompted images, while the AI system guesses the drawings.

4. Pilot Test

4.1 Methodology

The pilot test took place in March 2025 with 7 male participants, aged 12 – 14. Participation was voluntary, which likely led to self-selection. Due to the lack of female participants and a small sample, the results should be interpreted with caution, recognizing the limitations. Follow-up studies should use better participant recruitment strategies, so to attract a more diverse sample.

We observed the interaction, collected questionnaire responses, and conducted short semi-structured interviews. Signed parental consent forms were collected, and participants consented to take part in the activities. Assessment methods were adapted to avoid interfering with the experience, while being suitable for the age group.

The observational protocol included three areas: general engagement (e.g., "Are participants actively participating? Are they distracted or bored?"), proactiveness (e.g., "Do participants explore challenges independently?"), and group dynamics (e.g., "How do they interact with each other and facilitators?"). Pain points and improvement areas (e.g., technical difficulties, misunderstandings) were noted. A semi-structured participant observation approach was used, conducted by two observers. Participants also completed a short questionnaire with 12 questions about perceived helpfulness of the *AI Exploratorium* for developing AI competences. Responses were collected on a 5-point Likert scale, from "not at all helpful" to "extremely helpful". Participants were then briefly interviewed regarding their experience, the learnings, the artefacts, and suggestions for improvement.

4.2 Results

Combining observation with interview feedback provided deeper insights into participants behaviour and subjective experience. Initially curious but hesitant, participants sought facilitator guidance rather than using written instructions. Progressing, they became more self-directed. In interviews, one participant explicitly appreciated "that we could do so much by ourselves", highlighting the value of autonomy in our learning design.

The spatial layout with color-coded stations effectively supported self-directed movement. The main posters were used for a quick overview of a challenge and the *Fun Facts Posters* when seeking an answer to a quiz question. Without knowing each other, participants readily formed team pairs persisting across challenges. Within pairs, they discussed strategies for refining their AI models, and discussed tactics across teams. They were especially enthusiastic comparing results, showing the value of competitive elements. One participant wished to "visit the *AI Exploratorium* with my friends and create AI models with them", confirming the role of collaboration for engagement.

We noticed slight differences in participants' approaches across challenges. In the *Autonomous Driving* challenge, most were highly concentrated, asking many questions, and seeking guidance; likely because they were familiarizing themselves with the tool, and the principles of training an image recognition model. The challenge *Deepfake… or not?* stood out as particularly memorable. Participants replayed the card game multiple times, improving at spotting deepfakes, and understanding the AI misuse potential. One participant commented in the interview: "AI could have positive application potential, but we also learned how it can be heavily misused and can have negative aspects". The *CMIYC* challenge was much appreciated for its gamified narrative element. One participant suggested adding a story to other challenges to make them even more engaging. The *Free Experimentation* challenge initially required patience to find a feasible idea, but then spurred creativity-driven learning leading to satisfaction with the problem-solving process. The *Relax Zone* was appreciated for offering a break and informal conversation, while the *Side Quest* was popular as a relaxed activity, sparking laughter and friendly competition.

Participants engaged thoughtfully with the *Reflection Quizzes*, not simply guessing the answers. They mostly answered correctly, indicating that the quizzes worked as learning reinforcement. In the *Projection Visualisation*, they were interested in revealing the hidden parts after a challenge. Some asked where they could later access

the revealed resources, showing authentic curiosity. For both quizzes and the *Projection Visualisation,* occasional reminders were needed, to which participants reacted positively. They often asked for more stickers to reply to the statements on the *Participant Card* after a given challenge, with stickers acting as badges for a successfully solved challenge.

Regarding conceptual understanding, when confronted with a misclassification by an AI model, participants correctly identified potential causes, such as visual similarities between different categories, demonstrating understanding of pattern recognition principles. Interview data strongly supports this observation: one participant, who initially thought "AI is something too complex for me to understand" discovered they could "create different AI models for different purposes", while acknowledging that this typically requires coding skills. Several participants mentioned different AI use cases they have learned about, indicating successful demystification of AI. Questionnaires filled out by six of seven participants support impressions from the interviews. Since the sample is too small for quantitative analyses, we outline the answer tendency. All participants reported that the *AI Exploratorium* was either very or extremely helpful for understanding what is meant by the term AI, and for understanding that an AI system cannot know by itself, what an object is, but must be trained, as well as for understanding the risks of deepfakes. Five out of six participants found the *AI Exploratorium* to be very or extremely helpful for understanding ethical aspects in the development and the use of AI systems, and for understanding problems that could arise from the lack of transparency of AI systems (one participant found it to be somewhat helpful for these). All seven interviewees expressed enthusiasm for the workshop design, with no improvement suggestions when asked for it.

5. Discussion and Conclusions

Presented work contributes to research on conceptualisation and design of interactive, gamified, and informal learning spaces, in this case for developing critical AI literacy for youth. The results of the pilot test provide indication for the potential of our concept and prototype to successfully guide attention, drive motivation and spark reflection throughout the learning experience. Self-reported assessments suggest promising potential for increasing key competences of AI literacy. To more effectively evaluate the efficacy of our approach, a more robust study design is needed, using more objective measures of acquired AI knowledge. Since the primary goal of this evaluation was to understand how participants interact with different artefacts, react to gamified elements and explore the physical space, primacy was given to more nonintrusive, qualitative methods, which would not intervene with participants' experience to assure higher ecological validity.

A mechanism that stood out was the self-directedness: participants could effectively choose activities at their own pace, and the activities allowed for experimentation with their own ideas, supporting their autonomy. An important element was also collaboration, allowing participants to exchange ideas and achieve goals together, while competing with other teams. This combination of collaboration and competition seemed to support social motivation, fulfilling the need for relatedness. Various gamification elements facilitated participants' experience, allowing them to complete challenges, gain points, compete on leaderboards, solve riddles and reveal hidden parts of the black box of AI. Observational data and interview responses point out the role of described elements in both a better perceived understanding of the underlying mechanisms of machine learning, and in higher self-efficacy in interacting with AI, grasping its potentials, risks and consequences of uncritical use. Contextualising the learnings within real world AI use cases and providing accessible, no-code tools to explore how image recognition AI works in various applications, provided a low entry barrier for engaging with AI and developing AI literacy.

The varied design of different challenges focusing on different topics, and requiring different interaction styles, combining analogue and digital artefacts, successfully kept the participants engaged. They were curious to explore, and eager to repeat activities such as the *Deepfake* card game. We assumed that the younger generation would prefer digital artefacts, but analogue games engaged them just as well, especially when wrapped in a story, such as the *CMIYC* challenge. In contrast, reading instructions remained unattractive for this age-group, with a clear preference for verbal explanations. This suggests that the combination of different media formats seems to better spark engagement in younger generation, and dynamic, interactive objects need to be carefully integrated within the experience, so that important information provided as text grabs their attention. It also shows that adding limited facilitator guidance (onboarding, questions, technical support) to self-directedness was a good choice. Although this test obtained positive results, the limitations of our learnings need to be pointed out. The small sample does not allow for generalizable conclusions, even more so due to an unsatisfactory gender representation, lacking female participants. Future research should consider ways to framing the learning experiences to attract female participants as well, or find ways to avoid self-selection and

acquire a more diverse and representable sample. Additionally, a more objective measurement of AI competences could give a clearer understanding of the effectiveness of such approaches.

This work presents a preliminary exploration of the potential of experiential, gamified learning in addressing the challenges of teaching abstract, technical concepts. We have introduced the concept and prototype of an informal, exhibition-like learning space, integrating experiential learning with gamification elements, to demystify complex AI concepts, while supporting critical reflection on ethical implications. The developed design and prototype of the *AI Exploratorium* offer a blueprint for educators looking to facilitate critical AI literacy through playful approaches in various educational settings. Future work should focus on further investigating the effectiveness of this approach for diverse learner populations and integrating more rigorous and objective assessment methods to measure (long-term) impact on developing AI literacy. For this, we will make all the materials, data, and guides for organising and conducting the *AI Exploratorium* freely available online (iKIDO Web).

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Ethics Declaration: Ethical clearance was not required. Consent forms, with information about the project, were signed by the participants' parents.

AI Declaration: In creation of this paper, AI tool Grammarly was used for grammar checks.

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Defeating V.I.L.E. with Carmen Sandiego: GBL and Gamification for Teenagers with Intellectual Disabilities

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Abstract: Gamification is an educational methodology using game aesthetics, dynamics, and mechanics to enhance motivation and learning. In special education, this strategy has been shown to improve motivation, engagement, and knowledge retention, as it allows content to be adapted into a more interactive and playful format while promoting experiential learning. Additionally, gamification fosters autonomy and collaboration among students, which can be key in acquiring and reinforcing social skills and inclusion. This study is based on a gamified didactic proposal inspired by the Netflix series Carmen Sandiego, combined with a game-based learning methodology. A research-based design was implemented alongside a pilot experience in a Spanish public high school involving three adolescents with intellectual disabilities. The intervention consisted of five one-hour sessions using game mechanics, interactive storytelling, problem-solving challenges, and achievement-based rewards. Two data collection methods were employed: participant observation and a semi-structured interview with their teacher to assess the methodology's effectiveness after its implementation. The results indicated a high acceptance of gamification among the students. A firm initial and sustained motivation throughout the sessions was observed, along with a progressive increase in participation in the proposed activities. These positive results suggest that this approach can enhance student engagement and provide positive reinforcement for learning in students with intellectual disabilities. Moreover, the flexibility of the gamified approach was highlighted, allowing for the customization of content and its adaptation to the students' abilities, facilitating greater accessibility and comprehension of the topics covered. In conclusion, gamification based on the Carmen Sandiego narrative proved to be a practical methodology for motivating and improving the learning process of adolescents with intellectual disabilities. The promising results of this pilot study underscore the need for further research in this area. More extensive studies are recommended to confirm these findings and evaluate the long-term impact of gamification in special education, highlighting the importance of ongoing research in this field.

Keywords: Gamification, Game-Based learning, Intellectual disability, High school

1. Introduction

Intellectual disability (ID) is a neurodevelopmental disorder characterized by significant limitations in intellectual functioning and adaptive behavior, affecting conceptual, social, and practical skills necessary for daily living (DSM-5, 2013). These difficulties are intensified during adolescence due to the cognitive, social, and emotional changes typical of this developmental stage. Adolescents with mild ID tend to have poor cognitive flexibility, reduced capacity for abstract reasoning, and difficulties developing social skills, impacting their academic performance and social inclusion (Estrada Rollón, 2022).

Concerning schooling, it is common for these students to be in specific classrooms within ordinary schools. These classrooms offer individualised attention but can lead to isolation from the rest of the pupils if their active participation in school is not encouraged. In this context, maintaining motivation and engagement with learning tasks is crucial to promote their integral development and avoid disengagement phenomena, characterized by apathy, lack of initiative, and low academic self-esteem (Wang & Eccles, 2012).

At a broader level, digital accessibility in education faces several persistent challenges. Significant barriers include insufficient integration of accessibility standards in online platforms, a lack of adapted learning materials, limited personalization, and limited awareness among educators regarding inclusive digital practices (Screpnik, 2024; Sousa et al., 2023). Research has also highlighted that bridging the digital divide requires training programs targeting users with disabilities and their educators, focusing on digital skills and inclusive technologies (Murphy et al., 2024). These limitations impact adoption rates and learning outcomes, making designing digital experiences tailored to this population's needs essential.

With these challenges, active methodologies such as project-based learning (PBL), cooperative learning, and educational gamification emerge as educational strategies that allow content to be adapted and improve the learning experience. Educational gamification is understood as using elements of the game (mechanics,

dynamics, aesthetics) in non-playful contexts, such as the classroom, to increase motivation, involvement, and enjoyment of learning (Deterding et al., 2011).

Research shows the benefits of gamification for students with ID. For example, Abu et al. (2023) implemented play elements in a learning environment with students with mild and moderate ID, observing a significant increase in motivation and active participation. In a similar intervention, Ghasemi Arganeh et al. (2022) employed game-based instruction with students with ID, finding significant improvements in intrinsic and extrinsic motivation after 20 gamified sessions. The study revealed a statistically significant positive effect ($p < 0.01$), with effect sizes of 0.49 and 0.51 for each type of motivation. Koivisto and Hamari (2019) highlighted how personalized gamified environments can enhance student participation and a sense of belonging.

However, few studies integrate immersive, playful narratives and cooperative missions specifically adapted to the context of adolescents with mild ID in specific secondary school classrooms. This study presents a gamified proposal based on Carmen Sandiego's narrative. The main objective is to analyze how this gamified experience influences the motivation, active participation, and socio-emotional development of three adolescents with mild intellectual disabilities who were schooled in a specific classroom of a public secondary school.

2. Methods

This study is part of design research based on educational practice, with a quasi-experimental qualitative approach. It is a pilot experience in a public secondary school in Spain. Given the study's exploratory nature and the small number of participants, a quasi-experimental qualitative methodological strategy focused on describing and interpreting the experience was chosen.

2.1 Educative Proposal

2.1.1 Pedagogical justification

Adolescents with mild ID have cognitive characteristics that require specific methodological adaptations: concrete thinking, difficulties in abstract reasoning, the need for visual supports and scaffolding for comprehension, as well as longer learning times (Sajewicz-Radtke et al. 2022).

To face these challenges, gamification can offer a structured, motivating, and accessible educational environment, where learning is integrated through play, narrative, and emotional experience (Balarezo Lata et al., 2022). Several authors mention that the didactic possibilities of gamification facilitate the design of exploration, discovery, and positive reinforcement dynamics; constant and precise feedback; tasks adjusted according to the level of competence; and cooperative dynamics that facilitate interaction between equals (Kapp, 2012; Manzano-León et al., 2021).

In addition, the proposal is also nourished by Game-Based Learning (PBL), which allows the content to be approached from the logic of the game: clear rules, defined objectives, possibility of trial and error, and immediate feedback (Sánchez Montero, 2021). In the game, mistakes are not penalized, but become an opportunity for improvement and learning. This characteristic can be key for this student profile, as it reduces anxiety about failure and fosters a positive attitude towards learning.

On the other hand, when combined with Project-Based Learning (PBL), the functional and significant nature of the proposal is reinforced. PBL allows for working in an interdisciplinary way based on a challenge. In this model, Carmen Sandiego's narrative becomes the common thread of a great project: "Helping Carmen stop the plans of V.I.L.E. around the world". Thus, each weekly mission is a micro-project with clear objectives, various activities, games, and cooperative tasks.

2.1.2 Educational objectives

General objective

To design and implement a gamified learning experience based on Carmen Sandiego's narrative that promotes the comprehensive cognitive, affective, and functional development of three adolescents with mild ID, adapting the contents and dynamics to their curricular levels (1st and 2nd year of Primary Education) and their respective Individualized Educational Programs (IEPs).

Specific objectives by area of the IEP

- Area 1: Intellectual and cognitive development

- *Stimulate the processes of attention, memory, comprehension, and logical reasoning through playful activities adapted to the curricular level of 1st and 2nd year of Primary.*
- *Reinforce basic content of the curriculum in language and mathematics through brief, concrete, and visual gamified challenges.*
- *To promote planning, anticipation, and simple decision-making to promote the development of basic executive functions through games.*
- Area 2: Affective and emotional development
- *Enhance emotional expression through playful activities, facilitating the identification and verbalization of one's and others' emotions.*
- *Reinforce self-esteem through visible achievements and accessible rewards, favoring individual and group recognition.*
- *Promote tolerance to frustration in contexts of challenge and decriminalized error, as part of emotional learning in the classroom.*
- *Promote a favourable emotional climate in the group, based on cooperation, respect, and mutual support.*
- Area 3: Skill Development
- *Develop basic social skills (active listening, speaking turns, collaboration) through cooperative activities.*
- *To promote personal autonomy and responsibility in tasks structured through individual missions with progressively reduced support.*
- *Enhance initiative and choice through controlled options (reward selection, task order, in-game* decisions).
- *Improve visual-motor coordination and fine manipulative skills through games.*

2.1.3 Gamification design

The design of this gamified experience is based on the MDE model (Mechanics–Dynamics—Aesthetics) (Marczewski, 2015).

In this proposal, the aesthetics and narrative are inspired by the animated series Carmen Sandiego (2019), distributed by Netflix and created by Duane Capizzi, Jos Humphrey, and Kenny Park. The series reimagines Carmen Sandiego, a rebel former student of the international criminal organization V.I.L.E. who decides to switch sides and become a global vigilante. Accompanied by her team, she travels the world thwarting the plans of this organization. Within the framework of the gamified program, students assume the role of spies collaborating with Carmen, participating in special missions to recover stolen objects or prevent cultural, scientific, or technological crimes. Each session represents a mission in a different country, which allows curricular content (language, mathematics, science, social studies) to be worked on in a transversal way, together with learning related to culture, geography, and ethical values. On a didactic level, this narrative translates into a shared journey, in which learning becomes an adventure and each challenge is solved collaboratively.

The choice of this narrative responds to a series of pedagogical and motivational reasons (Manzano-León et al., 2023):

- Direct connection to youth interests: The series features an engaging plot, with elements of mystery, technology, and action that capture the attention of young audiences. The context of espionage and adventure offers multiple possibilities for playful adaptation without losing the pedagogical focus.
- Empowered female reference: Carmen is a strong, independent, intelligent, and ethical character, which allows for debates and reflections on equality, leadership, and gender stereotypes. This figure acts as a positive and diverse model, especially relevant in educational contexts that seek to make visible other references beyond the traditional ones.
- High audiovisual and contextual richness: The series offers explicit and adaptable visual material, which makes it easier for educators to have characters and scenarios already created, only having to adapt them for the different classroom challenges. Each chapter introduces real data on other countries, reinforcing the narrative's didactic value and connection with social science content and knowledge of the environment.
- Potential to integrate curricular content and social skills: Narrative facilitates the design of contextualized missions that integrate curricular content, while encouraging cooperation, group decision-making, and peer communication.

Game dynamics refer to the responses that mechanics generate in players, such as cooperation, overcoming challenges, exploration, competition, or decision-making. Concerning the dynamics of this gamification, these were carefully designed to promote meaningful learning, sustained motivation, and the acquisition of social and emotional skills in students with mild intellectual disabilities. Some of the main dynamics used in this program were: Shared visual progress based on a map-mission of the world, which served as an anticipatory element, generating expectations about the next destination; Cooperation, most of the challenges were carried out in groups, trying to get everyone to participate actively, even those who may have more difficulties in initiative; Time-limited challenges such as time trial missions, with a limited duration to solve a challenge or trial. This dynamic encouraged concentration, quick decision-making and emotional regulation in the face of time pressure, always in a safe environment and without penalty for mistakes; Immediate and understandable feedback, since each mission must end by offering an oral and visual review of the achievements obtained, and if they failed or had any doubts, the teacher helped with the doubts; A continuous and chained narrative where the story of Carmen Sandiego developed in an episodic and progressive way. Each session included a narrative fragment connected to the previous mission and left clues or challenges open for the next.

Mechanics are the concrete elements of the game's structure: rules, rewards, conditions, and tools that allow the gamified system to work. In this program, the mechanics were selected and adapted to be accessible, motivating, and understandable for the three participating adolescents with intellectual disabilities. Some of the most outstanding are a coin system, which assigns different coins to each activity passed in the classroom, and an extra-voluntary one outside the classroom for each mission. This system made tracking individual and group progress easier while reinforcing desirable behaviors through tangible recognition; the Spy card was given after each mission, and the first mission was where staff were rewarded for each mission achieved, to see the work done visually. This playful and symbolic element reinforced the sense of belonging to the game, the monitoring of individual progress and the motivation to participate in new missions; Rewards store where you can redeem the coins obtained for privileges previously negotiated with the group (e.g.: choose song, free rest, five extra minutes with favorite material, be helper of the day).

2.2 Participants

The participants of this intervention are enrolled in a specific secondary school classroom in southern Spain, in the autonomous community of Andalusia. According to current regulations, specific classrooms or Special Education classrooms located in ordinary schools are configured as a type of schooling aimed at students with special educational needs, when these needs cannot be adequately met in an ordinary classroom with supports. In these classrooms, students receive intensive and individualised attention, with specific personal and material resources, and with a curriculum adapted to their characteristics and potentialities, although always seeking the maximum possible inclusion in the life of the ordinary school.

Three adolescents, aged between 14 and 15, have participated in this experience: a boy and two girls. All of them have an updated psycho-pedagogical evaluation, carried out by the school's counselor. In this evaluation, the diagnosis of mild intellectual disability is determined following the criteria established by the recognized clinical and psycho-pedagogical reports.

Based on this diagnosis and the individualised assessment process, the teaching team has drawn up an Individualised Educational Programme (IEP) for each student, which includes significant curricular adaptations. The IEP refers to the curricular level equivalent to the First and Second Years of Primary Education in key areas such as Spanish Language, Mathematics, Knowledge of the Environment, and Personal and Social Development.

2.3 Instruments

Participant observation: It is a qualitative technique that allows the researcher to integrate into the participants' natural environment to observe their behavior directly and contextually. This technique is instrumental in educational studies where it is desired to analyze student interaction and responses in real time (Angrosino, 2007). During the five gamified intervention sessions, a research team member directly observed the three participants' interactions while performing the activities based on *Carmen Sandiego*'s narrative. The following indicators were documented: Initial and sustained motivation, participation in activities, reactions to challenges and rewards, and collaboration with peers.

Semi-structured interview: It is a data collection technique that combines previously designed questions with the flexibility to adapt new questions according to the interviewee's answers. This technique helps gain subjective and detailed insights, especially from experts such as teachers. According to Adams (2015), semi-structured interviews allow for a deep understanding of the participant's experience, balancing structure and

spontaneity. At the end of the experience, the teacher in charge of the group was interviewed. The interview focused on the teacher's perception of the methodology's effectiveness, changes observed in the motivation, understanding, and participation of the students, and assessing the flexibility and accessibility of the gamified approach.

2.4 Data Analysis

The analysis was conducted using a qualitative approach, using an inductive thematic analysis, due to the study's exploratory nature (Mieles Barrera, Tonon, and Alvarado Salgado 2012). Two primary sources were analyzed: observations of the sessions and a semi-structured interview with the teacher. The data were manually coded on a first reading, then grouped into thematic categories such as sustained motivation, active participation, and improvement in social skills. The triangulation between the observations and the interview allowed the findings to be validated from different perspectives.

3. Results

The participant observation and the semi-structured interview results reflect an upbeat assessment of the gamified experience by the three participating students and their teacher.

From the first session, a high initial motivation was evidenced, manifested in the enthusiastic attitude of the students at the beginning of the activity, their willingness to assume roles within the game, and their interest in the materials. The field notes recorded that the students were curious about the content of the missions and actively asked about the characters and the day's objective. This motivation was maintained and consolidated throughout the five sessions, thanks to the progressive narrative structure, the system of visual rewards such as the spy card, and the emotional connection with the different characters of Carmen Sandiego. According to the teacher, "From the moment they walked through the door, they were already asking what country we were going to today, they loved the idea of being spies with a mission to fulfil."

In terms of participation, a clear evolution was observed. In the first session, most of the interventions by the students were brief and required constant guidance. One of the students, in particular, avoided verbal participation. However, from the third session, a change was evident: "during the mission in Australia, [student 1] raised her hand on her initiative to propose a solution to the enigma of one of the activities and she was very excited when she got it right, I think it was the most beautiful thing of the day". In the last session, the three students actively participated in the group's decisions, shared ideas confidently, and engaged engagingly throughout the session. The teacher also highlighted this progress: "One of the girls has a hard time starting an activity without support, but here she saw the challenge on the screen and immediately wanted to participate; that is not usual with other academic tasks [...]. While [the student] has a hard time concentrating more than ten minutes on the same task, and especially on the last day with the final escape room, he worked all hours without complaining, I would like to continue doing this type of activity to promote his concentration."

The social and emotional dimension also showed a remarkable development throughout the process. While in the first session, more individualistic behaviors or conflicts to interact were detected, in the fifth session, fluid cooperation was observed. "The students offered each other help, respected the turns, and celebrated the team's successes together," said the teacher. In addition, an improvement in error tolerance was noted. In one of the final sessions, after making a mistake in a mission against the clock, the three students reacted with humor and expressions such as "it is okay, let us go again!", which reflected a change in emotional regulation in the face of frustration.

A small evolution in autonomy was also observed. At the beginning of the program, students expected constant prompts on what to do next. For the last session, although they required support from the teacher, they first tried to do one or two resolution tests before asking for help. This coincided with the teacher's perception, who stressed that "everyone felt part of Carmen's team and wanted to do their part, increasingly on their initiative."

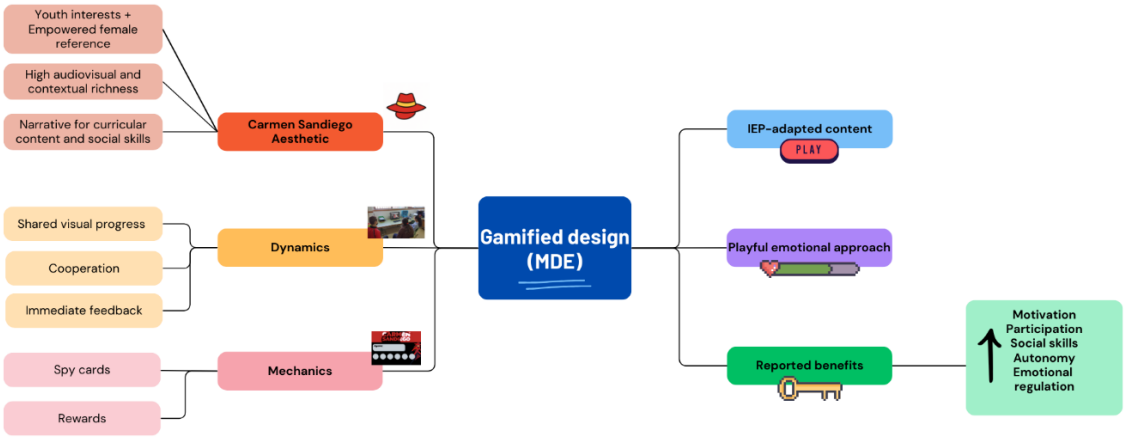

Figure 1: Diagram of the results of implementing the Carmen Sandiego-based gamified learning experience

4. Discussion and Conclusions

The results obtained in this pilot study confirm that gamification, when intentionally designed and adapted to students' needs, can positively impact the motivation, participation, and socio-emotional development of adolescents with mild intellectual disabilities. The gamified experience based on Carmen Sandiego's narrative facilitated the active involvement of the students from the first session. It sustained their interest throughout the five sessions, which was reflected both in the enthusiasm observed and in the comments of the teacher, who highlighted the spontaneous commitment of the students to history, missions, and materials. These findings are consistent with recent studies that have shown the potential of gamification as an inclusive educational strategy. For example, Abu et al. (2023) highlight how incorporating playful elements in educational settings can increase the desire to participate and improve learning attitudes among students with intellectual disabilities, especially when significant roles, rewards, and challenges are integrated. Likewise, Rahmatullah (2024) showed that multisensory methodologies based on play increase cognitive engagement and contribute to progress in basic areas of learning, such as vocabulary, memory, and sustained attention.

The positive evolution of students in this experience, both in their autonomy and in their tolerance to frustration, is supported by Cruz and Palaoag (2019), who argue that gamified environments with immediate feedback, clear narrative structure, and visible rewards stimulate persistence in the task and self-efficacy among students with specific needs. Similarly, the role of intrinsic motivation and the feeling of competence has played a fundamental role in sustaining students' effort and attention, especially in tasks such as the final escape room, which demanded more time and concentration (Alramammnh et al. 2024).

In addition to the motivational value of game dynamics and mechanics, students' motivation can be influenced by narrative and its Pygmalion effect, understood as the positive influence of high expectations on students' performance and attitude. When teachers project positive beliefs about their students' abilities, even those with more significant difficulties tend to respond with greater commitment, self-confidence, and perseverance (Isamail et al., 2022). This phenomenon is especially relevant in special education contexts, where low expectations can limit the development of key cognitive and emotional skills. In this sense, the narrative used in the gamified proposal – focused on the figure of the student as a spy who must save the world together with Carmen Sadiego – not only provided the framework for the development of the didactic proposal, but also conveyed an implicit message of confidence in the students' abilities: "We need you to save the world. Without you, V.I.L.E. will win." Such a design may have generated an emotionally safe and stimulating environment that favored a positive self-image and reinforced intrinsic motivation, in line with what Weinstein (2018) proposes, who points out that educational interventions with high expectations can become authentic "positive prophecies of self-confidence" when applied to historically marginalized students or students with special needs.

However, these results should be interpreted cautiously, as the study has several limitations inherent in its design. The sample comprised only three students, which prevents any statistical generalization. In addition, it was a short-term experience without a control group or longitudinal follow-up, which limits the possibility of establishing causal relationships between the intervention and the changes observed. Despite these limitations, the study provides relevant evidence consistent with recent research, which reinforces the relevance of continuing to explore gamification and GBL as an educational tool in special education contexts. Future studies

could incorporate a mixed design, with larger samples and quantitative assessment tools, and explore the long-term effects of this type of methodology on the academic, social, and emotional development of students with intellectual disabilities.

In conclusion, this study has shown promising indications about the potential of play strategies to improve motivation, active participation, and socio-emotional development in students with intellectual disabilities. Despite the limitations inherent in the study's exploratory nature, the results allow us to glimpse relevant pedagogical benefits, especially in special education contexts where commitment to the task and methodological accessibility are key factors. Experience suggests that didactic proposals based on play and narrative can foster more inclusive, meaningful, and emotionally positive environments, in which students feel like protagonists of their learning process. The need to continue research in this line is highlighted, incorporating broader and more systematic designs that allow for a more in-depth evaluation of the impact of gamification and GBL on inclusive education.

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Ethics declaration: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of the Bioethics Committee of the University of Almería (Ref. 126/2020).

AI declaration: While preparing this work, the authors utilized GPT-4 and Grammarly to enhance the work's English language. After using this tool, the authors reviewed and edited the content as necessary and took full responsibility for the publication's content.

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Testing the Game: Gamma Finance as a Design-Based Prototype for Financial Literacy in Higher Education

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Abstract: This study presents Gamma Finance -GF, a high-fidelity instructional game designed to explore the potential of gamification in enhancing financial literacy among university students. Grounded in gamification and experiential learning principles, GF enables participants to engage in active decision-making, problem-solving, and strategic thinking within simulated financial scenarios. The study followed a design-based research approach, employing a quasi-experimental methodology without a formal control group, which limits the ability to infer causality. The findings should therefore be interpreted as exploratory and formative. Data were collected through expert validation, pilot testing, focus groups, and iterative design refinements. The study offers initial insights into how students interact with the game and perceive its educational value. Participants reported increased engagement and motivation, with 91% expressing strong interest in learning financial concepts through gameplay. Additionally, qualitative feedback and performance indicators suggest the game may help develop analytical, mathematical, and financial decision-making skills. These findings position GF as a promising prototype and an example of how gamified learning tools can complement traditional approaches to financial education. Future research should further investigate its impact through controlled studies and assess its scalability across diverse educational contexts.

Keywords: Financial education, Gamification, Instructional game, Experiential learning, Financial literacy

1. Introduction

Financial education has become an essential skill in the 21st century, enabling individuals to make informed decisions about saving, investing, credit management, and budgeting. Despite its recognized importance, global financial literacy levels remain alarmingly low, even in advanced economies (Lusardi & Mitchell, 2011; Lusardi & Messy, 2023). This knowledge gap is particularly critical among university students, who often transition into the workforce and assume financial responsibilities without a solid understanding of key financial concepts (Stepnova, Starchikova & Kurashova, 2024). Poor financial literacy can lead to excessive debt, poor financial planning, and missed economic opportunities.

In Colombia, the situation is no different. According to Asobancaria (2021), the national Financial Education Index has shown a decline, underscoring the urgent need to strengthen financial education. Higher education institutions are uniquely positioned to address this challenge, offering a platform for students to develop critical financial skills before entering the professional world. However, traditional methods of teaching financial literacy, often focused on theoretical content, struggle to capture students' interest or promote long-term retention.

To address this gap, innovative teaching strategies such as gamification have gained prominence. Gamification, defined as the use of game elements in non-game contexts, has shown promise in enhancing student motivation, engagement, and learning outcomes (Pashaei et al., 2024; Lotter & Okoro, 2023). In financial education, gamified tools provide an opportunity for students to experience financial decision-making, manage resources, and solve problems in a risk-free environment.

This study introduces Gamma Finance -GF, a physical, high-fidelity board game designed as a proof of concept to explore the potential of gamification for improving financial literacy. The game engages students in negotiation, decision-making, and problem-solving tasks across three difficulty levels, each aligned with different levels of financial knowledge and age groups. By doing so, GF seeks to bridge the gap between theoretical instruction and experiential learning.

Rather than aiming to produce validated evidence of effectiveness, this study introduces GF as a design-based research initiative, one that iteratively develops and refines an educational tool while gathering insights into its perceived educational value, usability, and alignment with learning goals. Specifically, the research seeks to address the following questions:

- How do students experience and interpret the educational value of GF?
- What design elements contribute most to engagement and perceived learning?
- What insights can be drawn to guide future iterations or broader implementations of gamified financial education?

The study employed a quasi-experimental framework involving 45 undergraduate students and drew upon expert validation, pilot testing, focus groups, and iterative design refinements. While the results are exploratory, the findings suggest that GF offers meaningful learning experiences and design insights for the development of gamified financial literacy tools.

Ultimately, this study contributes to the growing body of design-based educational research, particularly within the context of emerging economies. GF, developed in Colombia, offers a locally grounded yet globally relevant perspective on the role of games in financial education. Its development process underscores the importance of iterative, user-centered design and positions the game as a springboard for further innovation and cross-cultural dialogue in game-based learning.

2. Theoretical Background

In the 21st century, higher education institutions are expected to fulfil a transformative role, not merely transmitting knowledge but fostering active, experiential learning. This involves adopting innovative pedagogical methods such as gamification, which can revitalise traditional instruction. Financial education has emerged as a key competence, enabling students to develop analytical, systemic, and critical thinking for responsible economic decision-making (Pashaei et al., 2024; Reddy and Taj, 2024)

The digitalisation of society and the expansion of fintech services have altered how individuals engage with financial management, promoting financial inclusion through improved access to digital tools (Lyons and Kass-Hanna, 2021). Yet, despite these technological strides, financial literacy remains critically low worldwide (Lusardi and Mitchell, 2011; Lusardi, 2019; Lusardi and Messy, 2023), necessitating stronger educational initiatives.

Robust financial education not only supports personal wellbeing but also strengthens economic stability by empowering individuals to make informed decisions about savings, debt, and investment (Péter and Ambilikumar, 2020; Stepnova, Starchikova and Kurashova, 2024). Gamified interventions like GF exemplify how experiential learning can reinforce financial competencies while maintaining student engagement.

Universities are thus called to adopt teaching strategies beyond traditional models. Gamification offers clear potential, particularly when aligned with rigorous design and measurable learning outcomes (Kurnianti et al., 2023; Kraitzek and Förster, 2023; Ambuehl, Bernheim and Lusardi, 2021).

Literature widely recognises the link between financial education and financial wellbeing. Munisamy, Sahid and Hussin (2022) found that financial knowledge influences responsible credit use and economic resilience. Their study in Malaysia showed that financial education promoted healthy habits and improved household financial stability, particularly in low-income groups.

In the digital era, financial illiteracy is further complicated by the rise of online banking and the risk of digital fraud. A recent Russian study (Stepnova, Starchikova and Kurashova, 2024) demonstrated that targeted financial literacy programmes improved students' understanding of interest rates and financial markets between 2020 and 2023. These findings support the integration of financial education as an elective within university curricula.

Financial education also intersects with entrepreneurship and strategic decision-making. Pashaei et al. (2024) highlight how economics education enhances students' entrepreneurial skills, suggesting broader applications of financial literacy beyond personal budgeting to include enterprise management.

The OECD (2011) defines financial education as the process through which individuals improve their understanding of financial products and risks, developing the skills necessary for informed decision-making. A lack of such knowledge can undermine household economic security. Lusardi (2019) notes that financially literate individuals are more likely to save, invest efficiently, and avoid excessive debt, especially among youth and economically vulnerable populations.

Klapper and Lusardi (2020) and Tahir, Richards and Abdullah (2021) similarly found that stronger financial education correlates with reduced credit card debt. Ludlum et al. (2012) revealed that fewer than 10% of students knew basic credit terms, and Allgood and Walstad (2013) showed that older students are less likely to repay debt in full, highlighting the ongoing need for financial education throughout life.

Developing financial literacy requires more than technical skills, it also involves emotional awareness and strategic foresight. Embedding these components into university courses can equip students with holistic financial management skills.

Recent innovations demonstrate that digital tools and planning exercises can improve financial literacy (Kurnianti et al., 2023). Kraitzek and Förster (2023) propose assessing competencies through emotional recognition systems and practical evaluations, reinforcing the importance of immersive learning.

Game-based learning (GBL) has gained attention post-pandemic due to its effectiveness in increasing learner engagement and decision-making capacity (Lotter and Okoro, 2023). While gamification in financial education remains under-researched, scholars such as Reisdorfer et al. (2025) underline the importance of addressing three core dimensions: financial knowledge, attitudes, and behaviours. These can be enhanced through contextual and experiential learning models tailored to youth.

To respond to these challenges, universities must design structured, technology-enhanced programmes that integrate gamified tools and real-world applications. Initiatives like GF at the Universidad Tecnológica de Bolívar serve as promising models, bridging academic content and practical financial competence for long-term student wellbeing.

3. Methodology

This study adopts a design-based research (DBR) approach to explore the development, implementation, and refinement of GF; a high-fidelity educational board game aimed at strengthening financial literacy among university students. DBR is particularly suited to educational innovation, as it enables iterative cycles of design, testing, and revision in real-world learning environments, while generating both practical solutions and theoretical insights (Design-Based Research Collective, 2003).

The research was conducted at the Universidad Tecnológica de Bolívar (Cartagena, Colombia), a higher education institution committed to the integration of experiential and active learning within its pedagogical model. The study involved 45 undergraduate students enrolled in social science and engineering programmes, selected through purposive sampling to ensure diversity in academic backgrounds and financial knowledge.

Participants were divided into guided and unguided groups to observe the potential role of instructional support in gameplay-based learning. All participants were informed of the study's aims and gave their consent in accordance with ethical standards for educational research.

3.1 Design and Development of GF

GF was conceived as a physical board game incorporating core elements of financial education, such as income management, budgeting, savings, investment, and debt. The game is structured into three progressive levels of difficulty, allowing for adaptability across varying levels of financial literacy and age groups. Its mechanics integrate negotiation, risk assessment, problem-solving, and strategic decision-making.

The design process followed iterative prototyping cycles, involving expert reviews, pilot testing with students, and ongoing refinement based on feedback. This ensured both pedagogical alignment and user engagement. Content validation was conducted by three subject-matter experts in finance and education, who assessed the accuracy, relevance, and clarity of game scenarios and rules.

3.2 Data Collection Methods

Multiple qualitative and quantitative techniques were employed to gather data across different stages of the intervention:

- Focus groups were conducted before and after gameplay sessions to explore students' expectations, perceptions, and reflections.
- Observation protocols were used to document student interaction, decision-making processes, and collaborative behaviours during gameplay.

- Post-session questionnaires measured self-reported changes in motivation, perceived learning, and financial confidence.
- Satisfaction surveys employed a 10-point Likert scale to assess student engagement and enjoyment.
- Comparative analysis between guided and unguided groups provided exploratory insights into the role of facilitation in learning outcomes.

3.3 Data Analysis

Data were analysed using a mixed-methods approach. Quantitative data from surveys and questionnaires were processed using descriptive statistics to identify patterns in motivation and satisfaction. Qualitative data from focus groups and observations were coded thematically to capture emergent insights on learning dynamics, engagement, and concept assimilation. This multi-method strategy enabled a comprehensive understanding of the educational value and design implications of GF within a university setting.

Process Description

- *Content validation:* Experts assessed the coherence of the financial content, the clarity of the instructions, and the alignment with the educational objectives. Recommendations from experts were integrated to improve the game's precision and applicability.
- *Pilot testing in classroom contexts:* The game was implemented in two class sessions, each lasting 40 minutes. These courses were selected intentionally to represent different levels of financial competency and academic progression (implemented in an introductory-level course -first semester and an advanced-level course -ninth semester), thus supporting the robustness of the quasi-experimental design. Students participated in small groups and played GF following the established rules. Observers documented student interactions, their financial decision-making abilities, and their level of engagement.
- *Focus groups:* 12 students were selected intentionally to participate in guided discussions. Using the FESTIN protocol (Easy, Attractive, Social, Timely + Fun) (Chaparro et al, 2020), their perceptions of the experience, challenges encountered, and the learning outcomes achieved were explored.
- *Iterative design improvements:* Feedback from students and experts was consolidated into a feedback matrix. Adjustments were made to the game's rules, the complexity of financial questions, and the clarity of instructions. Four independent classroom observers, and four co-designers who participated in both formative development and iterative refinement stages. The final design of GF incorporated these changes to optimise its educational effectiveness.

The process outlined above is summarised in Table 1.

Table 1: Summary of validation phases and instruments

Phase	Methodological Technique	Participants	Instrument/Tool	Purpose
Content validation	Expert Review (See Figure 1)	3 experts (finance and pedagogy)	Checklist	Ensure theoretical and educational coherence of the game.
Pilot testing	Classroom observation (See Figure 3 and 4)	45 students	Observation sheets and questionnaires	Evaluate playability and understanding of concepts.
Focus groups (See Figure 2 and 5)	Semi-structured discussion	12 selected students	FESTIN protocol	Gather qualitative feedback.
Iterative improvement	Collaborative analysis	Design team and experts	Feedback matrix	Optimise the gaming experience

Figure 1: Expert Review

Figure 2: Focus group discussions (research team)

Figure 3: Pilot Application

Figure 4: Pilot Application (control)

Figure 5: Focus group discussions (users)

4. Results and Discussion

4.1 Gamma Finance

GF is structured into three levels of difficulty; each tailored to varying levels of prior knowledge and age groups. At each level, participants are required to negotiate, solve problems, and make decisions through managing a game board, thereby creating a controlled and secure environment for experimentation. Additionally, the reward and challenge system played a key role in sustaining motivation and engagement, encouraging active participation and continuous feedback. The complete game board at the advanced level is presented in Figure 6 and Table 2. The hexagonal board design represents a significant departure from traditional financial education games, which often rely on linear or square formats. Its spiral paths and triangular cells promote non-linear navigation and strategic decision-making, thereby fostering critical thinking. Each cell is embedded with thematic symbols related to financial literacy, while the coloured zones at the centre and edges suggest thematic territories, enabling players to begin from different starting points and pursue unique learning trajectories. This personalised and decentralised structure reinforces the notion that there is no single path to success, an

important pedagogical shift that acknowledges the complexity and diversity of real-life financial experiences. Moreover, the network-like layout fosters cooperative interaction rather than zero-sum competition, aligning with more progressive and inclusive educational approaches. The modular and symbolic nature of the design further allows for physical or digital adaptation and thematic expansions, reinforcing its potential as an innovative and flexible tool in contemporary financial education.

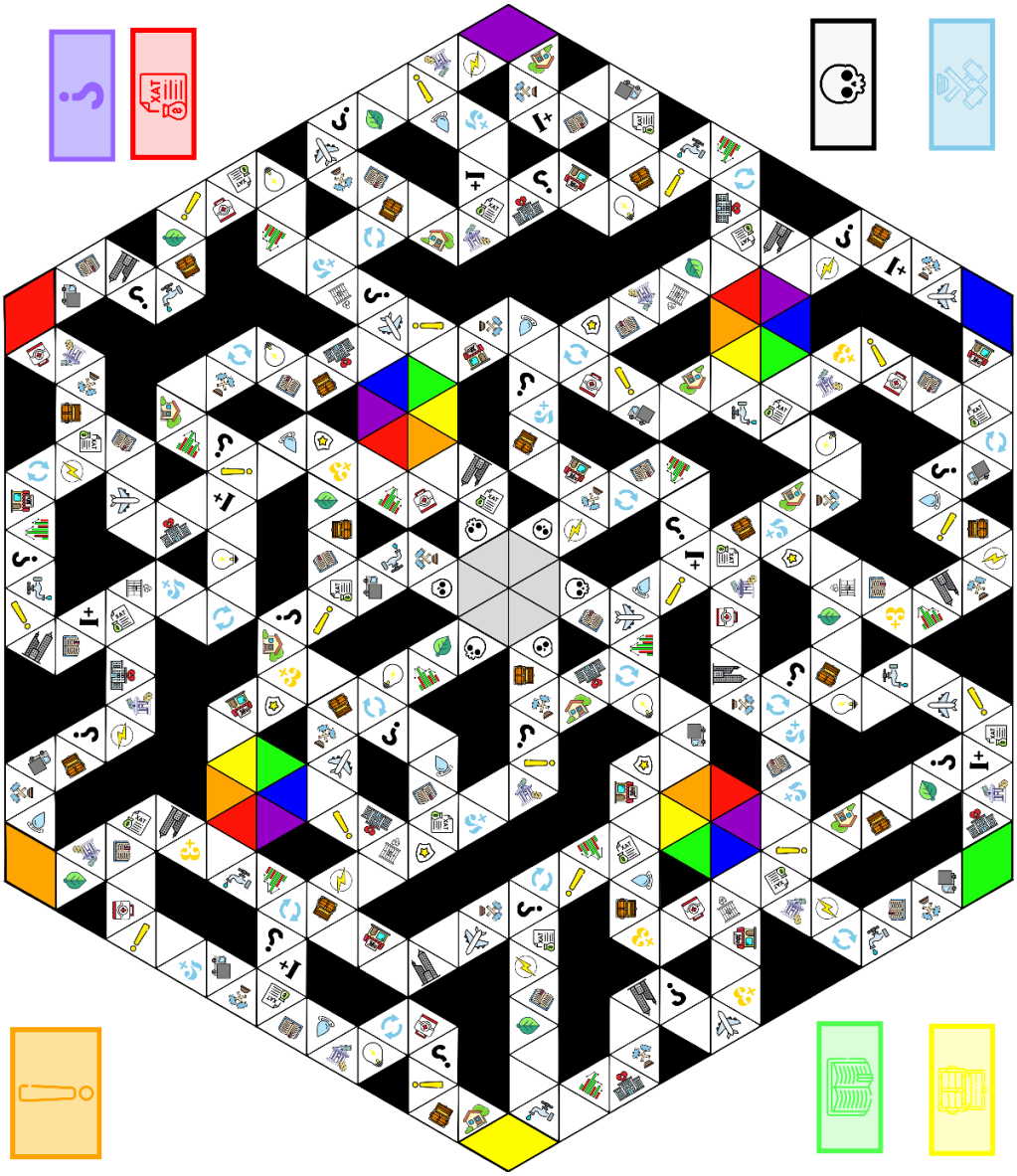

Figure 6: Game Board GF (Advanced Level)

Table 2: Symbols and iconography

Symbols and iconography	Description
	Starting the game: Each player begins on a coloured starting point with an initial balance of 500 units
	Roulette tiles: Upon landing on a roulette tile, roll the colour die.
	Purchasing properties
	Types of cards: There are seven types of cards, each with unique effects: Financial Bonds (Yellow), Concepts (Green). Penitentiary (Blue), Question (Purple), Taxes (Red), Missions (Orange), Financial death (Black): Severe penalties that may lead to bankruptcy.

Symbols and iconography	Description
	Gamma Market
	Movement-related spaces
	Immunity Tile
	Confinement rules

The comparative evaluation of GF against other gamified financial learning tools (See Table 3) reveals a clear strength in its multilevel design, physical engagement, and research-based approach. While digital platforms like FinAI and CashCoach excel in accessibility and scalability, they often lack the immersive roleplay and scenario-based strategy embedded in GF. Similarly, although games such as FinPlan and ISCA Family Game provide engaging simulations, they tend to focus on narrow segments of financial literacy, either planning or budgeting, whereas GF addresses a broader conceptual spectrum, including negotiation, analytical reasoning, and financial ethics. The inclusion of adjustable difficulty levels, reflection of real-world financial roles, and alignment with pedagogical principles such as self-determination and goal orientation mark GF as a potential comprehensive educational tool. This positions it not only as an innovative game but as a structured academic intervention capable of reinforcing curricular objectives in financial education.

Table 3: Comparative analysis of financial education games

Name	Country	Target Population	Methodology	Objective	Format	Results	Key Differentiator	Citation
FinAI	India	University students and financially literate youth	Google-based course selection, quizzes, chatbot, real-time data	Evaluate platform's effectiveness in simplifying financial concepts	Digital interactive platform	Increased student interest in finance through gameplay	AI integration and quiz-based progression	Deshmukh (2025)
ISCA Family Game	Portugal	Students aged 12–18 from primary to university levels	Kahoot quiz, budgeting simulations, reflective exercises	Raise financial awareness and responsible consumption	Physical board game with character tokens	Increased awareness and engagement	Pre/post assessments and reflection	Estima and Peguinho (2024)
META-Z	Indonesia	Gen Z youth (18–26 years)	Role-based financial simulations	Improve Gen Z financial literacy	Hybrid physical-digital	Higher satisfaction and motivation	Wealth multiplier goal mechanic	Lisana (2025)
Moonshot	Germany	Secondary school students	Scenario cards for financial transactions	Empower responsible daily financial choices	Physical card-based game	Enhanced perceived value of financial literacy	Personal life project alignment	Platz and Zauner (2025)
CashCoach	Germany	Secondary school students	Quizzes, missions, knowledge duels	Gamified digital financial literacy	Digital animated app	Awarded 'Best Scientific Analysis'	Strong digital engagement and competition	Ambacher et al. (2023)
FinPlan	Malaysia	Lower secondary students (15–16 years)	AR-enhanced board game simulating incomes and expenses	Improve personal financial planning	Board game with AR	Enhanced financial planning knowledge	Focus on planning, AR feature	Yin et al. (2025)

4.2 Experience

4.2.1 Participant profile and engagement

The study involved 45 (NS=45) undergraduate students (53% female, 47% male) from the Universidad Tecnológica de Bolívar, aged 18-26, enrolled in two finance-related courses (implemented in an introductory-level course -first semester and an advanced-level course -ninth semester: ITC for business and Finance I) together with their teachers (NT=2). The participants were divided into guided and unguided groups to assess

the impact of instructional support on gameplay and learning outcomes. A detailed overview of participant characteristics is provided in Table 4.

Table 4: Participant Demographic

Characteristic	Percentage (%)
Gender	Female: 53% Male: 47%
Age range	18-26 years
Academic background	Business: 56% Engineering: 27% Other: 17%
Group distribution	Guided: 52% Unguided: 48%

4.2.2 Student perceptions of GF

Participants' perceptions of the game were assessed through a post-session questionnaire and focus group discussions.

- *Interest in Financial Education*: 91% expressed strong interest in learning financial concepts through the game.
- *Self-perceived Financial Knowledge*: Basic: 44%, Intermediate: 44%, Advanced: 4%, No prior knowledge: 7%
- *Keywords used to describe the game (Positive, Cognitive and Financial): Positive:* "Fun" (16 mentions), "Educational" (5), "Good" (4), "Interesting" (3), "Didactic" (3), "Innovative/Creative/Different" (3), "Enriching", "Complete", "Cool" (1 each). *Cognitive:* "Strategy", "Analytical", "Reasoning". *Financial:* "Accounting", "Investment", "Finance"
- *Overall satisfaction:* On a 10-point scale, the game received an average score of 8.78, indicating high satisfaction.
- *Impact of gameplay experience:* Participants reported engaging with a range of simulated financial tasks, most notably: property acquisition (91%), calculating interest, rent, or taxes (74%), answering financial questions (70%), managing money (70%). Facing business dilemmas (48%) the lowest, likely due to randomness in gameplay mechanics (e.g., dice rolls and tile landings)
- *Iterative Decision-Making:* 72% of students reported that they changed their strategies during gameplay, indicating active reflection and adaptation. The variability in exposure to activities reflects the intentional game design incorporating chance, allowing players to simulate real-life unpredictability in economic decision-making. This feature, while introducing asymmetry in experience, mirrors authentic financial environments, reinforcing the learning objectives.
- *Cognitive and affective learning outcomes:* Participants were asked to rate their agreement with six learning outcomes (Analytical capacity, Problem-solving skills, financial decision-making, Mathematical skills, Motivation to learn financial concepts, Development of financial knowledge) on a five-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). All responses clustered within the top two agreement levels (Agree/Strongly Agree). These exploratory findings suggest that the game effectively supported both cognitive and affective dimensions of learning. Its format promoted situated problem-solving and engaged multiple intelligences (logical-mathematical, interpersonal, and strategic reasoning), thus aligning with pedagogical theories underpinning experiential and constructivist learning.
- *Qualitative insights, student feedback:* a thematic analysis of focus group discussions revealed four key themes: (a) Engagement and motivation: *"I never thought finance could be this fun.", "The game made me think about money in a completely different way.";* (b) Practical learning: *"Understanding interest rates became much easier because I saw how they worked in the game.", "It was like managing a small company, but with no risk.";* (c) Strategic thinking: *"I had to plan my moves carefully, just like in real life.", "The decisions we made had real consequences in the game.";* (d) Peer interaction: *"It was fun to negotiate with other players.", "We learned a lot by discussing strategies with our classmates."*

GF as a design-based research initiative is a viable educational tool for enhancing financial literacy in higher education. Preliminary findings from the pilot implementation are summarised as follows, demonstrate that students do not merely learn through the game, they enjoy and internalise the experience. This confirms the central tenet of game-based learning: cognitive immersion through meaningful play. Moreover, the analysis reveals that the game succeeds in bridging theoretical knowledge with practical simulation, encouraging students to make decisions under constraints, negotiate, and reflect on outcomes, all essential elements of real-world financial behaviour. The inclusion of both guided and unguided groups also opens possibilities for further comparative analysis of instructional scaffolding in gamified environments. Future studies could employ pre- and post-intervention measures to quantify knowledge gains or examine longitudinal retention of concepts introduced during gameplay.

4.3 Discussion

It is important to note that, although quasi-experimental in nature, this study did not include a separate control group. As such, the design is best interpreted as an exploratory educational intervention rather than a validated test of efficacy. The results of this study suggest that GF holds promise as a design-based educational prototype for enhancing financial literacy among university students. By integrating gamification and experiential learning principles, the game offers a dynamic, interactive environment in which learners actively engage with financial concepts rather than passively consuming information.

These preliminary findings resonate with existing literature on gamified learning, which emphasizes the value of active environments in promoting higher-order thinking skills (Kiili, 2005; Lotter & Okoro, 2023). Through real-world-inspired financial scenarios, GF enabled students to apply theoretical knowledge in practice, especially regarding complex topics such as interest rates and investment strategies. The game mechanics encouraged risk analysis, strategic planning, and adaptive thinking, which simulate authentic financial behaviour.

Qualitative feedback frequently included terms such as "Fun," "Educational," "Strategy," and "Analytical", suggesting a meaningful blend of enjoyment and cognitive stimulation. The game's negotiation-based structure fostered peer learning and collaborative reflection, enriching the overall learning environment.

In terms of the OECD's financial literacy framework, encompassing knowledge, skills, and attitudes (OECD, 2011) GF showed potential to contribute in the following areas:

- Knowledge acquisition: Students demonstrated improved comprehension of core financial concepts such as interest, taxes, and investment.
- Skill development: Gameplay encouraged practical behaviours like budgeting, negotiation, and risk evaluation.

In comparing GF with other gamified financial education initiatives such as FinAI, ISCA Family Game, and META-Z, several distinguishing features emerge:

- Tactile learning: Unlike digital platforms, GF emphasizes physical interaction, encouraging face-to-face social learning and teamwork.
- Adaptability: The three-tiered difficulty structure allows the game to accommodate diverse levels of financial literacy, from beginners to advanced learners.
- Design-based development: The iterative prototyping process ensured pedagogical coherence and continuous improvement through user feedback and expert input.

While GF has shown encouraging potential as a learning tool, several areas warrant further exploration:

Building on the current development of a digital version, future iterations of GF could explore hybrid implementations combining physical gameplay with digital interfaces. Potential avenues include developing a web-based or app-based platform for remote or asynchronous participation, integrating analytics to track player decisions, and incorporating adaptive difficulty through algorithmic feedback. These advances would support broader accessibility, especially in low-resource or distance-learning environments, while enabling scalable data collection for future evaluation and refinement.

4.4 Limitations

This study presents several limitations. First, the lack of a formal control group restricts the ability to draw causal conclusions from the observed outcomes. Second, reliance on self-reported measures, such as perceived learning and motivation, may introduce bias and limit the objectivity of the findings. Third, the study was conducted within a single institutional setting, which may affect the generalisability of results to other contexts

or populations. Future research should address these limitations through controlled trials, longitudinal assessments, and multi-institutional comparisons.

Overall, this study offers a proof of concept for the use of gamification in financial education within higher education settings, particularly in emerging contexts. Further studies, including those with control groups and longitudinal data, are recommended to evaluate long-term learning outcomes and scalability.

5. Conclusion

This study presents GF as a design-based research initiative aimed at exploring innovative approaches to financial education through gameplay. By integrating gamification, experiential learning, and strategic decision-making, the game offers a more dynamic educational experience than traditional methods.

Preliminary findings suggest that students perceived improvements in their understanding of financial concepts and analytical skills, while reporting motivation and satisfaction. Facilitator support appeared to enhance the learning experience, highlighting the potential value of guided implementation in game-based environments.

Although GF remains at an early stage of validation, the initial results provide a solid foundation for further, more rigorous investigation. Future research should consider longitudinal studies to assess long-term behavioural impact, explore its adaptability across diverse educational contexts, and advance the development of a digital version to increase scalability and access.

In sum, GF is more than an instructional game, it is an emerging pedagogical tool with the potential to transform how financial literacy is taught in higher education, particularly in contexts that demand more engaging and applied learning experiences.

Ethics declaration: This research was conducted in accordance with the ethical and regulatory guidelines of the Technological University of Bolívar, with institutional approval for its execution. All participants involved in the study provided informed consent after receiving a detailed explanation of the research objectives, methodology, confidential use of data, and their right to withdraw at any time without consequences. Collected data were anonymized and stored under strict security protocols, in compliance with Colombian personal data protection regulations (Law 1581 of 2012).

AI declaration: Regarding the writing and linguistic adaptation process, AI-powered tools were employed to support the translation of content from English to Spanish. Machine-generated translations underwent critical review and manual adjustments by the authors to ensure technical accuracy, contextual coherence, and cultural appropriateness. This hybrid approach (AI + human oversight) preserved academic integrity and enhanced the document's communicative clarity.

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Game Over (GO!): A Transformative Model for Entrepreneurship Education through Game-Based Experiential Learning

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Abstract: This study explores Game Over (GO!), an innovative educational model that integrates gamification, experiential learning, and interdisciplinary collaboration to enhance entrepreneurship education. GO! transforms classrooms into dynamic innovation labs where students design and prototype physical games to solve real-world challenges, aligning with the Sustainable Development Goals (SDGs). Adopting a mixed-methods approach, the research analyzed data from five editions of GO!, involving 652 students who developed 117 game prototypes. Quantitative data include prototype evaluations and participant surveys, while qualitative insights were obtained through interviews with judges and participant observation. Results show that 80% of the prototypes aligned with the SDGs, and 80% of teams refined their designs multiple times following feedback from users and early adopters. Judges highlighted the initiative's creativity, depth, and real-world impact. This study demonstrates that gamification, beyond being a teaching tool, is a catalyst for developing critical thinking, creativity, and collaborative skills. The findings offer a scalable model for integrating game-based learning in entrepreneurship education across diverse contexts.

Keywords: Gamification, Experiential learning, Entrepreneurship education, Innovation, Sustainable development goals (SDGs)

1. Introduction

Entrepreneurship education (EE) has evolved significantly, shifting from traditional theoretical approaches to more dynamic, experiential methods. Within this context, gamification and experiential learning have emerged as powerful pedagogical strategies for fostering creativity, critical thinking, and entrepreneurial competencies. These methods engage students in active problem-solving, allowing them to acquire knowledge through hands-on experiences rather than passive instruction.

Game Over (GO!) is an educational model designed to leverage these principles by transforming university classrooms into interactive innovation labs. Through GO!, students become "corporate detectives" tasked with designing physical games that address real-world challenges. This approach not only enhances student engagement but also bridges the gap between theoretical knowledge and practical application, aligning with the Sustainable Development Goals (SDGs).

The model is implemented within the Creativity and Entrepreneurship courses at Universidad Tecnológica de Bolívar (UTB). Students work in interdisciplinary teams, engaging in a phased design process that includes empathy, ideation, prototyping, and validation. These prototypes are then tested in real-world contexts, with students receiving feedback from industry stakeholders and expert judges.

This study aims to explore the impact of the GO! model on student learning outcomes and its potential as a scalable approach to entrepreneurship education. Specifically, it addresses the following research questions:

RQ1. How does game-based experiential learning impact students' entrepreneurial skills and competencies?

RQ2. To what extent do student-designed games align with real-world challenges and SDGs?

RQ3. What are the perceptions of external judges and stakeholders regarding the quality and impact of the student-created prototypes?

To answer these questions, a mixed-methods approach was adopted. The findings contribute to the growing body of knowledge on Game-Based Learning (GBL), offering a scalable and adaptable model for entrepreneurship education.

2. Literature

2.1 Game-Based Learning

Overview of Global Trends

A search for the term 'game-based learning' in high-impact databases such as Scopus reveals a consistent increase in publications on the topic since the early 2000s. The most significant growth has occurred in the

second decade of the 21st century, during which the number of studies more than doubled. For example, in 2024 alone, nearly 1,000 publications were recorded. As of early May 2025, a total of 8,780 documents were indexed under this keyword. These can be categorised by disciplinary area as follows: computer science (34%), reflecting the rise of digital games, followed by social sciences (30%) and engineering (13%). Other fields appear in smaller proportions (under 3%), including mathematics, psychology, medicine, arts and humanities, decision sciences, business, and others. This distribution underscores the interdisciplinary and cross-sector applicability of game-based learning. The top 10 countries by institutional affiliation contributing to this body of literature are: United States, Taiwan, United Kingdom, Germany, Spain, Malaysia, China, Greece, Indonesia, and Canada. As expected, only one Spanish-speaking country appears in this list. The most prolific authors in the field, their work serves as a foundational reference in game-based learning research:

James Lester's work has been foundational in demonstrating the affective and cognitive dimensions of GBL environments. Lester and colleagues have shown that emotional states such as curiosity and flow positively correlate with deeper engagement and learning outcomes, while negative states like boredom and frustration impede learning (Sabourin & Lester, 2014). His research underscores the importance of affective engagement as a critical design consideration for serious games.

Hueitse Hou has contributed extensively to the development of both digital and analogue educational games, with a particular emphasis on mobile technologies and augmented reality. His most cited studies illustrate how immersive systems can foster greater involvement and motivation among learners (Chang et al., 2014). His dual focus on technological innovation and intrinsic motivation has made a substantial impact on the use of educational board games and simulation-based environments in formal education settings (Hou & Keng, 2021; Hou, 2012).

Kristian Kiili has been instrumental in conceptualising the experiential nature of learning through digital games. His seminal work (Kiili, 2005) demonstrates that well-designed online games can serve as effective learning environments by meeting key pedagogical criteria such as challenge, feedback, and control. Kiili has also developed design principles aimed at fostering “flow experiences” in educational games, advocating for the integration of educational theory with game mechanics (Kiili et al., 2012). His frameworks are particularly useful for educators seeking to balance cognitive load, engagement, and instructional effectiveness within gamified settings.

Game-based learning environments are intentionally designed to promote high levels of student motivation and engagement, particularly when tackling complex subjects. These environments offer learners the freedom to explore and interact with game elements that reinforce knowledge acquisition (Taub et al., 2020). A distinguishing feature of such environments is their capacity to deliver effective and immersive educational experiences (Emerson et al., 2020). Well-designed game-based instruction fosters motivation and decision-making skills in real-world scenarios (Hou, 2012). Such environments provide innovative settings that enhance student engagement and academic performance (Hsieh et al., 2013). Research confirms that the emotionally engaging nature of games supports learning processes (Ninaus et al., 2019). Serious games enhance education by offering realistic simulations and emotionally resonant contexts (Bellotti et al., 2011), highlighting the need for rigorous scientific and engineering methodologies in their development. This underscores the necessity of closer collaboration across all stakeholders involved in the serious game’s lifecycle, with pedagogy playing a central role.

Together, these scholars have advanced a multi-dimensional view of GBL that incorporates affective, motivational, cognitive, and socio-technical elements. Their contributions continue to inform both the theoretical foundations and practical design of game-based interventions across educational levels and disciplines. In light of their work, the development of new pedagogical models gains greater relevance, as it aligns with the principles of emotional engagement, user immersion, and experiential learning espoused by the GBL literature.

2.2 Entrepreneurship Education

When searching for the term “entrepreneur* education” in high-impact databases such as Scopus, an analysis of the results provided by the platform reveals that publications on the topic have been steadily increasing since the first decade of the 2000s. In the 2000s, the highest peak occurred in 2010 with 153 documents, while in the second decade of the 2000s, the highest peak was recorded in 2024, with nearly 900 documents.

Of the 7,301 results retrieved by the platform (as of early May 2025), the top 10 countries with the highest proportion of documents by affiliation are China, the United States, the United Kingdom, Malaysia, Germany,

Spain, India, Indonesia, Finland, and South Africa, respectively. The most prolific author in this field is Alain Jean Claude Fayolle, with over fifty publications, making him a key reference in these topics.

The most cited document, with 1,033 citations, presents a systematic review of the impact of entrepreneurship education (EE) in higher education, emphasizing the relationships between pedagogical methods and specific outcomes. It calls for further research on the impact of university-based entrepreneurship education, particularly those related to emotion and mindset (Nabi et al., 2017). Notably, efforts to equip students with teamwork skills using games as a pedagogical resource have been highlighted (Verzat et al., 2019).

EE has evolved through a variety of theoretical lenses (Talukder, Lakner, and Temesi, 2024), reflecting its growing interdisciplinary nature. One of the most widespread approaches is the competency-based framework, which emphasizes the development of individual entrepreneurial skills such as creativity, leadership, and resilience, with a strong focus on employability (Nabi et al, 2017). In parallel, pedagogical or andragogical models have stressed the value of active methodologies, such as project-based learning and experiential education, where the learner assumes an active, central role. Additionally, the institutional or ecosystem perspective highlights the university's role as a key actor connecting industry, government, and society, often positioning EE as a catalyst for innovation and knowledge transfer.

Despite their contributions, these frameworks are not without limitations. Critical and emancipatory approaches have challenged the prevailing utilitarian and market-oriented visions of entrepreneurship, advocating instead for frameworks grounded in agency, critical narrative, and social transformation (Talukder, Lakner, and Temesi, 2024). Similarly, gendered and intersectional perspectives have drawn attention to structural inequalities embedded in entrepreneurial ecosystems, promoting more inclusive and context-sensitive educational models. The sustainable and social entrepreneurship framework has further argued for the integration of the SDGs, emphasizing ethical, environmental, and societal impact. However, in practice, these emerging paradigms often face implementation challenges, such as methodological fragmentation, lack of curricular integration, or limited institutional support. In response to these persistent gaps, the following section introduces a pedagogical model that seeks not only to integrate these diverse theoretical traditions but also to operationalize them through a game-based, interdisciplinary, and socially anchored educational approach.

3. Methodology

This study employed a mixed methods design to explore the impact of the Game Over (GO!) model on entrepreneurship education. Conducted at the Technological University of Bolívar (UTB) between 2023 and 2025, within the mandatory Creativity and Entrepreneurship course, the research adopted an applied, exploratory, and descriptive approach. Data were collected across five editions of the course, involving 652 students from diverse disciplines, including Social Sciences, Business, and Engineering, who collaboratively designed 117 game-based prototypes. Additionally, 11 external judges from industry and academia participated in the evaluation process, and student-led teaching evaluations were reviewed to assess the course's effectiveness, relevance, and innovative methodology.

3.1 About our Course Model Methodology

Students engage in physical game design, advancing through prototyping levels and testing market viability. The challenge prompt positions students as 'business detectives' uncovering concealed organizational challenges to address through game-based solutions.

Our pedagogical model

We propose an innovative model aimed at fostering creativity and entrepreneurship in higher education: *The Expedition Route – Game Over GO!* This model has been carefully documented and designed to develop core competencies in creativity, innovation, and entrepreneurial thinking among undergraduate students. The model is structured as a playful expedition with progressive stages, integrating elements from active learning methodologies such as Design Thinking, Lean Startup, Challenge-Based Learning (CBL), and Gamification. Its implementation transforms the learning process into an immersive experience that stimulates critical thinking, problem-solving, and the creation of social or business value.

Creativity and entrepreneurship have become essential competencies in higher education, particularly in the context of digital transformation, climate change, and social crises. Traditionally, these subjects have been approached through theoretical frameworks, often neglecting the value of active and experiential learning. In response to this need, the GO! model presents an educational journey divided into multiple stages, where students confront real-world challenges through prototyping, user validation, and business model development.

The stages of empathy, definition, ideation, prototyping, and testing are present throughout the proposed expedition route. Support tools such as cognitive immersion and empathy maps correspond to the early phases of Design Thinking and facilitate a deep understanding of user needs. The model incorporates tools like the Lean Canvas, external and campus-based validations, and short-form pitch sessions, which are central elements of the Lean Startup methodology, allowing for rapid iteration on user-centred prototypes.

The model begins with the launch of a challenge that activates the educational process. This pedagogical strategy promotes engagement, real-world connections, and the development of transversal skills such as leadership, teamwork, and creativity. The use of the term "expedition", the phased structure, challenges, tests, and the final GO! festival with juried presentations are gamification mechanisms that enhance intrinsic motivation, a sense of achievement, and student engagement.

Model description -The Expedition Route: Game Over GO!

The expedition consists of eight sequential phases plus a final phase, during which student teams publicly present their projects in a simulated academic-game setting. Each phase includes specific tools that guide the development process.

Table 1: The expedition route: Game Over GO! -From brief to boardgame

Badge	Name	Description	Objective
	The Signal	Launch of the design challenge	Detecting the call to adventure: understanding the core challenge or opportunity.
	The Sketch	First low-fidelity prototype	Daring to draw the first map: transforming ideas into tangible concepts.
	The Encounter	Validation & playtesting	Facing the field: testing ideas with users, clients, and experts.
	The Spark	Value proposition design	Distilling the why: identifying what makes the game matter and work.
	The Mask	Branding & creative refinement	Giving the game its identity: refining aesthetics, components, and tone.
	The Landscape	Market & competitor analysis	Mapping the terrain: understanding where the game fits and stands out.
	The Engine	Business model	Fueling the future: designing how the game creates, delivers, and captures value.
	The Voice	Pitch preparation	Crafting the story: how to present and persuade with impact.

The Game Over (GO!) course model represents a compelling pedagogical innovation in entrepreneurship education (EE), addressing several well-documented shortcomings in the field. Recent high-impact literature has called for a shift away from abstract, business-plan-centric approaches towards more experiential, socially embedded, and emotionally resonant forms of entrepreneurial learning. GO! directly responds to this call through its expedition-based structure, which integrates design thinking, gamification, and real-world problem-solving.

Firstly, the course cultivates interpersonal skills such as leadership, effective communication, and teamwork, competencies widely recognised as essential yet often underdeveloped in traditional EE. By intentionally forming interdisciplinary teams across faculties, GO! simulates the complexity of authentic entrepreneurial environments, where collaboration across diverse domains is standard practice. *"One of the greatest strengths of this initiative is the involvement of students from diverse academic backgrounds. This interdisciplinarity leads to more comprehensive solutions and game designs that tackle challenges from multiple perspectives. It was particularly striking to witness Finance students developing a game on consumer rights, or engineering students designing a game focused on mental health, simply remarkable" (testimony of one of the external judges)*

Secondly, GO! fosters a genuine entrepreneurial mindset, placing strong emphasis on resilience, iterative thinking, and action orientation. These are not treated as abstract ideals but emerge organically as students face critical feedback, encounter failure, and adapt their designs. By embracing failure as part of the learning process, GO! aligns with the "entrepreneurship as practice" perspective, in which action, reflection, and iteration are central. Thirdly, the course facilitates meaningful and transferable learning by requiring students to test their creations in unsimulated, real-world contexts. This degree of immersion enhances knowledge retention and practical relevance, reinforcing the argument that EE must engage with real-world complexity. In GO!, students validate their game-based prototypes in industry settings, often refining them multiple times, demonstrating a genuine feedback-driven design process. *"We are grateful to UTB for aligning with our "day without the blackboard" strategy and for engaging our schoolteachers in making their lessons more dynamic. Developing the bank of educational needs for students to work on real solutions was a brilliant initiative" (testimony of one of the external judges)*

Perhaps most significantly, GO! links innovation with social value creation, guiding students to develop prototypes rooted in sustainability and global challenges. This reflects a broader shift towards transformative entrepreneurship education, which transcends profit-making to incorporate societal and environmental concerns. Finally, GO! embeds students in interactions with industry stakeholders, reinforcing the "entrepreneurial ecosystem" approach. This grounds learning in authentic social contexts and equips learners with both hard and soft skills necessary to navigate uncertainty, complexity, and change.

The entire model is complemented by other complementary activities like *wildcard missions and real cases*

Wildcard Missions: wildcard challenges are surprise tasks introduced weekly to test students' creativity and entrepreneurial skills. Imagine a secret door opening each week, filled with mysteries and possibilities, where students must use their knowledge and ingenuity to overcome unexpected challenges. At least three wildcard challenges are carried out each semester, with students working in groups. One example of a wildcard challenge introduced in January 2025 was *"Chicha"of the Future*. Chicha is the name given to various types of beverages primarily derived from the non-distilled fermentation of maize and other cereals native to the Americas. Students were tasked with discovering the best alchemist team for chicha, working in groups to develop an innovative proposal that reimagined chicha with new ingredients, presentations, or unexpected uses. The outcomes included presentations of novel products based on chicha, incorporating unconventional ingredients such as ginger or unique formats like a cream.

Learning Based on Real Cases of Green Entrepreneurs: Green Business Talks (GBT) is an initiative that compiles real stories of entrepreneurs who have overcome challenges with creativity and resilience (Marrugo-Salas & Pérez, 2024). Learn more here: https://www.utb.edu.co/green-business-talks/

Each story represents a piece of knowledge that students must collect to uncover the secrets of entrepreneurial success. This innovative platform has, in recent years, gathered nearly 60 cases of social entrepreneurship models, mainly in Colombia, but also featuring cases from Mexico, Brazil, and Chile. Each group is assigned a case, and in a specific session, they must present their analysis results through:

- A visual map.
- At least one gamified activity to verify their classmates' learning.
- The design of at least five guiding questions related to the course topics.
- The use of storytelling connected to the case in their presentation.

All the above contributes to the design of the proposed model and enables students to engage in real immersion in game-based learning, not only in their final project but throughout the course experience.

3.2 Game Over -GO! Fest

The GO! model culminates in a biannual festival that showcases high-fidelity game prototypes developed by students, often in collaboration with external organisations. The event combines a public exhibition with a private evaluation session modelled on the 'Shark Tank' format, fostering both visibility and critical appraisal. It engages a diverse audience, including educators seeking to gamify learning environments, companies exploring innovative problem-solving approaches, and creative professionals interested in designing games that are both educational and impactful, positioning GO! as a dynamic platform for experiential learning and cross-sector collaboration.

Figure 1: Participants GO! 2023-01

Figure 2: Juries GO! 2024-01

Figure 3: Winner GO! 2024-20

4. Results and Discussion

4.1 Participant Demographics and Prototypes Developed

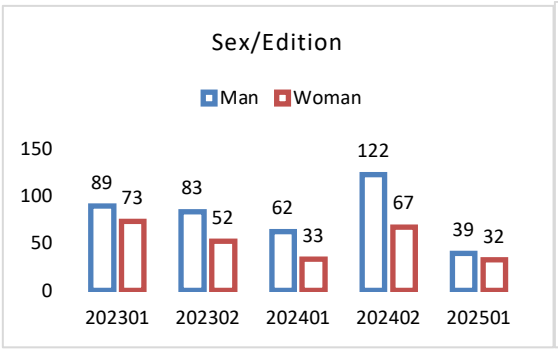

Figure 4: Participants' sex

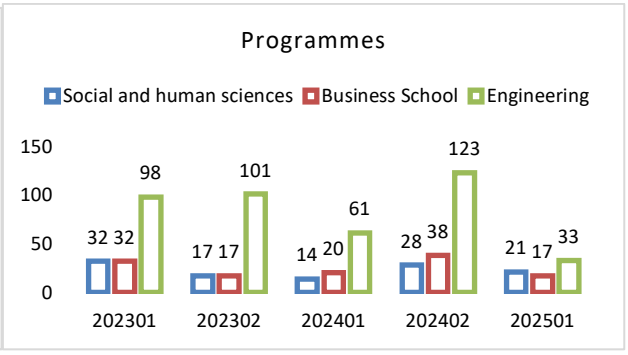

Figure 5: Participants' program

Table 2: GO! Resume

GO! (Edition)	Participating Courses	Number of students impacted	Number of prototypes	Prototypes/Total (%)	Juries	Winning Game	Theme
2023: 1.0	4 courses	162	21	18%	2	Zero	Gender equality

GO! (Edition)	Participating Courses	Number of students impacted	Number of prototypes	Prototypes/Total (%)	Juries	Winning Game	Theme
2023: 2.0*	4 courses	135	29	25%	2	"Duelo de mentes"	Primary Education (Science, Mathematics, History)
2024: 3.0*	3 courses	95	18	15%	3	"Lex Lúdica"	Consumer rights
2024: 4.0	4 courses	189	34	29%	4	Science Slam	Education (Science)
2025: 5.0	2 courses	71	15	13%	3	"JugArte" and Check In	Social inclusion and development (autism) / Passenger rights in air transport
Total		652	117	100%			

Prototype Evaluation Results

Prototypes were evaluated based on four qualitative criteria and based on a scale: (0-5 points)

1. Innovation: Novelty and originality of the game concept.
2. Business Model: Feasibility of the game as a sustainable solution.
3. Quality: Design, aesthetics, and functionality of the game.
4. Communication: Effectiveness of the game's presentation and storytelling.

Sustainable Development Goals -SDGs

The initiative directly contributes to several SDGs, particularly depending on the themes explored by the games. In reviewing the topics addressed in the games, we identified the Sustainable Development Goals (SDGs) to which they directly contribute. This analysis involved comparing each SDG target with the specific objectives of the games. The SDGs identified were 3, 4, 5, 8, 9, 10, 11, and 12. In some cases, interrelated SDGs were observed, particularly in games focused on environmental education.

Figure 6: High-fidelity prototype called "2085" associated with SDG 6 and SDG 12 and 13

The analysis showed that 80% of the prototypes developed were directly aligned with one or more SDGs, with the most frequent being:

- **SDG 4:** Games related to preparation for ICFES exams (higher education entrance tests), vocational guidance, teaching in primary and secondary education (miscellaneous), entrepreneurship education, professional education, and financial education, among others.
- **SDG 3:** Games focused on mental health, road safety education, sexual education, workplace well-being, and drug prevention, among others.

- **SDG 12:** Games aimed at environmental education, covering topics such as circular economy, waste management, water, energy, and climate change, among others.

From these results, we can conclude that students are most interested in developing physical games that contribute to sustainability, with a particular focus on SDGs 4, 3, and 12. This demonstrates their motivation to address the challenges of their environment.

4.2 Perceptions

The analysis was conducted using constructivist grounded theory methodology combining empirical data collection with iterative coding. A total of 11 semi-structured interviews were conducted with evaluators who participated as jurors during the 2023 and 2025 editions of the event. Interviews were conducted in person, each lasting approximately 30 minutes on average. The participants, reflects on her role as an evaluator, offering rich insights into the learning, design, and engagement dynamics of the event.

Table 3: Axial coding

Emerging categories	Description and testimonies
Transformative potential of play	*"The game remains a powerful tool to transform the way we learn, understand, and undertake."* This category highlights how play is perceived not merely as entertainment but as a pedagogical instrument for transformation, particularly in learning environments. It aligns with literature on game-based learning and experiential education
Multidimensional evaluation of prototypes	*"I appreciated those prototypes that balanced aesthetics, gameplay, and educational content."* The testimony foregrounds a triadic model of evaluation: aesthetic design, mechanics, and formative content. This suggests a holistic assessment framework for educational games.
Emotional and social engagement	*"We were all debating rules, the device itself, team roles and personal experiences."* The reference to collective reflection indicates the emergence of affective learning spaces through play, where emotional engagement fosters deeper cognitive and social impact.
Need for iterative development	*"I would suggest a prior pitch phase or rehearsal."* This suggests the need for a scaffolded learning model, where iterative cycles of feedback and refinement are embedded in the creative process.
Bridging academia and real-world needs	*"These spaces are key to connecting academia with the real environment."* A significant theme is the alignment of educational initiatives with social realities, reinforcing the civic and practical value of project-based learning.

Selective coding: core category

"Game-based experiential learning as a transformative bridge between academic creativity and real-world problem-solving." All themes coalesce into a central grounded theory: that Game Over acts as a platform for transformative learning where students, through gamified creation, synthesise creativity, social responsibility, and interdisciplinary collaboration.This analysis contributes to the growing body of knowledge on game-based learning ecosystems by highlighting how jury experiences provide feedback loops essential for programme evolution. Moreover, the reflection implies that jurors not only evaluate but also learn, suggesting their role as co-constructors of the pedagogical experience. It also supports the integration of design thinking methodologies in education, where play, iteration, and narrative converge to foster innovation, empathy, and critical dialogue.

Testimonials reveal the pedagogical power of play, not just as a student tool but as a multistakeholder engagement strategy. It calls for further incorporation of reflective and iterative practices within educational game design and supports the expansion of Game Over as a scalable and meaningful model in higher education.

Student feedback reveals a consistently positive perception of the Game Over (GO!) course model, highlighting its practical orientation, creativity, and pedagogical innovation. A review of teaching evaluations from GO! courses delivered between 2023 and 2025 further supports these findings. One student noted that the course "teaches students to become entrepreneurs and business owners, not employees, which is what is needed nowadays" (S15), while another emphasised the value of applying theory to practice by "creating an innovative and creative business model" (S50). The engaging nature of the methodology was frequently mentioned, with participants describing the activities as "novel" (S120), "hands-on" (S70), and conducive to both cognitive and creative development (S150). Others praised the varied forms of assessment and the instructor's commitment to the teaching process: "a wide range of assessment methods helped open our minds and encouraged creativity" (S200). Moreover, the relevance of the content to real-life contexts was recognised as a key strength (S350), alongside the structured completion of themes and the enjoyment of the GO! activity itself (S100). Collectively, these reflections suggest that the GO! model successfully fosters entrepreneurial mindsets, enhances engagement through experiential and creative methodologies, and bridges academic content with real-world application.

4.3 Expanding, Challenging, and Refining Existing Frameworks

This study extends existing conceptual frameworks in EE by introducing a transformative pedagogical model grounded in experiential learning and the design of physical games. Unlike traditional approaches, which often rely on theoretical instruction or digital simulations, GO! model creates immersive environments where students act as active agents in processes of design and innovation. This model not only fosters essential entrepreneurial skills, such as creativity, resilience, and problem-solving, but also aligns directly with SDGs, thereby positioning entrepreneurship as a tool for social transformation rather than merely economic advancement.

The bibliometric review conducted by Talukder, Lakner, and Temesi (2024) underscores that EE encompasses more than the technical transfer of knowledge. It also involves drawing attention to relevant societal issues, promoting personal growth, and nurturing a deep sense of self-efficacy. In Global South contexts, EE assumes a particularly strategic role as a driver of socio-economic development. In doing so, students are exposed to a universe of possibilities, as the games they design are potential income-generating alternatives. Notably, the model has revealed a particular interest among systems engineering students in converting their physical game prototypes into digital formats, opening up entrepreneurial pathways in the creative and tech industries. GO! challenges conventional models of entrepreneurship education that predominantly emphasise business content and economic outcomes. Instead, it proposes an "expedition route" that privileges iterative learning, user empathy, and social value creation. In this regard, GO! not only introduces a novel didactic methodology but also contributes to reconfiguring the epistemological underpinnings of how entrepreneurship is conceptualised within higher education. Ultimately, GO! refines and enriches existing frameworks by foregrounding physical game design as a pedagogical medium that mediates between academic creativity and real-world challenges. The empirical evidence gathered reveals that games, when carefully designed, are far from superficial motivational tools; instead, they function as transformative bridges between theory and action. By fostering emotion, interdisciplinary collaboration, and critical thinking, GO! positions itself as a scalable and context-sensitive model with strong potential to enhance entrepreneurial learning processes across diverse educational environments.

5. Conclusion

This study presents Game Over (GO!) as an innovative, practice-oriented model for entrepreneurship education, grounded in experiential learning, interdisciplinary collaboration, and real-world problem-solving. Beyond its pedagogical contributions, this research is particularly significant as it emerges from a Global South context, specifically, a Colombian higher education institution actively engaging with local realities and global challenges.

In a field historically dominated by models and frameworks developed in the Global North, the visibility of context-sensitive, socially grounded educational innovations from the Global South is crucial. Initiatives like GO! challenge one-size-fits-all approaches and demonstrate how entrepreneurship education can be reimagined to address both local needs and global priorities, such as the Sustainable Development Goals. They also highlight the creative potential of underrepresented regions to contribute to global academic and pedagogical discourse.

By showcasing a model that integrates sustainability and applied learning within a developing country context, this study contributes to the diversification of knowledge production in entrepreneurship education. It calls for greater recognition and dissemination of Southern-led innovations that offer scalable, impactful, and culturally relevant alternatives to traditional pedagogical practices.

Future Research and Recommendations

- Expand GO! to other Universities: Test the model in different cultural and institutional contexts to assess its adaptability.
- Enhance presentation skills: Integrate a pitch rehearsal phase to help students improve their storytelling abilities.
- Strengthening industry partnerships: continue to engage external stakeholders for more authentic and challenging problem scenarios.
- Long-Term impact assessment: conduct longitudinal studies to evaluate the long-term impact of GO! on students' entrepreneurial skills and career trajectories.

By turning classrooms into playgrounds for problem-solving, GO! equips students to be architects of change, not passive learners. ¿Ready to play the future of entrepreneurship education?

Ethical declaration: This research was conducted in accordance with the ethical and regulatory guidelines of the Technological University of Bolívar, with institutional approval for its execution. All participants involved in the study provided informed consent after receiving a detailed explanation of the research objectives, methodology, confidential use of data, and their right to withdraw at any time without consequences. Collected data were anonymized and stored under strict security protocols, in compliance with Colombian personal data protection regulations (Law 1581 of 2012).

AI declaration: Regarding the writing and linguistic adaptation process, AI-powered tools were employed to support the translation of content from English to Spanish. Machine-generated translations underwent critical review and manual adjustments by the authors to ensure technical accuracy, contextual coherence, and cultural appropriateness. This hybrid approach (AI + human oversight) preserved academic integrity and enhanced the document's communicative clarity.

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Enhancing Student Engagement and Knowledge Retention Through Game-Based Learning: A Comprehensive Framework Integrating Game Design and Learning Theories

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Abstract: Game-based learning (GBL) has emerged as a transformative educational approach, using interactive game elements to enhance student engagement and knowledge retention. Although research underscores the potential of GBL, challenges persist in aligning game elements with learning theories to optimise learner engagement and knowledge retention. This study addresses this challenge by proposing a comprehensive framework that integrates game elements through the lens of established learning theories, such as Cognitive Load Theory. The framework emphasises the interplay of game elements to foster engagement and retention, offering actionable insights for educators and serious game designers. Obtaining learner engagement and knowledge retention, key recommendations from this study include embedding adaptive challenges to balance skill and difficulty and personalising feedback through serious game mechanics. The study also highlights the critical role of real-world relevance in the design of GBL. Although the framework provides a solid foundation, future research should explore long-term efficacy across diverse educational contexts, age groups, and emerging technologies such as augmented reality. By bridging theoretical rigour with practical application, this work advances GBL as a tool for fostering meaningful, adaptive, and inclusive learning experiences.

Keywords: Engagement, Knowledge retention, Game design theory, Learning theory, Player characteristics

1. Introduction

The integration of game-based learning (GBL) into educational settings has gained significant momentum in recent years as digital technologies (such as cell phones and virtual reality headsets) continue to develop, improve and become more commercially available. GBL uses the engaging and interactive nature of games to create immersive learning experiences that improve student motivation and knowledge retention (Qian & Clark, 2016). Research on GBL has shown that well-designed educational games can foster critical thinking, problem solving skills, and collaboration among learners (Plass et al., 2015). GBL also plays a pivotal role in fostering engagement and motivation and aligns the three core pathways to engaged learning: (1) encouraging active participation and collaboration among students, (2) focusing on individual student needs and learning styles, and (3) adapting to contemporary teaching methods and technologies (Sung & Hwang, 2018; Shu & Liu, 2019; Murillo-Zamorano, López Sánchez, Godoy-Caballero & Bueno Muñoz, 2021). Despite its potential, the effective implementation of GBL remains challenging due to many theories on improving player engagement and knowledge retention for serious games (Rye & Sousa,2025). The number of possible theories that currently exist seems limitless, which can become a nightmare for designers and educators, especially when they want to implement specific and relevant theories to address issues related to engagement and knowledge retention in GBL. For example, Krath *et al*. (2021) conducted a systematic review of the theories generally used for gamification, serious games, and game-based learning. The study identified 118 different theories used for research to address these aspects. The researchers categorised the theories associated with game-based learning into five different groups. These include theories on motivation and affection, learning processes, behavioural change and intervention, player engagement and social interaction, and cognitive load and learning efficiency. Krath et al. (2021) present an integrative framework for game-based learning by synthesising multiple theories that explain how games can foster educational outcomes. Their framework is organised into several thematic domains, as seen in Figure 1 hereafter.

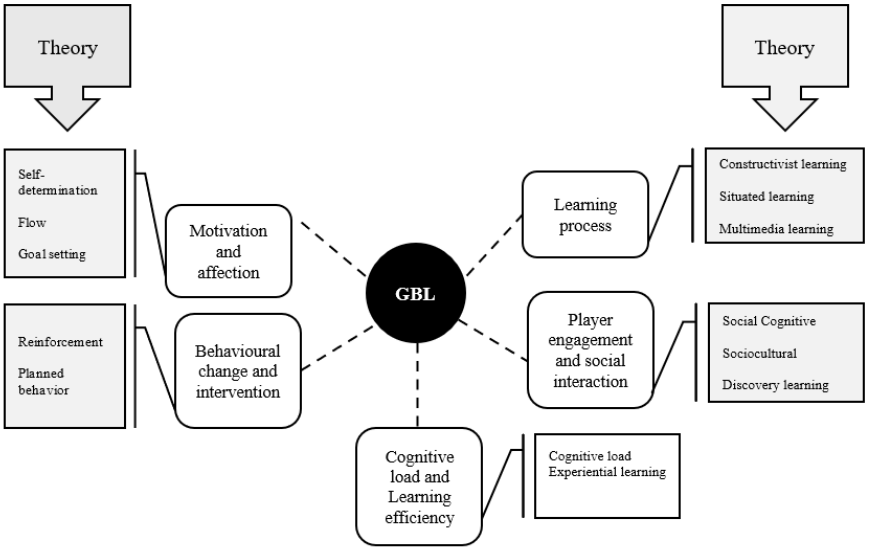

Figure 1: Theories in Learning Engagement (adapted from Krath *et al.,* 2021)

Krath *et al.* (2021) argue that these theoretical foundations provide complementary insights into the multifaceted impacts of GBL. By addressing motivational drivers, learning processes, behavioural interventions, social interactions, and cognitive efficiency, their framework offers a holistic view of how digital games can be designed to enhance educational experiences. This integrative approach is instrumental in understanding both the potential benefits and the practical challenges involved in the effective implementation of GBL in diverse educational settings. Recent research has further validated the application of these theories in GBL, demonstrating their effectiveness in fostering engagement and knowledge retention (Sailer & Homner, 2020; Nietfeld et al., 2019). Additionally, they also provide a solid foundation for understanding how learners interact with game-based environments and identify the key factors that contribute to successful learning experiences.

2. Problem Statement

Despite the growing evidence supporting the benefits of GBL, its effective implementation in educational contexts remains problematic. The rapid evolution of digital technologies has introduced a wealth of opportunities for GBL; however, the practical adoption of these strategies is hindered by the sheer number of theoretical frameworks available to guide design and evaluation. This multiplicity creates ambiguity for educators and designers who struggle to determine which specific theories are most relevant and how to integrate them cohesively into instructional practice. As a result, there is a critical need for an integrative framework that not only streamlines the application of these diverse theoretical perspectives, but also provides clear, evidence-based guidelines for enhancing learner engagement and knowledge retention in GBL environments. This research aims to address the theoretical complexity and practical challenges by evaluating and synthesising key frameworks, ultimately proposing a coherent model to inform the effective design and implementation of GBL in modern educational settings.

3. Research Questions

Based on the introduction and the identified gaps from the background, the research question is established:

RQ1: How can game-based learning frameworks, grounded in Cognitive Load, Flow, and Self-Determination Theories, be utilized in real-world scenarios to enhance engagement?

RQ2: What specific elements of game design interact with different player characteristics, theories, and environmental factors in terms of engagement and knowledge retention?

These questions directly address the challenge of navigating the extensive array of existing theories, the need for an integrated approach that aligns these theories with practical design and implementation strategies, and ultimately a goal of improving learner engagement and effectiveness within the GBL contexts.

4. Methodology

This study used a systematic literature review to investigate the intersection of game-based learning (GBL), game design, and learning outcomes such as student engagement and knowledge retention. Due to the fast paced development in game design and serious game development, this review will only focus on the latest literature published between 2020 and 2025 in order to keep the discussion on available theories and their application current. A structured search strategy was used across academic databases, primarily Google Scholar, supplemented by the AI-powered research assistant, Elicit, to improve the breadth and organisation of search results. The following keywords and combinations thereof guided the search: *"Game-Based Learning," "Student Engagement," "Knowledge Retention," "Game Design,"* and *"Learning Theories."* The review followed these steps:

1. Search and Identification

- Elicit AI generated an initial pool of 50 peer-reviewed articles by cross-referencing the above keywords and filtering for relevance to educational outcomes, theoretical foundation, and GBL application.

2. Inclusion and Exclusion Criteria

- The pool of 50 articles was reduced to include criteria: (a) were published between 2010 and 2025, (b) were Q1 and Q2 journal articles, and (c) addressed GBL in formal education contexts.
- Exclusion criteria: Articles were excluded if (a) they focused solely on entertainment games, (b) were opinion pieces or editorials, or (c) lacked methodological rigour or theoretical grounding.

3. Screening and Selection

- A final set of 10 articles most cited from the Q1 and Q2 journals was selected for in-depth analysis. See Tables 1 to 3.

4. Data Extraction and Thematic Analysis

- Key data points were extracted: publication year, context, methodology, elements of game design, learning theories, and reported results.
- A thematic synthesis approach was applied to identify recurring patterns, gaps, and theoretical alignments in the literature.

This systematic approach ensured a balanced and comprehensive review, integrating both empirical findings and theoretical perspectives relevant to game-based learning and its educational impact. Additional manual searches on Google Scholar were conducted to ensure coverage of seminal works and any studies potentially missed by automated tools (see Tables 1 through 3).

5. Literature Review

From the literature review conducted, Tables 1-3 provide an overview of the key theories underlying GBL organised by category. It also outlines the core concepts of each theory and describes how they are applied within GBL contexts. The purpose of the tables is to succinctly present the various theoretical frameworks that inform the design and evaluation of GBL.

Table 1: Understanding how theory contributes to student participation and knowledge retention

Theory & Category	Key Concepts	Application in GBL	References
Self-Determination Theory (Motivation & Affection)	Emphasis on intrinsic and extrinsic motivation. Highlight three psychological needs: autonomy, competence, and relatedness.	GBL environments that allow player choice, present challenging tasks, and foster social collaboration support these needs, improving intrinsic motivation and engagement.	Goole Scholar: Deci & Ryan (1985); Ryan & Deci (2020); Habgood & Ainsworth (2011); Hwang & Chen (2021). Elicit: Xu, Luo, Zhang, Xia, Qian, & Zou, X. (2023).

Theory & Category	Key Concepts	Application in GBL	References
Flow Theory (Motivation & Affection)	Describes the state of deep, focused engagement when the task challenge aligns with the skill levels.	Adaptive game design adjusts difficulty to maintain player flow state, increasing engagement, and improving learning outcomes.	Goole Scholar: Csikszentmihalyi (1990); Hamari et al. (2016). Elicit: Bado (2022).
Goal Setting Theory (Motivation & Affection)	Clear, specific, and challenging goals enhance performance.	Setting goals (such as levels or achievements) in GBL motivates students to continue learning.	Goole Scholar: Locke & Latham (1990). Elicit: Abdul Jabbar & Felicia (2015).
Constructivist Learning Theory (Learning Processes)	Learners actively construct knowledge by integrating new information with previous experiences.	GBL facilitates hands-on interaction and reflection, allowing meaningful connections between prior and new knowledge.	Goole Scholar: Piaget (1973); Vygotsky (1978); Garrick (2021). Elicit: Barz, Benick, Dörrenbächer-Ulrich & Perels (2024).
Situated Learning Theory (Learning Processes)	Learning occurs in authentic contexts and communities of practice.	Simulated GBL contexts mimic real-world scenarios and foster social interaction, deepening understanding.	Goole Scholar: Brown, Collins & Duguid (1989); Lave & Wenger (1991); Huang & Liaw (2020). Elicit: Dahalan, Alias & Shaharom (2024).
Multimedia Learning Theory (Learning Processes)	Combining text, images, and sound helps reduce cognitive load and improve retention.	Effective multimedia integration in GBL reinforces learning through multiple sensory channels.	Goole Scholar: Paivio (1971, 1986); Mayer (2001, 2009, 2014).
Cognitive Load Theory (Cognitive Load & Learning Efficiency)	Distinguishes between intrinsic, extraneous, and germane cognitive loads.	Game design that reduces extraneous load and manages cognitive effort improves retention.	Goole Scholar: Sweller (1988).
Experiential Learning Theory (Cognitive Load & Learning Efficiency)	Learning through concrete experience, reflection, conceptualisation, and experimentation.	GBL engages learners in cycles of experience and reflection to deepen their learning.	Goole Scholar: Kolb (1984); Kolb & Kolb (2017). Elicit: Tavares (2022).
Discovery Learning Theory (Cognitive Load & Learning Efficiency)	Exploration and problem solving with scaffolding support learning.	Open-ended game scenarios promote inquiry and critical thinking, supported by scaffolding.	Goole Scholar: Bruner (1961); Shen & Ke (2021). Elicit: Bado (2022).

Source: Own research

Table 1 outlines the foundational learning theories and their applications in GBL. *Self-Determination Theory* and *Flow Theory* emphasise motivation, autonomy, and balancing challenge with skill to sustain engagement. *Constructivist* and *Situated Learning Theories* focus on active knowledge construction through hands-on, context-rich tasks, while *Cognitive Load* and *Experiential Learning Theories* optimise retention by managing mental effort and embedding reflection cycles. *Multimedia Learning Theory* uses dual coding (text, visuals, sound) to reduce cognitive load and reinforce understanding. Researchers suggest that environmental factors, such as learning context and social dynamics, are critical components for the successful implementation of GBL interventions. Furthermore, game elements include an engaging narrative, various game mechanics, progression or levelling-up in the game, collaborating with other players, personalisation ability of players, using real-world examples, multimedia usage, and encouraging exploratory learning.

Table 2: GBL Design Elements Associated with Knowledge Retention

Design Element	Description and Source(s)
Clear Learning Objectives	Ensures topics align with desired outcomes and assessments track understanding (Deterding et al., 2011; 2020). Include real-world scenarios to enhance relevance and retention (Foster & Shah, M, 2020).
Feedback	Encompasses instant, summative, and peer responses (Hattie & Timperley, 2007). Immediate feedback helps students understand their progress and areas for improvement, reinforcing learning, and aiding retention (Bado, 2022).
Scaffolding	Provides step-by-step guidance and visual aids to support learning (Squire, 2005; Bado, 2022).
Assessment and Reflection	Incorporating spaced repetition for better retention of information over time, as it encourages revisiting concepts and, therefore, assessment is continuous (Shute, 2008; Plass, Homer, & Kinzer, 2015).
Accessibility	Supports diverse learners with formats and tools tailored to different needs (Al-Azawei, Serenko & Cater, 2016). For example, customising learning experiences based on individual progress can help maintain engagement and improve retention by addressing specific learning needs (Foster & Shah, 2020).

Source: Own research

Table 2 identifies elements of the GBL design linked to knowledge retention, such as *feedback mechanisms* (timely guidance to correct mistakes), *scaffolding* (step-by-step support for complex tasks) and *spaced repetition* (revisiting concepts over time). These elements align with theories like Cognitive Load Theory (reducing extraneous load) and Experiential Learning (reflection), ensuring learners internalise knowledge through structured, contextually relevant practice.

Table 3: GBL Design Elements Associated with Engagement

Design Element	Description and Source(s) Google Scholar	Description and Source(s) Elicit
Narrative	Features relatable characters and structured plots for emotional connection (Barata, Gama, & Jorge, 2013).	Research in game-based learning (see, e.g., Plass, Homer, & Kinzer, 2015) indicates that narrative elements not only increase emotional engagement but also support deeper cognitive processing.
Game Mechanics	Using points, challenges, and rewards to motivate learners (Gee, 2003).	A systematic review (Abdul Jabbar & Felicia, 2015) underscores that well-designed game mechanics are essential to maintaining engagement. When game mechanics are properly aligned with instructional goals, they lead to improved cognitive outcomes and participation (Barz et al., 2024).
Progression	Involves levels and skill advancement to maintain motivation (Gee, 2007).	Dahalan et al. (2024) report that structured progression models, which include clearly defined levels and skill increments, enhance learner motivation and support continuous skill development.
Collaboration and social interaction	Encourage teamwork and competition through leaderboards (Johnson & Johnson, 1999).	Findings from teacher education research (Foster & Shah, 2020) suggest that collaborative elements in game-based environments enhance peer-to-peer interaction and active learning. Social interactivity, whether through competition or teamwork, builds communication skills and fosters a community of practice among learners, which in turn can translate into better overall learning experiences.

Design Element	Description and Source(s) Google Scholar	Description and Source(s) Elicit
Personalised Gameplay	Allows topic selection, personal goals, and content adaptation (Kapp, 2012).	Research in specialised fields such as medical education (Xu et al., 2023) and in broader instructional settings (Tavares, 2022) shows that personalisation can lead to improved engagement and knowledge retention.
Multimodal Learning	Engages different learning styles with multimedia and interactivity (Aldrich, 2005).	Garcia et al. (2020) reveal that multimodal approaches in game-based learning help address various cognitive processes and foster the development of soft skills.
Real-World Linkages	Connects content to practical examples like case studies (Gee, 2007).	Incorporating real-life scenarios or case studies is shown to bridge the gap between theoretical content and practical application. Bado (2022) emphasises that using real-world contexts enhances learning transfer by making academic content more relevant and applicable, which can boost both learner motivation and the overall impact of the educational intervention.
Challenging Tasks	Includes realistic and progressively difficult challenges (Csikszentmihalyi, 1990).	As noted in systematic reviews (Abdul Jabbar & Felicia, 2015), well-calibrated challenging tasks promote states of "flow" where learners become fully immersed. This balance of task difficulty with learner ability helps develop critical thinking and problem-solving skills while preventing boredom or frustration.
Tangible Rewards	Reinforce learning with incentives like certificates (Hamari, Koivisto, & Sarsa, 2016).	Barz et al. (2024) report that rewards can reinforce learning outcomes by providing clear goals and immediate feedback. This extrinsic reinforcement complements intrinsic motivation, thereby producing a more comprehensive incentive structure in learning environments.
Exploration	Foster engagement through content discovery (Piaget, 1976).	Emphasising open-ended exploration supports inquiry-based learning, where learners actively discover information on their own. Based on Piaget's constructivist theory, this approach has been shown - through studies like Dahalan et al. (2024) and Abdul Jabbar & Felicia (2015) - to increase participation and deepen understanding.
Visual and Interactive Elements	The use of rich visuals and interactive components can make learning more appealing and engaging, encouraging students to actively participate.	Dynamic visuals and interactive features capture attention and enhance information processing. Research (see, e.g., Aldrich, 2005; Garcia et al., 2020) demonstrates that these multimodal elements reduce cognitive load and cater to varied learning styles, promoting active participation.

Source: Own research

Table 3 highlights the elements of GBL that drive engagement, such as narratives (emotional storytelling), game mechanics (points, levels), and collaboration tools (team challenges). These are rooted in theories like Social Learning (peer interaction), SDT (autonomy through choice), and Flow Theory (adaptive difficulty). Personalisation and multimodal learning cater to diverse preferences, while real-world linkages and tangible rewards bridge gameplay with practical relevance, sustaining interest and effort.

6. Findings and Discussion

The focus of this study is to establish a framework (Figure 2) that addresses (i) theories in learning engagement, (ii) how each theory contributes to student engagement and knowledge retention, (iii) elements of the GBL design associated with knowledge retention, and (iv) GBL design elements associated with engagement (Table 4).

Table 4: Toward setting a framework integrating game design and learning theories.

Theory/Principle	Game Element (Mechanism)	Outcome	Connection to GBL Framework
Self-Determination	Customisable avatars (completely relatedness & emotional connection)	Sustains intrinsic motivation	Engagement: Social interaction drives emotional investment.
Flow Theory	Adaptive Difficulty (Balances challenge and skill)	Masters learning outcomes	Engagement: Maintains the "flow state" for focused learning.

Theory/Principle	Game Element (Mechanism)	Outcome	Connection to GBL Framework
Constructivist Learning	Explore the Game World (Encourages experimentation)	Builds understanding via application	Knowledge retention: Active construction embeds knowledge.
Situated Learning	Real-World Scenarios (Immersive case studies)	Links knowledge to practice	Knowledge retention: The contextual application aids transfer.
Cognitive Load Theory	Scaffolding & Feedback (Guided skill progression)	Reduces mental overload	Knowledge retention: Optimises effort for retention.
Experiential Learning	Scenario-based missions (concrete experiences + reflection)	Solidifies learning through reflection	Knowledge retention: Reflection reinforces concepts.
Social Learning	Peer Review Systems (Teamwork & observational learning)	Reinforces concepts via discussion	Both: Collaboration increases engagement and retention.
Multimedia Learning	Diverse Learning Styles (Supports visual/auditory/kinesthetic)	Accommodates learner diversity	Engagement: Inclusive design maintains motivation.
Goal-Oriented Design	Motivation & Affection Systems (Skill development focus)	Mastery of objectives	Both: Clear goals drive effort and retention.

Source: Own research

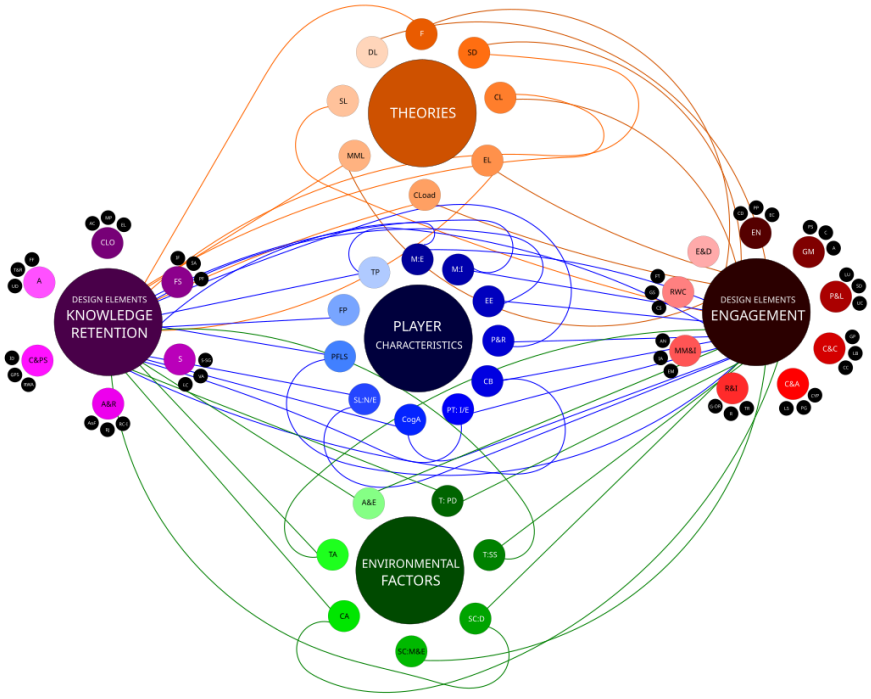

Figure 2: Framework Integrating Game Design and Learning Theories

Figure 2 operationalises the research question and directly addresses the problem statement by visually synthesising diverse learning theories with targeted GBL design elements. It consolidates theories into a coherent framework that highlights their specific contributions toward enhancing both student engagement and knowledge retention. By mapping theoretical constructs to practical design strategies, such as adaptive challenge levels, integration of real-world scenarios, and personalised feedback—the figure offers educators and game designers a clear pathway to mitigate the complexity and ambiguity inherent in selecting multiple theoretical approaches, thus streamlining the effective implementation of GBL in educational contexts.

7. Conclusion, Limitations, and Recommendations

In summary, this study highlights the advantages of GBL in enhancing student engagement and knowledge retention. By merging established learning theories with effective game design, the proposed framework offers valuable insights for educators and developers. The framework is purely theoretical, and future empirical studies

(e.g., randomised and controlled trials under experimental conditions) to test its efficacy are suggested. Future research should also investigate GBL's long-term effects (such as completion rates of games, replayability, etc.) across various contexts and technologies, ensuring its continued relevance and potential to transform education into a more engaging and adaptive experience for all learners.

Ethical clearance: This work is solely a literature review involving no new data collection from human or animal subjects; nevertheless, umbrella ethical clearance for the broader research project was obtained. All sources consulted are publicly available and have been properly cited in accordance with academic standards.

AI declaration: The original article content was condensed to meet the submission's page-limit guidelines through the use of an AI language model, GPT-4o-Mini. Figures included in this manuscript were generated with assistance from the AI tool Napkin.AI. All AI-assisted outputs were reviewed, edited, and validated by the authors to ensure accuracy, clarity, and alignment with the study's scholarly standards.

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Expert Validation of an Empathic Design Thinking Framework: For Digital Serious Game Development

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Abstract: The design and development of serious games is a multifaceted process that often lacks a comprehensive, user-centered approach despite the availability of numerous design frameworks. The systematic review of current serious game design frameworks reveals a focus on technical and instructional aspects. This paper introduces Empathic Design Thinking Framework (EDTF), a novel framework tailored to support educational designers, researchers, developers, and practitioners in creating digital serious games, that pretends to address this gap by integrating co-design and iterative user research throughout the entire process, ensuring alignment with end-user needs. A key innovation is its focus on co-design and co-development, where learners and instructors collaborate with designers and developers throughout the whole process. This approach contrasts with traditional methods, where user research is often limited to specific phases after the initial game concept is proposed. By integrating user research into every phase, from ideation and concept development to prototyping, testing, and deployment, it ensures that the final product aligns closely with the needs and preferences of its target audience. The EDTF was developed and refined through a design science research approach, incorporating literature review, concept mapping, and theory development. It was further validated and iteratively revised by 18 experts and practitioners in the field of serious games with focus on comprehensibility, feasibility, usability and limitations of the framework. Experts acknowledge the framework's elaborateness, but highlight its depth and practical value in structuring the game design process, particularly for educational and training games. The step-by-step approach provides clarity, reduces uncertainty, and supports both novice and experienced designers and developers. While few suggestions for streamlining were noted, the framework's emphasis on continuous iterative testing, systematic user-driven progression was praised for enhancing project outcomes. In conclusion, the EDTF's consistent focus on users needs and its ability to balance complexity with practical utility make it a robust tool for creating impactful, efficient, useful, desirable well-structured serious games. This study underscores the framework's potential to address real-world design challenges and improve the usability and effectiveness of serious games in educational and training contexts.

Keywords: Empathic design thinking framework, Serious games framework, User experience in serious games, Artificial intelligence in game design, Educational games

1. Introduction

Digital serious games have become a powerful instrument for blending education with digital interactive experiences, enabling learners to acquire knowledge, develop skills, and shape attitudes through engaging gameplay (Lamarti et al., 2014). While many frameworks for serious game development exist, they often focus on instructional or technical elements, overlooking the deeper emotional and experiential needs of users (Plass et al., 2016). This gap has prompted a growing interest in more human-centered approaches, particularly those that embed empathic design principles. Empathic design, rooted in understanding users' feelings, motivations, and cognitive states, offers a promising direction for creating games that not only teach but also resonate with users on a personal level (Kouprie & Visser, 2009). To address this gap, this paper introduces the *Empathic Design Thinking Framework (EDTF)*, a novel framework designed to support the creation of digital serious games through a co-design and co-iterative user research process. Unlike traditional frameworks, which tend to involve user input only in later stages, EDTF integrates empathic and user-centered principles across all phases of design and development, from initial ideation, prototyping, and testing, to continuous post-development assessment. Created using a design science research approach and validated by 18 experts in digital serious game design, EDTF aims to provide a structured and practical methodology that centers real user needs throughout the entire game design and development process. Its step-by-step guidance helps reduce uncertainty, support collaboration between learners, instructors, designers, and developers, and enhance the relevance and impact of digital serious games in educational and training contexts. By bridging the gap between academic theory and design practice, this work offers both researchers and practitioners a framework for integrating empathic design principles in complex, user-centered creative processes.

2. Digital Serious Game Design

Digital serious games represent a unique category of interactive experiences designed not just for entertainment but for education, training, health, and strong social impact. By mixing the gameplay with purposeful goals, they facilitate skill development, knowledge retention, and behavioral change (Michael & Chen, 2006; Laamarti et al.,

2014). Examples range from simulation-based training in fields like medicine and aviation to educational games that teach subjects like mathematics, chemistry, languages or history, as well as health-focused games that encourage physical activity or disease management. Persuasive games extend this further, aiming to influence social attitudes toward issues like environmental conservation or justice (Alvarez & Michaud, 2008; Connolly et al., 2012; Sitzmann, 2011; Baranowski et al., 2016; Janakiraman, 2021). Despite their potential, the success of digital serious games depends heavily on how well they connect with users, not just functionally but emotionally and experientially. Therefore, they should be carefully designed with focus on both educators and learners' needs and motivations.

In that regard, frameworks play a fundamental role in structuring the design process, offering systematic ways to analyze and address complex challenges. Their effectiveness hinges on key attributes such as clarity, coherence, simplicity, and generalizability, ensuring they serve as reliable guides for research, design and development (Bunt et al., 2024). A well-constructed framework must balance accessibility with rigor, simple enough to be intuitive yet robust enough to withstand empirical testing and adapt to varied contexts. These qualities are especially critical in the design of digital serious games, where structured approaches are needed to merge engagement with real-world objectives.

This is where many existing digital serious game design frameworks fall short. While they often emphasize functionality and user-centered design, according to the current academic literature, summarized in different reviews, they frequently overlook the deeper, more nuanced aspects of empathic design, understanding players' emotions, motivations, and lived experiences (Maxim & Arnedo-Moreno, 2025; Bijl et al. 2024; Avila Pesantez et al., 2017). Empathic design shifts the focus from mere usability to meaningful engagement, ensuring games resonate on a personal and emotional level. Without this, even well-structured games may fail to sustain interest or drive lasting impact. The difference lies in recognizing that learning and behavioral change are not just cognitive processes but emotional ones, requiring designs that foster immersion rather than just efficiency.

The principles of empathic design align closely with broader user-centered approaches, prioritizing the user's needs alongside functional requirements. This involves iterative collaboration with end-users, leveraging methods like interviews and usability testing to refine designs based on real feedback. The goal is to create experiences that are not only educationally sound but also immersive and emotionally compelling (Kouprie & Visser, 2009). The key aspects include intuitive interfaces that reduce friction, progression systems that instill a sense of achievement, and aesthetics that evoke emotional responses, all of which deepen engagement and enhance learning outcomes. The potential of an empathic design thinking approach in enhancing the development of digital serious games has been increasingly recognized by educators and researchers (Maxim & Arnedo-Moreno, 2021). Current practices in serious game development often relegate user experience considerations to later stages, such as prototype testing or post-production evaluations. While agile methodologies have improved flexibility, they tend to treat user feedback as a final checkpoint rather than an integral part of the entire design process (Cano et al., 2015). This limits opportunities to iteratively refine games based on empathic design principles. A more holistic approach would embed empathic design approach at every phase, from initial conceptualization to final evaluation, ensuring that experiential needs inform decisions early and consistently.

Addressing this gap, a novel framework that integrates empathic design principles systematically across all stages of game development.

3. Empathic Design Thinking Framework (EDTF)

The Empathic Design Thinking Framework (EDTF) was developed through an integrative review of existing literature, drawing from both digital serious game (DSG) and entertainment game design (DEG) frameworks (Maxim & Arnedo-Moreno, 2025). The primary objective of EDTF is to support the complete design and development cycle of serious games, with a strong emphasis on understanding and addressing user needs. This user-centric focus was woven into every stage of the framework. By centering the needs and experiences of both educators and learner-players, it ensures that DSGs achieve more than just functional goals, they create meaningful, memorable interactions that drive engagement and lasting impact.

EDTF is grounded on Empathic Design (ED) and Design Thinking (DT) principles, as well as core Human Computer Interaction methods like empathy mapping, journey maps, and personas (Cai, 2009; Kouprie & Visser, 2009; Gibbons, 2018; Campoverde-Durán et al., 2023). ED focuses on emotional immersion, uncovering latent needs, and co-creating with learners and educators (Battarbee & Koskinen, 2005; Afroogh et al., 2021). DT adds iterative cycles of ideation, prototyping, and testing, supporting rapid feedback and continuous refinement of learning

mechanics and engagement (Brown, 2009; Doorley et al., 2018). EDTF introduces several novel contributions for digital serious games. It embeds emotional and learner-centered needs from the very first phase, rather than addressing them only during testing after design or development are done. The framework systematically integrates co-design and co-participation of end users approach in every phase, lightweight instructional tools, and iterative low-to-high-fidelity prototyping, making it feasible for resource-constrained educational contexts. Additionally, EDTF aligns game mechanics explicitly with learning outcomes based on real users' involvement, ensuring a balance of engagement, usability, and instructional effectiveness throughout all phases.

EDTF, represented in Figure 1, unfolds through ten iterative and structured phases, each guiding the development of engaging and effective learning games: (1) Empathize focuses on understanding users' needs, motivations, and challenges to ensure a user-centered design. (2) Co-Design Scenario maps the learning journey and creates user personas, promoting cross-stakeholder collaboration with lecturers and learners. (3) Co-Design Instructional Content aligns educational content with learner needs and instructional strategies to support defined learning goals. (4) UX Evaluation (Storyboard) assesses and refines the visual and narrative structure to maintain engagement and support learning objectives. (5) Low-Fidelity Prototype develops sketches or wireframes to test concept engagement and resonance before digital development. (6) Iterative UX Evaluation conducts early usability testing on low-fidelity prototypes, focusing on navigation, task understanding, and flow to refine concept comprehension and structure. (7) High-Fidelity Prototype builds an interactive version for advanced testing, analyzing engagement and learning outcomes. (8) Development finalizes the game collaboratively across design, development, and content teams to align all components with educational goals. (9) Evaluation and Assessment measures effectiveness and long-term learning impact, identifying areas for further iteration. (10) Deployment & Change Management implements the game in real contexts with strategies for scalability, sustainability, and continuous updates.

<table>
<tr>
<td>Phase 1: Empathize
Context: Game conceptualization and foundational mechanics
UX Focus: Evaluating user needs, motivations, pain points, behaviors, and emotional responses
Opportunity Potential: Assessing the solution's visionary potential for addressing real user challenges
Goals & Tasks:
• Identify and segment target users (learners, instructors, stakeholders)
• Understand user values, attitudes, and behaviors through qualitative research
• Develop deep empathy for user experiences
Artifact: Empathy Maps (visualizing user thoughts, feelings, and behaviors)</td>
<td>Phase 2: Co-Design Scenario
Context: Learning journey and narrative structure
UX Focus: Story mapping to align gameplay with educational progression
Opportunity Potential: Paradigm Shift – Encouraging new perspectives in learning through interactive storytelling
Goals & Tasks:
• Map critical decision points in the user journey
• Refine user personas based on real-world insights
• Facilitate co-design workshops with educators and learners
Artifact: Journey Map (illustrating key interactions and learning milestones)</td>
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<tr>
<td>Phase 3: Co-Design Instructional Content
Context: Alignment of game mechanics with learning objectives
UX Focus: Ensuring content meets learner needs while supporting instructional strategies
Opportunity Potential: Technically Challenging – Innovating in learning technology integration
Goals & Tasks:
• Define measurable learning objectives
• Structure content to balance engagement and pedagogy
• Collaborate with subject-matter experts for accuracy
Artifact: Instructional Design Document (detailing learning outcomes and content flow)</td>
<td>Phase 4: UX Evaluation (Storyboard)
Context: Visual and narrative coherence of the game
UX Focus: Assessing storytelling effectiveness and engagement
Opportunity Potential: Multidisciplinary Collaboration – Bridging gaps between designers, educators, and developers
Goals & Tasks:
• Validate narrative flow with stakeholders
• Identify and resolve potential disconnects between story and learning
• Refine storyboard based on feedback
Artifact: Storyboard (visualizing scenes, interactions, and transitions)</td>
</tr>
<tr>
<td>Phase 5: Low-Fidelity Prototype
Context: Early-stage concept validation
UX Focus: Testing core mechanics and usability with minimal investment
Opportunity Potential: Actionable – Rapid iteration based on real user feedback
Goals & Tasks:
• Develop wireframes or paper prototypes
• Conduct usability tests with target users
• Identify key pain points and areas for improvement
Artifact: Low-Fidelity Prototype (sketches, paper models, or digital wireframes)</td>
<td>Phase 6: Iterative UX Evaluation
Context: Usability refinement and interaction design
UX Focus: Enhancing user interface and experience through continuous testing
Opportunity Potential: Continuous Improvement – Ensuring adaptability based on user data
Goals & Tasks:
• Conduct structured usability tests
• Gather and analyze qualitative and quantitative feedback
• Refine UI/UX before high-fidelity development
Artifact: Usability Test Reports (documenting findings and recommended changes)</td>
</tr>
<tr>
<td>Phase 7: High-Fidelity Prototype
Context: Advanced gameplay and engagement testing
UX Focus: Refining interactivity, aesthetics, and learning impact
Opportunity Potential: Technically Challenging – Solving complex development hurdles
Goals & Tasks:
• Develop a near-final interactive prototype
• Assess engagement, learning retention, and technical performance
• Optimize before full production
Artifact: High-Fidelity Prototype (polished, functional demo)</td>
<td>Phase 8: Development
Context: Full-scale game production
UX Focus: Ensuring final product aligns with tested prototypes
Opportunity Potential: Multidisciplinary Execution – Coordinating designers, developers, and educators
Goals & Tasks:
• Implement final game mechanics, assets, and content
• Conduct quality assurance (QA) testing
• Prepare for deployment
Artifact: Final Game Solution (complete, deployable product)</td>
</tr>
<tr>
<td>Phase 9: Evaluation and Assessment
Context: Measuring learning outcomes and engagement
UX Focus: Summative assessment of educational and experiential impact
Opportunity Potential: Far-Reaching – Evaluating long-term effectiveness
Goals & Tasks:
• Conduct post-deployment assessments
• Measure knowledge retention and skill development
• Identify areas for future iteration
Artifact: Evaluation Reports (quantitative and qualitative findings)</td>
<td>Phase 10: Deployment & Change Management
Context: Real-world implementation and scaling
UX Focus: Monitoring performance and adapting to user feedback
Opportunity Potential: Actionable – Ensuring scalability and sustainability
Goals & Tasks:
• Roll out the game in target environments
• Gather live user feedback
• Release updates and improvement.
Artifact: System Updates & Release Notes (documenting changes and fixes)</td>
</tr>
</table>

Figure 1: Summary of the Phrases in Empathic Design Thinking Framework (EDTF)

Most current frameworks prioritize instructional design, technical functionality, or gamification mechanics. They often treat the user as a reactive participant, only considering their needs at specific checkpoints like late-stage usability testing. This can lead to superficial understanding of the user's emotional and cognitive experience. In contrast, EDTF proposes direct engaging with users to uncover their unspoken motivations, frustrations, and desires. This approach embeds user insights from the very beginning, ensuring the final product is not just functional and educational, but also emotionally resonant and personally meaningful.

Overall, EDTF distinguishes itself from existing serious game design frameworks in one important way: its systematic and deep integration of empathy throughout the entire development process. EDTF makes this commitment actionable by weaving empathic principles into every single phase, from initial ideation to final deployment. This creates a process that is emotionally intelligent, responsive, and genuinely inclusive. For educational and training contexts, this means building digital games that respect learners' lived experiences, effectively bridging the gap between pedagogical goals and genuine, long-term engagement.

4. Expert Evaluation

This section outlines the expert-based evaluation method used to assess the Empathic Design Thinking Framework (EDTF), a widely applied approach in Human-Computer Interaction (HCI) studies (Waljas, 2009; Lallemand et al., 2014). The evaluation aimed to validate the framework's effectiveness in guiding the design of DSGs by examining its comprehensibility, usability, feasibility, usefulness, and ease of use.

When evaluating the EDTF framework for designing serious games, *comprehensibility* refers to how easily game designers and stakeholders can understand the framework's steps, principles, and how to apply it to serious game development. *Usability* measures how effectively and efficiently designers can follow the EDTF process to create engaging, educational games without unnecessary complexity (Panach et al. 2008, Maxim & Arnedo-Moreno, 2024). *Feasibility* assesses whether using EDTF is realistic within project constraints like time, budget, technology, and team skills. *Usefulness* evaluates whether the framework genuinely helps designers build games that meet educational and empathic goals, ensuring the final product addresses real user needs. Finally, *ease of use* focuses on how intuitive and straightforward it is for designers (especially those new to the framework) to apply the EDTF method without extensive training or frustration (Davis, 1989; Bark et al., 2005; Boland et al., 2014; Nie et al. 2022).

4.1 Method

The expert evaluation was designed to assess the EDTF framework using a mixed-method approach, combining both quantitative and qualitative data collection through cognitive walkthrough design (step-by-step evaluation) and semi-structured interview protocols. A total of 18 experts participated, recruited through Usertesting.com. The group included 12 instructional game developers and 6 instructional game designers, with varied levels of experience: 50% had 1-3 years, 28% had 3-5 years, and 22% had more than 5 years. The participants were predominantly 30% female and 70% male, and most had experience with Unity, Unreal Engine, and GameMaker.

Experts participated in 1-hour evaluation sessions, during which they were introduced to the 10 phases of EDTF, including its context, goals, and intended outcomes. After the exploration, experts completed a semi-structured interview protocol and rated the framework on five key dimensions: comprehensibility, usefulness, usability, feasibility, and ease of use. Each dimension was measured using a single Likert-scale item with the following wording: e.g., *"The framework is comprehensible: 1 (Strongly Disagree) – 5 (Strongly Agree)."* Quantitative ratings were analyzed by calculating mean scores for each dimension, providing an overview of expert perceptions. Qualitative feedback, including first impressions and comments on clarity, usefulness, and overall evaluation, was collected via Zoom and manually coded in Excel.

4.2 General Results

The expert evaluation of the Empathic Design Thinking Framework (EDTF) revealed valuable insights across five key dimensions: comprehensibility, usefulness, usability, feasibility, and ease of use.

For **comprehensibility**, 89% of experts rated the framework 4 or 5, resulting in a mean score of 4.2/5. The remaining 11% indicate minor suggestions for simplification. Experts highlighted that the phased approach, guiding stakeholders from conceptualization to deployment with co-involvement of the real users, was well-structured and logically sequenced.

For **usefulness**, the framework received a mean of 4.5/5, with 83% of experts rating it 4 or 5. The remaining 17% expressed potential objection about aligning EDTF with agile development timelines, reflecting the potential

challenge for teams under tight deadlines. **Usability** scored 4.0/5, with 78% of experts rating it positively (4 or 5). The remaining 22% indicated that the testing-intensive phases might be resource-demanding, especially for smaller teams.

Feasibility had a mean of 3.8/5. While 80% of experts felt implementation was achievable with sufficient resources, 20% highlighted that multidisciplinary skills would be necessary to fully adopt the framework in real-world educational game projects. Finally, **ease of use** scored 4.3/5, with 94% of experts rating it 4 or 5. The remaining 6% noted potential complexity in later, technical phases, which could challenge teams less familiar with advanced game development processes.

4.3 Phase-by-Phase Evaluation

The framework's clarity, practicality, and usability were also reflected in the expert evaluations of its individual phases. Each phase was assessed for its contribution to the overall process and its real-world applicability in educational game development.

1. *Empathize:* experts unanimously found this phase valuable for setting a human-centered tone from the outset. All evaluators emphasized the importance of deeply understanding user needs, motivations, and challenges. *"Understanding user pain points isn't just a box to check—it's the compass for everything that follows"* (P12). While some noted that this phase's abstract nature could be challenging for novices, there was broad agreement that it lays a strong foundation for all subsequent design work and ensures that the final product resonates with users.
2. *Co-Design scenario:* this phase, which focuses on mapping the learning journey and creating personas, was valued for encouraging collaborative shifts in mindset. Experts recognized its role in aligning stakeholders from different disciplines early in the process. *"It forces subject-matter experts and designers to speak the same language early on"* (P9). Some experts suggested including scenario-building templates to guide less experienced teams in structuring their thoughts.
3. *Co-Design instructional content:* experts emphasized this phase's critical role in ensuring that instructional strategies are closely aligned with learner needs. Most experts agreed that this alignment is crucial for creating meaningful and effective learning experiences. "*Without this step, you risk creating a fun game that teaches nothing—or a lesson nobody wants to play*" (P7). However, a few noted challenges in integrating educators, learners and instructional designers consistently, especially in resource-limited settings. For this phase they need role-specific guidelines to improve the interdisciplinary collaboration. *"Teachers and developers often have wildly different priorities, so we need clearer mediation strategies"* (P2).
4. *UX evaluation (storyboard):* the clarity and actionability of this phase were praised, particularly for its ability to align game design with educational objectives early on. Experts highlighted the usefulness of storyboards in communicating ideas to stakeholders, especially non-technical team members. *"Storyboards turn vague ideas into something everyone can critique, even non-technical stakeholders"* (P11) This phase was also appreciated for its low-risk nature, allowing for early iterations and reducing the likelihood of costly rework later. *"Catching flaws on paper saves months of coding dead-ends"* (P17).
5. *Low-fidelity prototype:* the introduction of basic prototypes received strong support for transforming abstract ideas into testable models. Experts saw this phase as a valuable tool for gathering early feedback. However, some experts pointed out the resource-intensive nature of creating prototypes, particularly for small teams. The use of rapid prototyping tools and templates was suggested to alleviate this burden.
6. *Iterative UX evaluation:* experts hailed this phase for its role in collecting real user feedback to refine the design. It was recognized as one of the framework's strongest phases, supporting evidence-based design. However, the phase was also seen as demanding, requiring time, user access, and analytical expertise. Experts expect to have clear checklists and protocols to streamline the process.
7. *High-fidelity prototype:* at this stage, the framework transitions from abstract concepts to detailed, experiential products. Experts noted that the high-fidelity prototype provides valuable insights into user engagement and learning alignment. However, the increased technical demands of this phase raised concerns about feasibility for smaller teams without specialized skills.
8. *Development:* experts expressed positive but cautious feedback about this phase. While they appreciated the integration of visual, narrative, and functional elements into a cohesive product, they also noted that this phase often presents challenges related to time and budget constraints. Clear role

definitions and agile development plans were identified as key factors for success. "*This is where interdisciplinary teams often fracture without strong project management*" (P13).

9. *Evaluation and assessment:* this phase was recognized as essential for validating learning outcomes and measuring long-term impact. Experts appreciated the framework's inclusion of both formative and summative evaluations. "*Most frameworks stop at deployment, but measuring actual learning impact is revolutionary*" (P5). However, they emphasized the need for appropriate metrics and tools to measure learning gains, particularly in behavioral and cognitive domains.
10. *Deployment & change management:* the final phase of the EDTF was praised for its focus on the long-term success and scalability of the educational game. Experts acknowledged the importance of sustainability, stakeholder adoption, and ongoing improvements post-launch. *"Launching is just the beginning—this phase ensures the game evolves with user needs"* (P16). Several evaluators suggested incorporating ongoing feedback loops and monitoring tools to ensure effective change management.

4.4 Discussion

The expert evaluation of the Empathic Design Thinking Framework (EDTF) highlighted its strengths and areas for improvement. Overall, experts found the framework clear and logically structured, with its phased approach making educational game design more accessible. The early *"Empathize"* phase was especially praised for its user-centered focus, though some noted that phases like *"Co-Design Scenario"* might be challenging for beginners. A simplified terminology or additional guidance, such as templates, could help.

Experts agreed the EDTF is highly useful, particularly its iterative testing process, which ensures games are both engaging and educationally effective. However, some raised concerns about aligning the framework with agile workflows, suggesting that adaptable guidelines could help teams working under tight deadlines. While the framework's step-by-step structure was seen as useful and feasible, resource-intensive phases like usability testing and prototyping could strain smaller teams. Experts also suggested that some automated tools or streamlined checklists might ease this burden. Additionally, the EDTF's multidisciplinary nature makes it best suited for teams with diverse expertise. For solo developers or small teams, scaled-down versions with core principles could improve feasibility.

The later phases, namely evaluation, deployment, and long-term monitoring, were recognized as important for sustainability. Experts recommended enhancing post-launch data collection to support ongoing improvements. Finally, although AI can automate tasks such as documentation, analyze user data, generate design suggestions, and assist in rapid prototyping, experts emphasized that human cognitive judgment remains essential for interpreting insights, understanding nuanced user needs, and making user-centered design and development decisions.

5. Conclusion

In conclusion, the expert evaluation of the EDTF highlights its strengths in clarity, usability, and practicality, particularly in its power to guide designers and developers through each phase of the digital serious game design and development process. The EDTF bridges a critical gap in serious game design by uniting design thinking, empathic design principles research, and participatory principles in a structured, actionable format. It offers a scalable, adaptable, and robust instrument that supports the creation of serious games that are desirable, useful, usable, and impactful. By anchoring the process in continuous collaboration with users, the EDTF stands to significantly improve the relevance, effectiveness, and success of DSG in real-world educational and training environments.

Since the EDTF has undergone validation through expert assessment, the next step is to move towards its real-world application. With the framework now validated for its structure, clarity, and usefulness, it will be applied in actual digital educational game development projects. This transition marks a critical step in the evolution of EDTF, allowing it to be tested for its ability to genuinely include users' perspectives throughout the entire design process, from initial concept to final deployment. Through hands-on application, the framework's adaptability and effectiveness will be further substantiated, providing evidence of its practical value for educational game designers and developers. At the same time, expert feedback highlighted resource challenges, particularly for small teams with limited time or multidisciplinary expertise. To address this, an EDTF toolkit version to be adapted will be created, combining certain phases and employing lighter-weight tools for empathy research, co-design, and prototyping. These adaptations would preserve the framework's core principles of user inclusion and iterative refinement, while making it feasible for smaller teams to implement it effectively.

Ethics Declaration: This study did not require formal ethical clearance. All participants provided informed consent prior to their involvement, and all data were collected and handled in accordance with standard ethical research practices.

AI Declaration: No AI tools were used in the development, writing, or analysis of this paper.

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Development of A Serious Game for British Sign Language Education

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Abstract: Learning the alphabet is a fundamental part of any language, especially British Sign Language (BSL). Without an understanding of the alphabet, learners may lack awareness of where signs outside the alphabet originate from, which leads to gaps in proficiency. Although the BSL Scotland Act 2015 promotes the use of BSL, many learners in Britain continue to face challenges that hinder language acquisition, such as limited access to learning materials, classes, and groups. Serious games have captured great interest and have been applied in a plethora of areas for education, training, or awareness through engaging gameplay. They offer a unique approach to overcoming these barriers, promoting deaf awareness and encouraging sign language learning through engaging material. This paper presents the development of a novel, hangman-inspired serious game prototype designed to facilitate learning the BSL alphabet and vocabulary. The game integrates spelling exercises with visual sign representations, aiming to connect the BSL letter recognition to the corresponding dynamic sign. This prototype serves as a step towards addressing resource gaps and accommodating the community by offering a potential model for sign language learning through a serious game. Immersive serious games can add a level of engagement and potential haptic interaction to BSL education. This paper will also provide a preliminary scoping literature review of the state of the art of the application of VR and serious games for sign language education.

Keywords: Serious games, Sign language, BSL, Language learning, Education, Games-Based learning

1. Introduction

In the United Kingdom, there are approximately nine hundred thousand profoundly Deaf BSL users (HearingLink, 2025), and typically hearing individuals will only learn British Sign Language (BSL) due to a hearing-impaired family member or friend. This means that deaf individuals are usually born into societies where their native language is virtually never used, therefore being excluded from the hearing world. Notably, BSL was only registered as an official independent language by the UK government in 2003 (A language of the UK, 2003), which is remarkably recent, highlighting how historically overlooked BSL and its users have been. It wasn't until 2015 that Scotland officially recognised BSL by creating the BSL Scotland Act 2015 to promote and facilitate the use of BSL (British Sign Language (Scotland) Act 2015, 2015). Although some progress has been made in recent years, we have yet to see the effects, as BSL's status remains almost non-existent. Poor promotion in mainstream schooling with BSL not being part of the national curriculum, widespread gaps in Deaf awareness and limited sign language learning materials further contribute to the exclusion of the Deaf community. Due to limited resources, researchers have been turning to gamification as an alternative to traditional BSL teaching methods. Serious games serve as an engaging approach for learning, with researchers increasingly exploring serious games to facilitate learning. Serious games seem promising in relation to sign language as it offers an inexpensive, engaging and convenient method for learning the basics. Although sign language compromises many components like facial expressions, hand gestures, lip pattern and body language, serious games offer a promising start for hearing individuals to learn the BSL basics. Teaching the sign language alphabet serves as a foundational step in promoting global Deaf awareness and ensuring hearing individuals acquire at least basic signing skills, helping to reverse the exclusion of Deaf communities in today's society. Learning BSL is also a very expensive commitment and the use of Serious Games can raise awareness and allow learners to gain foundational knowledge utilising a supplementary learning approach. Not only will this enhance diversity in terms of providing diverse supplementary learning opportunities but will also enhance inclusion by raising awareness of a minority group requirements.

2. Serious Games

Serious Games are designed with a purpose other than purely entertainment, they are designed for players to carry out a set of activities that build on skills or knowledge rather than the primary purpose being to entertain (Johnson et al, 2017). Serious Games provide a learning experience which can be more engaging and motivational than traditional learning methods. This unique learning experience can be used in a plethora of contexts, such as raising awareness, developing skills, or simply educating. Additionally, Serious Games have been applied to a number of diverse fields, including but not limited to healthcare (Wattanasoontorn, et al,

2013), science education (Ullah et al, 2022) and language learning (Ishaq et al,2022). The term 'Serious Games' refers to a broad spectrum of games-based learning experiences. Recently, Din, Baig and Khan (2023) conducted an updated systematic literature review on Serious Games, which included, categorising the selected papers into the various types of Serious Games, like games developed for computers, games developed for 3D virtual environments, software games that use Lego toys, games developed for specific consoles, board games, web app games, mobile app games, and lastly online Role-Playing Massively Multiplayer games (MMORPG). It is evident that Serious Games support a wide range of pedagogical methods, for example, Serious Games for language learning (Ishaq et al,2022) has been widely explored in web-based applications, mobile applications and VR in particular. Johnson (2010) develops a system to help users learn foundational language skills in foreign languages and cultures, the system is based on a military game made in Unreal Engine, utilising artificial intelligence to capture learners speech which is then interpreted and then evaluated.

3. Serious Games in VR for Sign Language

Focusing on language learning through Serious Games, in particular BSL learning. Serious Games hold great prospects for sign language acquisition, with researchers and developers beginning to integrate sign language learning through various types of Serious Games.

In the context of this study, a preliminary scoping review (Arksey and O'Malley, 2005) was employed to provide an overview of the current state of literature concerning applications of virtual reality serious games for sign language education. The review specifically focuses on applications that integrate sign language learning through VR to present the many techniques that researchers are employing for sign language and serious games to date. This targeted review aimed at VR, and not the broad types of Serious Games, is due to the limited literature regarding sign language in all types of Serious Games. With VR proving to be most popular, this review aims to understand what has been done to date within the inclusion of sign language in technologies.

This scoping review selects literature from databases such as ACM (Association for Computing Machinery), Scopus, and IEEE (Institute of Electrical and Electronics Engineers) and the literature matching the inclusion criteria of sign language learning was selected. The selected relevant articles were then thematically analysed and categorised into two themes.

3.1 Static Gestures

A key theme that emerged were that several studies focused solely on static gestures of sign language alone like the static signs of the alphabet. For example, studies like (Rho et al, 2020) and (McCloskey, 2022) teach static gestures in VR with technologies like Leap Motion and neural networks, to effectively teach static gestures, achieving high accuracy and positive feedback. Additionally, gamified learning approaches like a whack-a-mole game by (Wang et al, 2023; 2024) and a Serious Game by (Economou et al, 2020) which employs an instructional scaffolding approach, demonstrate how different Serious Games can increase engagement.

3.2 Dynamic Gestures

Similarly, dynamic gesture learning became a key theme with studies researched by (Schioppo et al, 2019) and (Bisio et al, 2023) highlighting the challenges in accurate recognition due to hardware and environmental constraints. Additionally, a Jenga-style game by (Shaw et al, 2023) specifically notes the limitations that gamification learning faces when involving two-handed gestures as well as dynamic signs.

3.3 Summary

The reviewed literature reveals that most serious games for sign language learning focus on either static or dynamic gestures solely. However, sign languages, such as BSL, combine both static and dynamic signs within the alphabet itself. For example, while most BSL letters are static, letters such as 'H' and 'J' involve movement. Despite this, dynamic gestures continue to pose challenges in existing literature.

More broadly, sign language encompasses many components beyond hand gestures, including facial expressions, body language, and lip patterns. The many components of sign language make full integration into Serious Games complex. As a result, researchers often turn to the alphabet as a more manageable starting point. However, applications tend to isolate static or dynamic gestures, rather than combining them into their natural form to create a more cohesive learning experience. This gap highlights an issue that current research fails to address, both the static and dynamic components of sign language alphabets.

This paper presents a novel approach to the foundational learning of BSL through an application called 'Hanghand', a hangman-inspired mobile prototype to learn and practise all 26 letters of the BSL alphabet. The application aims to address the lack of easily accessible learning tools for BSL learners, especially those with limited access to BSL learning materials.

4. Learning Theories and Models in Serious Games and Games-Based Learning

Serious games can achieve successful game-based learning through various paradigms of theoretical approaches and learning models. Learning theories refer to the frameworks that address how one absorbs, processes, and retains knowledge. In essence, a learning theory can be defined as how individuals learn. Alternatively, learning models are more practical, enforcing how individuals actually acquire knowledge, learning theories, through teaching or interactive learning. The most common learning theories that are widely used are Behaviourism, which introduces an external stimulus to trigger a conditioned response (Rehman et al, 2024), Cognitivism, based on a user's knowledge and how well they process and retain information (Sweller, 2011), Constructivism, focuses on linking new information with previous knowledge (Lave and Wenger, 1991), and Humanism, which focuses on motivation and personal growth for promoting learning (Kolb, 1984). These learning theories provide a framework for many pedagogical methods.

In the context of Serious Games, Schrader (2023) sums these frameworks into four categories motivational, affective, cognitive, and sociocultural. These approaches are often evident in successful Serious Games, with many researchers producing learning models that adopt these learning theories. For example, as mentioned previously, Kolb's Experiential Learning Cycle (Kolb, 1984) is a popular learning model which is grounded in the cycle of concrete experience, abstract conceptualisation, reflective observation and active experimentation.

The Serious Game prototype developed for this paper adopts an experiential learning model approach where players engage in concrete experience by interacting directly with the game to guess letters of the BSL alphabet, and they then receive immediate feedback, reflective observation. Over repeated gameplay players begin to recognise and improve their understanding of BSL signs, abstract conceptualisation, which is then reapplied in the gameplay, active experimentation.

5. Design

5.1 Target Audience

The prototype targets both beginners and early learners of BSL who may already be familiar with the basics of the language but lack opportunities for real-world practice. Hanghand, therefore, considers a wide range of users with different BSL backgrounds, such as those completely new to BSL and those with existing knowledge.

5.2 Content Integration

Serious Games can complement traditional learning by integrating educational context into games (Rodriguez-Calzada, Paredes-Velasco, and Urquiza-Fuentes (2024), intrinsically or extrinsically, to create meaningful and engaging learning experiences. To support the experiential learning approach that this paper adopts, Hanghand focuses on practising existing BSL knowledge or, for some users, acquiring and practising newfound BSL skills. The prototype incorporates intrinsic content integration, which focuses on the player's own desire and personal motivation in learning BSL (Gottfried, 2019).

All 26 letters of the BSL alphabet are visually displayed at the bottom of the screen using a BSL font, and players can directly interact with these letters to guess the displayed hidden word using the familiar hangman-style gameplay mechanic, which is adapted to the BSL letters. This is illustrated in Figure 1. The game replaces the traditional hangman figure with a hand that gradually forms with incorrect guesses, and the goal is to provide repeated exposure to BSL letters in a context that is both engaging and educational. In the context of content segmentation (Liu, 2024), which chunks information into smaller and more manageable pieces, this prototype prioritises this to avoid overwhelming the player. This is prevented by displaying one hidden word at a time, which is derived from a theme, allowing players to concentrate on active recall on a single word in each round.

Figure 1: Game screen displaying BSL font

Hanghand aims to establish a balance between game time and learning time to maintain motivation through correct word guesses that progressively reveal the full sign of each word. Each round of the game challenges players to recall and apply their knowledge of the BSL letters, which are displayed persistently. As users guess letters to uncover a hidden word, they must visually identify and mentally retain the correct BSL letter. HangHand has three difficulty modes: easy, medium and hard, to accommodate varying levels of BSL knowledge. The difficulty settings screen is shown in Figure 2.

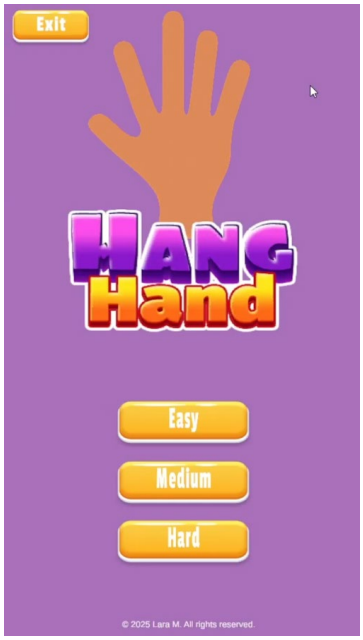

Figure 2: Difficulty settings screen

In easy mode, players have unlimited access to a BSL learning dictionary (Figure 3), which provides visual references of BSL fingerspelling which correspond to each letter of the English alphabet. This feature allows users who are unfamiliar with BSL to recall and familiarise themselves with the signs. Medium mode limits this dictionary's use to five uses per round, while hard mode completely disables the dictionary feature. This dictionary, on the easy and medium modes, supports learning by providing instant visual references, helping to ensure that users can learn and build on their knowledge progressively. Similarly, this feature can assist users with existing BSL knowledge by providing a support system when users struggle to recall or forget specific signs.

Figure 3: The BSL learning dictionary screen

The repetitive nature of the 'Hangman' mechanic, which is intrinsically embedded within the core gameplay, reinforces the BSL learning process through visually engaging gameplay. Users are given a limited number of attempts, which are visually displayed on screen, to guess the correct word. With each incorrect guess, a hand begins to form, mirroring the traditional hangman mechanic, until the hand fully forms, and the hidden word is revealed in red BSL, indicating an unsuccessful attempt. The round is then concluded, and a new word is introduced, continuing the learning cycle. However, when a player successfully guesses the entire word before reaching the limit, before the hand is fully formed, the letters turn green to signify success, and a short video automatically plays demonstrating the full BSL sign for that word. Figure 4a shows the incorrect guessing screen and Figure 4b shows the correct guessing screen.

Figure 4a: Incorrect guessing

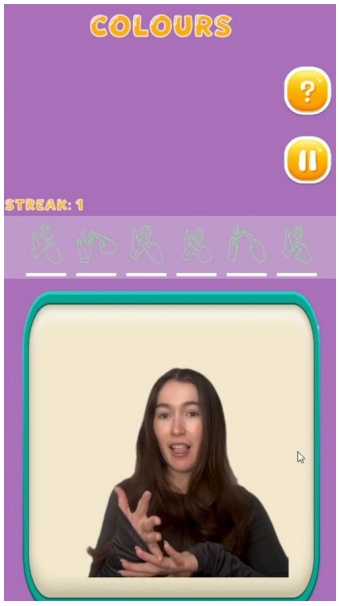

Figure 4b: Correct guessing

The experiential learning approach employed in this prototype ensures that the educational content displayed is absorbed in short, impactful sessions and is designed to successfully achieve the intended learning outcomes.

5.3 Assessment Integration

Assessment integration plays an important part in Serious Games to ensure that the learning outcomes are actively being reinforced. Without assessment, it is difficult to determine whether the player is actually engaging with and learning the intended educational content (Hainey, 2013). Considering this, this prototype establishes learning outcomes, with the implementation of assessment that can be measured against these outcomes to assess both the usability and effectiveness of achieving the intended learning outcomes within Hanghand, this Serious Game prototype.

As previously mentioned, the prototype supports users with both no previous knowledge and existing knowledge of BSL, facilitating the recognition and retention of basic BSL signs for both user groups. The assessment is intrinsically integrated into the game, ensuring that a player's ability to accurately identify and apply the correct BSL sign when guessing letters in the hidden word is a direct reflection of their understanding of the language. To assess the prototype's initial effectiveness, learning outcomes have been established to measure the successful acquisition of basic BSL, assessing the prototype's effectiveness in facilitating a successful Serious Game.

The learning outcomes developed for Hanghand are:

- LO1 to improve the player's familiarity with BSL letters.
- LO2 to support this knowledge through BSL spelling and word recognition.
- LO3 to promote foundational BSL skills through repetition.

Each of the difficulty modes that HangHand employs collectively contributes to the assessment and achievement of the defined learning outcomes. These modes reinforce familiarity with the BSL alphabet, LO1, through repeated exposure to recognising letters across all modes, similarly as one does when learning the alphabets in written languages such as English. Additionally, LO2 is supported through the correct identification of individual letters, leading to demonstration of the complete sign vocabulary, signifying the importance of understanding BSL beyond fingerspelling. Lastly, LO3 is addressed through each mode, promoting foundational BSL skills by providing repeated practice of isolated sign language letters as well as full sign equivalents.

6. Implementation

The prototype has been implemented as a 2D Serious Game, developed using Unity 6, a game engine commonly used for developing games or apps, with C# as the primary programming language. The prototype was specifically developed as a 2D mobile-friendly format for future development and employment on mobile devices. HangHand was implemented based on the traditional Hangman game, therefore, the main mechanic of Hangman, guessing the hidden word, remains at the core of this prototype's implementation. Three game modes, easy, medium and hard, were implemented based on the player's proficiency level in BSL. For the purpose of this prototype the game modes were implemented as a static variable, so that the selected difficulty can persist across the homepage and the gameplay scene in a lightweight manner. The letters of the BSL alphabet displayed as an alphabet keyboard at the bottom of the screen are automatically loaded upon playing and are presented as buttons using a custom BSL font, which represents each letter A – Z in BSL. Players select letters by clicking on them, and correct guesses reveal the letter in the word, while incorrect guesses trigger the gradual appearance of the hand. Each BSL letter is constantly visible throughout gameplay to support focus on the alphabet signs. The word lists are preprogrammed with fundamental colours, focusing on basic and commonly used colours, and are randomly selected from a text file. When a player successfully guesses the full word before their chances are up, the hand is completely formed, and a short video appears showing the corresponding sign for that word used in everyday BSL. This mechanic aims to reinforce the connection between fingerspelling and BSL vocabulary, for example, if the hidden word is 'Pink', the player must correctly spell P-I-N-K using the BSL alphabet. Upon successful completion, a video is shown demonstrating how to sign the word 'pink' in BSL. The corresponding full BSL word signs are recorded by the author of this paper, who is a fluent BSL user, using an iPhone 15 and the video editing software CapCut, which is then imported to Unity and linked to each of the words on the preprogrammed text file. Additionally, to increase motivation and engagement, the game incorporates a streak component that tracks the number of consecutive wins a player achieves. If the player loses, the streak resets to zero, therefore encouraging users to maintain a correct guessing streak across rounds.

7. Evaluation

7.1 Defining Evaluation in Serious Games and Games-Based Learning

In general terms, evaluation refers to the process of assessing something to understand its characteristics or quality (Wanzer, 2021). Evaluation concerning Serious Games measures the effectiveness of learning within the context of Serious Games (Pacheco-Velazquez, et al 2023). Evaluating games-based learning continues to be beneficial in a number of ways one being to improve the usability of the game for its target audience. However, there remains a lack of existing pedagogical frameworks to measure Serious Games. Despite this, there are two main evaluation methods that are broadly used, formative and summative evaluation. Formative evaluation focuses on the process of getting towards something, whereas summative evaluation measures the final goal.

7.2 Formative and Summative Evaluation

Formative and Summative evaluation methods can both be embedded into Serious Games for evaluation, for example,(Zolotaryova and Plokha, 2016) propose a conceptual framework which embeds both formative and summative to evaluate the games learning outcomes and motivational mechanics with the goal of measuring the balance between fun and the acquisition of learning outcomes. Formative evaluation in their framework takes part during the development process with a pre-evaluation of the game before it's built and virtual models to test the game, both focused on improving the overall game before the final software is developed. Additionally, summative evaluation was used once the game was created to measure if the game achieved the learning outcomes that were intended and to assess the motivation mechanic, this was evaluated through questionnaires, user testing and case studies.

7.3 Hanghand Evaluation

The evaluation of the 'Hanghand' prototype is mainly focused on a formative approach to assess the game's usability in relation to how effectively users achieve the intended learning outcomes highlighted previously. This initial evaluation in the prototype's development stages allows for iterative development based on real user feedback, and the empirical evidence collected will inform this.

The evaluation objectives are to address the game's learning outcomes. LO1 is evaluated through quantitative pre- and post-questionnaires to understand the player's current knowledge in BSL and whether familiarity was improved or acquired. LO2 is evaluated through gameplay observation, and quantitative data will be gathered to assess whether players can connect BSL fingerspelling with full word signs. LO3 will be assessed by observing patterns during the repetitive gameplay as well as following up with qualitative feedback.

7.4 Development of a Workshop for Evaluating a Serious Game

As stated, the prototype developed as part of this paper employs a formative evaluation approach to assess the effectiveness of the learning outcomes so far, which will assist in the iteration of the development process. Although formative assessment is primarily focused on the process, this approach is used in this instance as an exploratory assessment, which will be implemented through a small workshop. This workshop is the primary method of collecting empirical evidence, as participants will be invited to interact with the prototype and data will be collected in real time.

8. Conclusion, Limitations and Future Work

Despite the introduction of the BSL Scotland Act in 2015, the widespread promotion and integration of BSL remains limited across mainstream education and everyday life. As a result, Deaf individuals continue to be excluded from a society in which their native language is rarely taught, prioritised, or practised. BSL learning materials and classes are still difficult to access, and opportunities for consistent language exposure are often restricted to those with Deaf family members or close personal ties to the community. This prototype offers a fun and engaging method for reinforcing arguably one of the most fundamental components of BSL which is that of the alphabet. By combining the well-known hangman mechanic with visual BSL letters, the application encourages users to repeatedly engage with static and dynamic signs while spelling full words. Upon successfully completing a word, players are presented with a video of the corresponding BSL sign, helping to connect BSL letter recognition and sign vocabulary. In doing so, this application provides an opportunity for users, especially those with limited daily exposure to sign language, to continuously practise and retain their BSL knowledge. It supports language maintenance and recall through repetition and challenge, and reinforces connections between spelling and sign meaning. As with any language, continued use is key to retention, this

prototype aims to support that in an engaging and culturally respectful way. Additionally, while this application offers a space for practice and informal learning, it does not substitute formal BSL learning. BSL should be taught by qualified native Deaf users to ensure cultural authenticity, linguistic accuracy, and to protect Deaf representation within language education. This application is not intended to replace Deaf-led teaching, but rather to complement it by offering a tool for continued practice, especially for those who may not have regular exposure to sign language. A further limitation of this prototype is that the BSL vocabulary videos currently used are based on Scottish regional signs. BSL, like many natural languages, includes regional variation, however, native Deaf users are often able to distinguish and adapt to these differences. It is important to note that this version follows Scottish BSL conventions only. While the sign language videos were record by a CODA (Child of a Deaf adult), future development should consider incorporating regional sign options, allowing users to select the version of BSL most relevant to their location or community, and should involve native Deaf signers in the production of all sign language content to ensure accurate and culturally respectful representation.

Ethics Declaration: Ethical clearance was not required for this research.

AI Declaration: AI tools were not used in the creation of the paper.

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From Perception to Participation: A Case Study of Gamified Learning in Engineering Education

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Abstract: This study examines the relationship between gamification and Motivation, Perceived Learning, Teamwork, and Flow—a state of deep focus and enjoyment—among first and third semester university engineering students. Student responses were measured using the Motivation for Cooperative Learning Play Strategies (CMELAC) questionnaire at the semester's start and this feedback was used to inform and refine the implementation of gamified strategies in the courses to foster greater motivation and learning. Results showed a significant positive response, with 94% of students participating. On a Likert scale ranging from 1 to 5, where higher scores indicate greater agreement, the average ratings were as follows: 4.59 for Motivation, 4.27 for Perceived Learning, 4.32 for Teamwork, and 3.96 for Flow. Students were divided into two groups. First-semester students showed a moderately positive Spearman's correlation ($\rho = 0.675$) between Motivation and Perceived Learning, while third-semester students exhibited an even stronger correlation ($\rho = 0.778$) between these variables, suggesting that academic experience may be associated with increased responsiveness to gamified activities when highly motivated. Analysis revealed a consistent positive association between Motivation and Perceived Learning, while these findings do not establish causality, they indicate that well-structured gamification strategies tend to align with higher perceived learning when motivation is elevated. The stronger associations among advanced students point to the importance of tailoring gamification to students' academic level and familiarity with such strategies. These findings highlight the need for adaptable gamification approaches, requiring educators to adjust course design based on students' needs and levels. The study underscores the importance of structured, engaging activities with frequent feedback, especially for less advanced students, and shows that familiarity with gamification enhances its effectiveness. By measuring perceived effectiveness, educators can make informed pedagogical decisions and implement gamification from a holistic, evaluative perspective. Overall, the study provides insights on optimizing gamification to achieve educational goals through engaging, adaptive, and effective learning experiences.

Keywords: Educational innovation, Gamification, Motivation, Perceived learning, Personalized education, Engineering course engagement, Higher education

1. Introduction

Gamification is defined by Detering et al (2011) as "the use of game design elements in non-game contexts". This concept highlights the intent to apply the motivational dynamics and elements from games to influence user behavior across various domains, including education and training. Essentially, gamification seeks to foster participation, enhance engagement, and facilitate learning by simulating mechanisms that keep players immersed in gaming environments. In the context of engineering education, the relevance of gamification becomes clear when the unique demands of engineering courses are considered. Engineering courses are structured to integrate both theoretical knowledge and practical applications, equipping students with the technical skills required to solve real-world problems. As Sheppard et al (2008) note, effective engineering education must not only cover foundational theory but also encourage creativity, critical thinking, and adaptability—skills that align with the immersive and interactive nature of gamified strategies.

The course design principles applied in engineering education aim to support this multifaceted learning experience. Heywood (2005) emphasizes that course design in engineering education should follow principles like constructive alignment, therefore ensuring that learning objectives, instructional activities, and assessments are cohesively structured to facilitate deep learning. Further, he suggests incorporating collaborative learning experiences and leveraging educational technologies to enhance engagement and comprehension. These principles are particularly critical during the initial years of engineering education, as thoughtfully structured courses have been shown to improve student retention and motivation. Studies indicate that early exposure to design-focused, project-based learning enhances self-efficacy and professional

skills, which allow for students' persistence in engineering programs (Sperling et al, 2024). Additionally, integrating interdisciplinary approaches, such as incorporating artistic elements into STEM curricula, can reinforce students' commitment to their studies, as highlighted by Mena-Avilés et al (2023). Understanding and applying effective educational strategies within engineering courses is key to shape versatile, competent professionals. As Anil Yasin and Abbas (2021) note, integrating both technical and non-technical skills into engineering programs equips graduates to meet industry demands and societal needs, addressing competencies like communication and teamwork alongside technical expertise. Moreover, active learning strategies have demonstrated effectiveness in enhancing student engagement and retention, ultimately leading to better academic outcomes (Berna t-Maso, 2024).

Recent research strongly supports tailoring gamification to meet the diverse needs of students. For instance, a review on adaptive gamification in education (Hallifax et al, 2019) notes that aligning game elements with individual learning preferences and abilities leads to enhanced engagement and academic performance, as it strengthens students' connection to the material. Moreover, Ortiz-Rojas et al (2019) demonstrate that customized leaderboard dynamics, adapted to student preferences, increase competitiveness and engagement.

Gamification has been implemented in engineering courses through various innovative approaches. In an e-learning course on agile methods (John and Fertig, 2024), elements such as quizzes, videos, and badges were utilized to enhance intrinsic motivation, resulting in improved engagement and comprehension among students. Additionally, the "UBI Journey" mobile game (Santos et al, 2024) promoted socialization and exploration among students by employing geofencing and rewards to support integration and engagement within a university setting. In a matrix modeling course for engineering students (Santos-Guevara, Rincon-Flores and Méndez, 2024), a reward-based system was designed to reduce anxiety and improve motivation, leading to positive shifts in students' emotional responses to challenging content.

To evaluate the effectiveness of the gamification strategies implemented in this study, the Questionnaire on Motivation for Cooperative Learning Play Strategies (CMELAC), developed by Manzano-León et al. (2021), was employed. This psychometrically validated instrument, specifically designed for university contexts involving gamified dynamics, enables the analysis of four key factors that influence student engagement. The first task motivation assesses the extent to which students feel driven to actively participate in the proposed activities, recognizing their value and relevance. The second, perceived learning, measures how students interpret their own process of knowledge acquisition within gamified environments. The third factor, teamwork, evaluates the quality of peer collaboration—an essential component of the gamified educational model and a cornerstone for developing collaborative competencies. Finally, the flow experience refers to the sense of immersion and enjoyment during the activity, which has been identified as a key predictor of sustained engagement. These constructs not only capture students' perceptions of gamified activities but also provide a robust framework for exploring the transition from intention to action in gamified settings, aligning with the goal of understanding which motivational and experiential elements drive genuine student involvement.

Recent studies, such as Abd Wahid et al. (2025), have demonstrated that interactive gamification through Wordwall significantly enhances student engagement and comprehension in literary contexts. Although conducted in secondary education, their findings support the broader applicability of gamified strategies in fostering motivation, focus, and collaborative learning—dimensions also explored in engineering education through instruments like CMELAC

The Questionnaire on Motivation for Cooperative Learning Play Strategies (CMELAC), developed by Manzano-León et al. (2021), was selected for its conceptual and methodological relevance in assessing key dimensions within gamified environments in higher education. This instrument features a concise structure of 16 items and demonstrates high internal consistency (Cronbach Index $\alpha > 0.78$), allowing for efficient administration without compromising psychometric validity. It employs a five-point Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree), enabling accurate data collection on student perceptions. Its robustness lies in its ability to capture the transition from initial perception to actual student involvement through the correlation of its four constructs: task motivation, perceived learning, teamwork, and flow experience. As the authors note, "the instrument allows for the evaluation of students' perceptions regarding the impact of playful strategies on their motivation and learning," which aligns directly with the aim of this study—to understand how such perceptions translate into active participation in gamified contexts. The items used in this study, translated into English, were:

1. In general, I enjoyed this playful activity
2. I would repeat these types of activities
3. I have felt motivated
4. I improved my knowledge of the subject
5. My interest in the subject has increased
6. This activity format has been appropriate to check my knowledge of the subject
7. Helped me identify my weaknesses in the subject
8. It helped me understand the content of the subject
9. With these types of activities, I learn more than in traditional classes
10. I feel like I was able to connect with my teammates to learn
11. I learned from my classmates during the activity
12. I found the game elements fun
13. The game elements have motivated me to carry out the activity
14. While playing I was not aware of what was happening around me
15. I felt capable of carrying out the proposed activities
16. I found the activities comforting and valuable to me

In accordance with the classification proposed by Manzano-León et al. (2021) in the Development and Validation of a Questionnaire on Motivation for Cooperative Playful Learning Strategies, the CMELAC instrument groups its items into four key factors: Motivation for the task (items 1, 2, 3, and 13), Perceived Learning (items 4 through 9), Teamwork (items 10, 11, and 12), and Flow experience (items 14, 15, and 16). This categorization was used to analyze student responses and interpret their engagement with gamified learning activities.

2. Methodology

Building on evidence that supports the implementation of gamified strategies in engineering education, this study examines the impact of these educational innovation strategies on students' perceptions. The study proposes administering the CMELAC diagnostic questionnaire at the beginning of courses to evaluate students' perceptions regarding gamification. This approach enables the design of courses tailored to the specific needs of the student body, thereby promoting more active participation. Additionally, the aim is to strengthen students' connection with the course material, leading to enhanced learning and competencies development.

2.1 Research Approach

This descriptive study explores how first- and third-semester engineering students perceive gamified courses, focusing on examining the correlation between motivation, perceived learning outcomes, teamwork development, and flow experience during these activities.

2.2 Context of the Participants and Course Enrollment

The study was conducted in 2024 with first and third-semester engineering students (99 and 68 respectively) at a private university in Mexico. The sample comprised 115 men and 52 women (69% and 31% respectively). The students were enrolled in courses such as Differential and Integral Calculus, Physics on Conservation Laws, and Electrical Systems, where gamification was implemented as an educational innovation strategy. In Mexican engineering programs, the first three semesters are dedicated to general engineering education, with students from all disciplines interacting in shared courses. The subsequent five semesters focus on specialized training according to each student's chosen field. Therefore, selecting students from the first and third semesters was a strategic decision to capture perceptions during the foundational stage of their academic trajectory.

2.3 Data Collection Instruments

The CMELAC, previously validated in the Spanish university context, was utilized. This instrument assesses student motivation and learning perception in the implementation of playful strategies in the classroom. Since this genre of activities are defined as educational innovation tools, their use often implies that these methods differ from students' previous learning experiences. Therefore, implementing this questionnaire at the initial stage allowed for the tailoring of gamified activities designed to enhance learning through active participation.

2.4 Procedure

At the course outset, students were briefed on the educational innovation methodology to be employed, including the disciplinary and transversal competencies to be developed. They were informed about the project's objectives, scope, implications, confidentiality guarantees, and study limitations. Participation was voluntary, with students providing digital consent via an informed consent form.

During the first week, students completed the CMELAC, leading to adjustments in the instructional design of gamified activities. The study analyzed perception differences between first and third-semester students, with third-semester students having more prior experience in gamification. Figure 1 provides an illustration of the entire process and compares it with the actions undertaken to diagnose students' academic knowledge in an ordinary course.

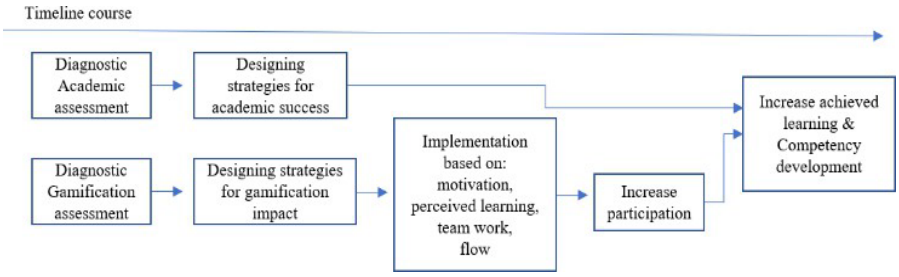

Figure 1: Procedure and CMELAC diagnosis timeline within a given course

2.5 Data Analysis

Statistical analysis methods, including frequency-based descriptive analysis and Spearman's correlation analysis, were utilized to interpret the collected data.

3. Results and Discussion

The analysis of data from the CMELAC revealed several key patterns in students' perceptions. The data analysis uncovered some compelling relationships between key variables for both 1st and 3rd semester students. To validate significant monotonic correlations, Spearman's analyses (95%) were conducted on the responses to each segment, as illustrated in Figure 2 and Figure 3.

Pairwise Spearman Correlations		N	Correlation	95% CI for ρ
perceived learning 1st	motivation 1st	99	0.675	(0.536, 0.778)
team work 1st	motivation 1st	99	0.678	(0.540, 0.781)
flow 1st	motivation 1st	99	0.546	(0.378, 0.679)
team work 1st	perceived learning 1st	99	0.559	(0.393, 0.689)
flow 1st	perceived learning 1st	99	0.550	(0.383, 0.682)
flow 1st	team work 1st	99	0.541	(0.373, 0.675)

Figure 2: Motivation, perceived learning, teamwork, and flow, Spearman's correlation coefficient. 1st semester engineering students with 95% CI

Pairwise Spearman Correlations		N	Correlation	95% CI for ρ
perceived learning erd	motivation 3rd	68	0.778	(0.642, 0.866)
team work 3rd	motivation 3rd	68	0.721	(0.563, 0.829)
flow 3rd	motivation 3rd	68	0.715	(0.555, 0.824)
team work 3rd	perceived learning erd	68	0.727	(0.571, 0.833)
flow 3rd	perceived learning erd	68	0.730	(0.575, 0.834)
flow 3rd	team work 3rd	68	0.695	(0.528, 0.811)

Figure 3: Motivation, perceived learning, teamwork, and flow, Spearman's correlation coefficient. 3rd semester engineering students with 95% CI

Considering this study aims to anticipate students' level of participation and identify which motivational and experiential elements facilitate the transition from intention to action, we analyzed the constructs with the highest Spearman correlation coefficients across semesters. Among first-semester students, the strongest positive correlations were observed between motivation and teamwork (ρ = 0.678) and motivation and perceived learning (ρ = 0.675) as depicted in Figure 4, both indicating moderate associations. These findings are particularly relevant for instructional design, as they suggest that when students feel motivated by gamified activities, they are more likely to perceive meaningful learning and engage collaboratively. To leverage this insight, we implemented weekly gamified activities—primarily team-based and supplemented with immediate feedback—to sustain motivation and provide tangible evidence of learning progress, whether students were engaging with new content or reinforcing prior knowledge.

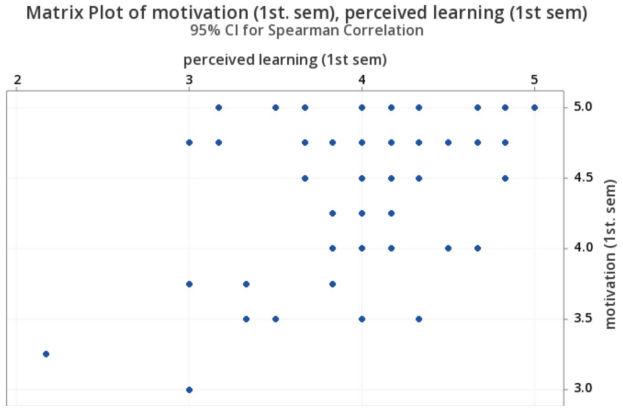

Figure 4: Correlation between Motivation and Perceived Learning among first-semester students

In contrast, the analysis for 3rd semester students revealed an even stronger Spearman's correlation of 0.778 between Motivation and Perceived Learning (IC 95%; 0.642, 0.866), as illustrated in Figure 5. This result indicates that more experienced students not only respond well to gamified activities but also experience greater learning benefits when they are highly motivated.

Additionally, we found a strong correlation of 0.730 between Perceived Learning and Flow (IC 95%; 0.575, 0.834), emphasizing the critical role of immersive and engaging experiences. To optimize these benefits, we refined our activities to ensure that they not only motivated but also fully engaged students, thereby enhancing both learning retention and interest through gamification.

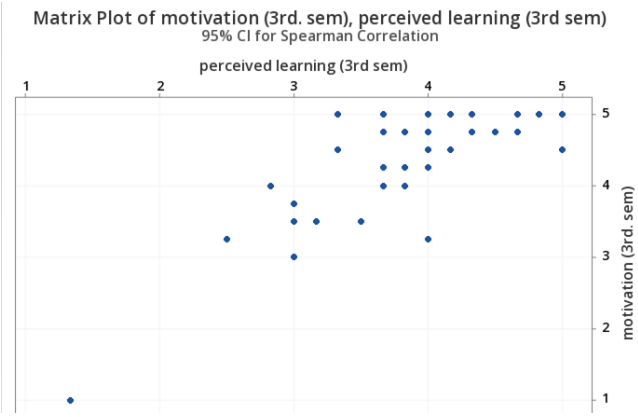

Figura 5: Correlation between Motivation and Perceived Learning among third-semester students

When analyzing the combined data from both groups, we found a consistent positive link between Motivation and Perceived Learning, as shown in Figure 6. This pattern suggests that well-designed gamification strategies can enhance perceived learning across the board when motivation is high. However, the stronger impact seen among more advanced students implies that the benefits of gamification increase as students advance academically.

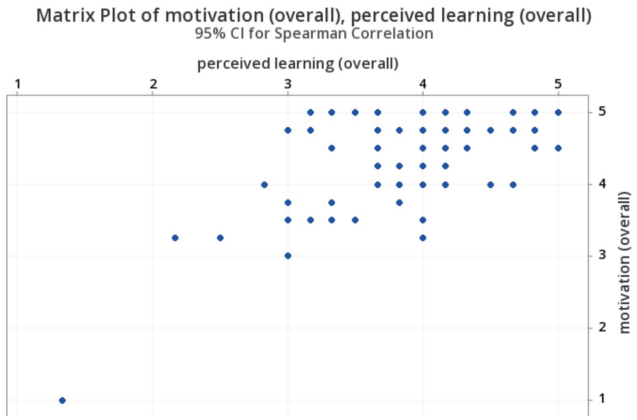

Figure 6: Correlation between Motivation and Perceived Learning among all students of both semesters

To further support these strategies, we developed an updated Activities and Competency Development Matrix (Table 2), based on the professional judgment and teaching experience of the academic team involved in this project. With over two decades of experience in university-level education, the team categorized various gamified activities—such as quizzes, team debates, interactive simulations, and gamified homework—according to their perceived impact on four key areas: Motivation, Perceived Learning, Teamwork, and Flow. While this matrix was not derived from statistical analysis, it reflects informed pedagogical reasoning and classroom experience across four student cohorts. Interactive simulations and team debates were considered particularly effective for fostering learning, teamwork, and engagement, making them suitable for immersive and collaborative environments. Quizzes and gamified homework, though less impactful for teamwork, were seen as useful tools for reinforcing learning and sustaining motivation through immediate feedback. Table 2 provides a practical framework for educators to design or select gamified activities aligned with specific instructional goals. Future studies may empirically validate this matrix to further refine its applicability across diverse educational contexts.

Table 2: Activities and Competency Development Matrix

Category	Quiz Challenges	Team Debates	Interactive simulations	Gamified Homework
Motivation	High	Medium	High	High
Teamwork	Low	Medium	Low	Low
Comprehension	Medium	High	High	Medium
Engagement	High	Medium	Medium	Low

Note: Ratings are based on expert consensus and prior teaching experience; empirical validation is recommended in future research.

Overall, these insights highlight the need for a thoughtful and adaptable approach to gamification. Professors should be prepared to adjust their course design and teaching methods based on students' needs, academic levels, and classroom dynamics. Much like academic assessments require adjustments to course content and schedules, gamification also demands flexibility. Although the matrix presented is grounded in expert judgment rather than empirical data, it underscores the importance of having a set of pre-designed gamified activities that can be seamlessly integrated into lesson plans to support effective learning outcomes.

The analysis also showed that 3rd semester students exhibited stronger correlations across all variables, suggesting that they have more confidence in the benefits of gamification. This observation is supported by the higher correlations in Figure 3, which indicates that as students become more familiar with gamified learning methods, they tend to appreciate and respond to these approaches more. Therefore, when designing gamified educational activities, it is important to consider generational differences and create immersive experiences for advanced students.

The integration of gamification into educational settings has been extensively researched, with studies affirming its potential to enhance student motivation, engagement, and learning outcomes. For example, Dichev and Dicheva (2017) found that incorporating game design elements into education can significantly increase learners' motivation and engagement. Sailer (2020) expanded on this by proposing the theory of

gamified learning, which outlines how instructional content, behaviors, game characteristics, and learning outcomes are interlinked in gamified environments. Additionally, Oliveira et al. (2023) conducted a systematic review that highlighted the versatility of gamification across various educational contexts, emphasizing its widespread applicability. Further research by Daineko et al. (2023) demonstrated that tailored gamification strategies could improve students' concentration, engagement, and performance while reducing frustration and demotivation.

In summary, our study identifies a consistent association between students' experience levels and their reported Motivation and Perceived Learning in gamified environments. To support educational outcomes, strategic and flexible planning with a diverse range of activities remains essential. The observed generational differences suggest that students' responsiveness to gamification may evolve over time, reinforcing the need for continuous innovation and adaptation in instructional design.

4. Conclusion

The study's findings emphasize that gamification, when thoughtfully implemented, may inform the transformation of instructional strategies. Like academic diagnostics, which requires professors to adapt their approaches based on students' knowledge levels, this gamification diagnostic approach necessitates flexible and data-driven course design. The moderate correlation observed among 1st semester students highlights the relevance of implementing structured and engaging activities with frequent feedback to sustain student motivation and enhance perceived learning.

The much stronger correlations found among 3rd semester students are associated with greater appreciation and trust in these learning methods. This suggests that gamified strategies may become more impactful as students' progress and gain familiarity with them, reinforcing the idea that a gradual introduction to gamification could yield long-term benefits. Educators can use this insight to scaffold gamified activities throughout the curriculum, increasing complexity and immersion as students advance.

The combined analysis supports the use of gamification across different academic levels but also underscores the need for tailored approaches. Understanding these relationships enables teachers to design more effectively gamified activities. For instance, if students respond well to team-based projects, continuing this approach may help sustain motivation and support perceived learning. Additionally, the matrix serves as a practical guide for selecting activities that align with desired competencies, emphasizing that strategic planning is essential to maximize the impact of gamification.

Moreover, these findings highlight the value of measuring the effectiveness of gamification with specific instruments. By assessing whether gamified activities are perceived to support learning, educators can make informed decisions about implementing or refining these strategies. This approach ensures that gamification is not just an engaging tool but also a pedagogically sound method that may contribute to meaningful learning experiences. The segmentation analysis further suggests that generational differences in responsiveness to gamification should be considered, with more immersive and reinforcing experiences being particularly effective for advanced students.

Overall, the study contributes to the understanding of how gamification can be optimized to support educational goals, providing educators with actionable insights for designing engaging, adaptive, and effective learning experiences.

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Sudoku-Based Educational Games for Developing STEM Skills

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Abstract: This paper presents the design and implementation of Sudoku-based educational games aimed at developing learners' mathematical and STEM-related skills, including computational thinking. The games incorporate traditional Sudoku puzzles enhanced with interactive elements and are tailored to various age groups and skill levels. The study applied a quantitative survey method involving participants from primary and secondary schools (sample sizes ranging from 17 to 43), who engaged in four distinct learning scenarios. Feedback collected via Likert-scale surveys assessed students' motivation, engagement, and perceived educational value. Preliminary studies showed that described Sudoku-based activities are well-received among students and teachers and have the potential to enhance students' motivation and engagement. This innovative approach highlights the potential of game-based learning to promote mathematical literacy, scientific literacy, development of computational thinking and bridges the gap between entertainment and education.

Keywords: Educational game, Game-Based learning, Computational thinking, Mathematics, Sudoku

1. Introduction

Games have been used as a learning tool since ancient times (Vankúš, 2005), and their integration into formal education is still of great importance today. Game-based learning utilises the natural motivation, engagement and sense of competition that comes from play to support the achievement of educational objectives. Numerous studies have emphasised the positive impact of this approach on learning outcomes (Vankúš, 2021). There are numerous implementations of game-based learning in mathematics and STEM (Deeb and Hickey 2019; Mikulić Crnković, Traunkar and Crnković, 2022; Erşen & Ergül, 2021; Moon et al., 2024). The use of games in mathematics is particularly important because it addresses a problem of mathematical anxiety. Many students find math intimidating or boring and games make it fun and reduce stress. Statistically significant reduction in math anxiety following game-based interventions was reported in (Dondio et al., 2023) where non-digital games were more effective than digital ones. Due to the positive effects on motivation, understanding and retention of concepts, there are many attempts to use game-based techniques in teaching mathematics (Vankúš, 2005; Vankúš, 2021; Divjak & Tomić, 2011).

This paper presents the design and implementation of Sudoku-based educational games aimed at improving STEM skills. While the traditional Sudoku has already been used in the classroom (Balakrishnan, 2015; Adaramaja & Ogunniyi, 2022), this study contributes to the field of game-based learning by transforming the classic Sudoku into an engaging learning tool. By incorporating dynamic, interactive and multiplayer elements, the redesigned game builds on the familiar benefits of traditional Sudoku and offers a more immersive experience. This approach not only makes mathematics more enjoyable for students but also supports the achievement of the key learning outcomes of the curriculum. Furthermore, in accordance with suggestions of (Dondio et al., 2023) the game incorporates social interaction and adaptability to better support math-anxious students.

2. Background

2.1 Computational Thinking and Mathematics

The foundations of computational thinking are laid in preschool, where children participate in activities that build essential pre-mathematical skills (Botički, Pivalica and Seow, 2018). These include sorting and comparing objects, arranging objects in a specific order, following multi-step instructions, recognising patterns, navigating spatial relationships, and visually grouping or evaluating objects. As children progress into formal schooling, these foundational skills should be further developed through increasingly complex tasks. Computational and analytical thinking is about breaking down complex problems into smaller, more manageable pieces and developing step-by-step strategies — or algorithms — to solve them. This includes skills such as abstraction, decomposition, algorithmic thinking, evaluation and generalisation (Shute, Sun and Asebell-Clarke, 2017). One of the ways to develop computational thinking and mathematical skills is by solving mathematical puzzles such as Tangram, Sudoku, Pentomino and many others.

Sudoku is a logic-based mathematical puzzle in which players have to fill a grid with numbers according to certain rules. Sudoku is a typical example of a recreational mathematics puzzle, but the game is also used in the classroom because it achieves multiple educational goals and promotes a range of cognitive benefits while being engaging and adaptable to different ability levels. It helps students develop strategies and test hypotheses, which is crucial for the development of computational thinking. It also requires minimal resources and no specialised training to implement. For all these reasons and advantages, Sudoku is used as an educational game in the classroom (Norte and Lobo, 2008; Balakrishnan, 2015; Adaramaja, et al., 2011). There are also examples of Sudoku inspired games (Urek, H., 2020; García-Ortega at al. 2025) which are used in classrooms to teach SI prefixes and chemistry. These games have the same gameplay as Sudoku, except that the numbers are replaced by words. The results show that students' comprehension, retention and engagement have improved. As far as we know, there are no examples of Sudoku-based educational games that change the gameplay of Sudoku.

2.2 Sudoku-Based Educational Games

2.2.1 Preliminary results and motivation

The scenarios described in this paper were created as an extension of the activities described by Holenko Dlab et al. (2024). Changes to the scenarios as well as new games and new scenarios were made based on the follow-up analysis described in (Holenko Dlab M. at al., 2024). The paper (Holenko Dlab M. at al., 2024) describes the activities carried out as part of the Pi-Day celebrations through extracurricular activities. Among others, the following activities were carried out: Assemble and Play Sudoku (in different grid sizes).

Total of 95 1st and 2nd graders played Assemble and Play Sudoku in a 4x4 grid on Pi-Day (the tasks were simple mathematical arithmetic problems). In addition to this game, the students also played the Race of Disobedient Robots game and evaluated both activities together. Here are their ratings: *I liked the games.* (AVG: 2.82; SD: 0.48); *It was fun for me*. (AVG: 2.74; SD: 0.58); *I want to play such games again.* (AVG: 2.68; SD: 0.68). Considering the popularity of highly rated games, game-based learning activities were designed based on proven, engaging activities that align with specific curriculum topics.

During Pi-Day, 64 7th grade students played *Assemble and Play Sudoku* in a 9x9 grid (vector problems). In addition to this game, they also played *Mathematics in other words*. The students rated the game *Assemble and Play Sudoku* with an average score of 2.44 (SD: 1.18). In addition, the students completed an evaluation in which they expressed their opinion on both games together. The following two statements and the corresponding student responses were of particular interest: *I believe that by playing such games, I can learn something new*. (AVG: 3.61; SD: 1.14); *Activities like this motivate me to learn mathematics and computer science*. (AVG: 2.88; SD: 1.14). As vectors are a fundamental and demanding concept in mathematics, it is necessary to rethink the way vectors are taught and to develop new innovative activities for this purpose. With this in mind, the activity carried out on Pi-Day was adapted for implementation in the classroom when teaching vectors. A total of 85 5th grade students played the game *Assemble and Play Sudoku* in a 6x6 grid on Pi-Day (simple, age-appropriate math problems). In addition to this game, students also played some commercial games (SET, Spot It, Tantrix). Students rated the game *Assemble and Play Sudoku* with an average score of 3.35 (SD: 1.55), while the commercial games were rated with an average score of 3.43 (SD: 1.55). Students also completed a rating and provided the following responses: *I believe that by playing such games, I can learn something new.* (AVG: 3.45; SD: 1.28); *Activities like this motivate me to learn mathematics and computer science.* (AVG: 2.81; SD: 1.33). From these ratings, it was concluded that the game had potential (as the rating was very similar to that of commercial games) and development of new games and scenarios was started. A new game, *Turtle Plays Sudoku*, was designed, with more attention paid to the rules and gameplay. The newly designed scenarios were also used to test how well-designed tasks affect students' attitudes. Interesting tasks from the Kangaroo without borders competition, an international maths competition to promote problem-solving skills, and the Beaver competition, a global competition for computational thinking to promote logical thinking, were therefore included in the activities.

2.2.2 Assemble and Play Sudoku

Assemble and Play Sudoku is a simple game based on the well-known Sudoku puzzle. The game consists of two phases. In the first phase, tasks must be solved to determine the initial positions and values in the Sudoku table. Figure 1 shows wooden 9x9 Sudoku table designed for *Assemble and Play Sudoku game*.

The second phase can be realised in two ways: the Sudoku table is filled in according to the Sudoku rules (version 1) or the player chooses whether to fill in the table according to the Sudoku rules or to solve additional tasks that reveal new positions and new values in the table (version 2).

The game can be prepared with cards/tasks for different topics and can be integrated into the educational process in different ways through learning scenarios.

Figure 1: Assemble and Play Sudoku wooden table

2.2.3 Turtle Sudoku

Turtle Sudoku is a board game based on Sudoku that is played by 3 players (or 3 groups of players). It is a game in which each player receives a pencil in their own colour: red, green and blue. Each player receives a figurine, and three task sets (red, green and blue set). In addition, a shared empty 6x6 Sudoku table with three marked arrows (red, green and blue arrow) is placed so that all three players can reach it. Each colour task is divided into two parts: the first part describes the movement of the figure through the Sudoku table, where starting position is indicated with an arrow, and the second part contains tasks whose solutions are numbers between 1 and 6.

The game is divided into three phases, as follows. In the first phase, each player solves the task of their colour such that the first phase is over when one player solves all their tasks. Each player enters their solutions in the shared Sudoku table, outlining the number with their own colour. Phase two consists of each player solving the other players' problems, with each player having the opportunity to correct (or complete) the other players. Phase two is time limited.

After the second phase, each player writes the numbers in the common table in the following way: the number is written with the player's colour and the outline is marked with the colour of the task, i.e. if the red player corrects the blue player, he writes the number with the red pencil and outlines it with the blue pencil, if the outline is not already marked.

Before the third phase, each player receives the following points: 2 points for solving your own tasks correctly (i.e. for each correct number written in the correct place and outlined with the same colour as the number) and 3 points for correcting another player's task (i.e. for each correct number written in the correct place and outlined with a different colour than the number written).

In the third phase, the players complete the Sudoku according to the usual Sudoku rules by writing the numbers in the common table in their own colour. At the end, each correct number in phase 3 is awarded one point. The player with the most points is the winner of the game.

2.3 Learning Scenarios

2.3.1 Orient yourself in Sudoku

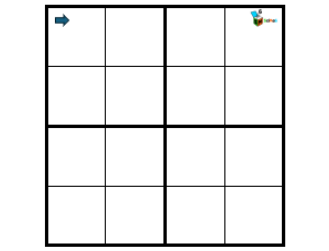
The learning scenario is based on the game *Assemble and Play Sudoku* (4x4 grid) and is intended for students at the very beginning of elementary education (in Croatia, this is the first grade of elementary school). In addition to developing computational thinking and pre-mathematical skills, this scenario achieves outcomes in the area of spatial orientation, which forms the basis of many STEM disciplines. The tasks are designed so that you have to move the figure in the given order (up, down, left, right) and "walk" through the Sudoku table, with the starting position marked with an arrow.

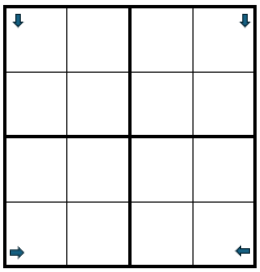
The activity is divided into two parts: an introductory activity where students are familiarised with the rules of the game *Assemble and Play Sudoku* (version 1) and the movements in the Sudoku table, and the second activity has been developed as an activity for pairs, so that each student gets his/her own cards and when playing the game *Assemble and Play Sudoku* each pair solves the same Sudoku, i.e. the initial values in the Sudoku table are shared between two players. Each player receives 2 points for the correct number in the correct position in phase 1 (i.e. 2 points for correctly solving the respective task) and 1 point for each correct number in the Sudoku

table in phase 2 of the game (i.e. for each correct number when solving the Sudoku puzzle). The two players compete against each other and try to collect as many points as possible.

During the 45-minute lesson in three classes at the Elementary School Fran Franković, Rijeka, Croatia, the introductory part of the activity was completed by having each student "walk" through the Sudoku table, following the given instructions and solving all the tasks to obtain the starting numbers in the Sudoku table. Afterward, all students completed the Sudoku puzzle.

If the students are familiar with the rules of the game *Assemble and play Sudoku*, the introductory activity can be skipped or shortened. All the cards prepared for this activity can be found in (SciMaG: Assemble and Play Sudoku (2025)). Some of the cards are shown in Figure 2.





PLACE A FIGURE THAT IS LOOKING IN THE DIRECTION OF THE ARROW: UPPER LEFT CORNER
MOVEMENT: 1 STEP FORWARD TURN RIGHT 1 STEP FORWARD
TASK: WRITE NUMBER 4
MOVEMENT: 1 STEP FORWARD TURN LEFT 1 STEP FORWARD
TASK: WRITE NUMBER 3
MOVEMENT: 1 STEP FORWARD
TASK: WRITE NUMBER 2
MOVEMENT: TURN LEFT 2 STEPS FORWARD
TASK: WRITE NUMBER 3

PLACE A FIGURE : UPPER LEFT CORNER **MOVEMENT:** TURN LEFT 1 STEP FORWARD **TASK:** WRITE DOWN THE SOLUTION: 1+3	**PLACE A FIGURE :** BOTTOM RIGHT CORNER **MOVEMENT:** TURN RIGHT 3 STEPS FORWARD **TASK:** WRITE DOWN THE SOLUTION: 5-3
PLACE A FIGURE : UPPER RIGHT CORNER **MOVEMENT:** 3 STEPS FORWARD TURN RIGHT 1 STEP FORWARD **TASK:** WRITE DOWN THE SOLUTION: 7-4	**PLACE A FIGURE :** BOTTOM LEFT CORNER **MOVEMENT:** 3 STEPS FORWARD TURN LEFT 1 STEP FORWARD **TASK:** WRITE DOWN THE SOLUTION: 1-0
PLACE A FIGURE : BOTTOM RIGHT CORNER **MOVEMENT:** 3 STEPS FORWARD TURN RIGHT 2 STEPS FORWARD **TASK:** WRITE DOWN THE SOLUTION: 8-6	**PLACE A FIGURE :** UPPER RIGHT CORNER **MOVEMENT:** 3 STEPS FORWARD TURN RIGHT 3 STEPS FORWARD **TASK:** WRITE DOWN THE SOLUTION: 9-8

Figure 2: Orient yourself in Sudoku (introductory part and cards for second activity)

2.3.2 Kangaroo plays Sudoku

This scenario is also based on the *Assemble and Play sudoku* game (version 2, 9x9 grid) with the aim of preparing students for the Kangaroo without Borders competition in supplementary mathematics classes (grades 3 and 4; grades 5 and 6).

The activity can be used both in regular mathematics classes and in extracurricular activities, as the tasks develop computational thinking and problem-solving skills.

This activity was conducted at Elementary School Sveti Matej Viškovo (grades 3 and 4; grades 5 and 6), Croatia, in the following way. Pupils were divided into groups, and all groups solved the same task. The tasks were divided into two envelopes: one for the initial set and one for each subsequent position in the Sudoku table. In the first part, the teacher drew a problem from the envelope, and each group solved the same problem. The first group to solve the problem correctly wrote down the number in the Sudoku table in their own colour. The student who solved the problem then explained the solution to the entire classroom.

2.3.3 Sudoku in the coordinate system

Another learning scenario based on the game *Assemble and Play Sudoku* (version 1, 9x9 grid). The aim of this scenario is to visualise vectors in a coordinate system and to repeat the procedures related to calculating with vectors.

The students are divided into five groups. Each group receives an envelope with 7-8 problems. The Sudoku grid is provided with coordinate positions, so that the bottom row is marked *(0,0)*, *(1,0)*, ..., *(8,0)* and the top right field is marked *(8,8)* (i.e. the Sudoku table is arranged in the coordinate system). To solve the task, the student

must visualise the given vector in the coordinate system and select its representative based on the given starting point, for example. An example of the task is: "*Let A(3,2), B(1,0), C(3,5). Find the point D so that the vectors AB and DC are equal. Write the number 6 in the field marked with the positions of point D.*" Each student receives a blank Sudoku table to help them visualize the vectors and solve the problem. All the tasks used in this activity can be found in SciMaG: Assemble and Play Sudoku (2025).

After they have solved all the problems, one student from each group writes the solutions in the Sudoku table on the board, each group with its own colour. Each group receives 2 points per correct number in their colour. If one of the groups solves their own problems while other groups are struggling with the problems, the students help each other. After evaluating the initial values in the Sudoku table, each group chooses a representative to solve the Sudoku puzzle on the board (by writing the numbers in the group colour), competing with representatives from four other groups. In phase 2, one point is awarded for each correctly written number. At the end, the points from phases 1 and 2 are added together and the group with the most points is declared the winner.

2.3.4 Turtle and Beaver Playing Sudoku

This scenario is based on the game Turtle Sudoku and is designed for preparation for the Beaver competition (grades 3 and 4) and activities that develop computational thinking in regular and extracurricular activities.

This activity is carried out by dividing the students into three groups and each phase of the game is limited in time: phases 1 and 2 are limited to 15 minutes and phase 3 to 10 minutes. Each set of tasks consists of 6 tasks from previous years of the Beaver competition, with the orientation steps written in the syntax of the FMSLogo programming language.

3. Methodology

The aim of this study is to assess the motivation, engagement and perceived learning benefits of Sudoku-based educational games for different age groups and to identify key factors for their implementation in the classroom.

The study applied a quantitative research approach by using a survey to gather feedback from participants about their experiences with the Sudoku-based educational games. This method was chosen to gain insights into how the activities were perceived in terms of their educational value and appeal, and to enable comparison with findings from previous experiments. The primary research question guiding the investigation was whether students perceived the Sudoku-based activities as motivating, beneficial to learning, and recommendable.

3.1 Procedure and Participants

The study involved participants from primary and secondary schools in Croatia who took part in the implementation of four different Sudoku-based learning scenarios. The implementation of each learning scenario was carried out during regular or supplementary mathematics classes in schools or during school fieldwork at the Faculty of Mathematics. Students first participated in the Sudoku-based activities, which were facilitated by researchers and their classroom or mathematics teachers following the scenario.

In the first scenario, *Orient yourself in Sudoku*, first graders from Elementary School Fran Franković participated (N=43). In the second scenario, *Kangaroo plays Sudoku*, fourth, fifth and sixth grade students from Elementary school Sv. Matej Viškovo participated (N=17). The third scenario, *Sudoku in the coordinate system*, was conducted in two rounds: seventh grade students from Elementary School Trsat (N=22) and seventh grade students from Elementary School Čavle (N=17). The fourth scenario, *Turtle and Beaver Playing Sudoku*, was conducted in three rounds in the elementary school and one round in the secondary school. The participants were fifth graders from Elementary School Čavle (N=24), fifth graders from Elementary School Jurja Dobrile – Scuola elementare "Juraj Dobrila" Rovinj (N=18), fifth and sixth graders from Elementary School Vladimir Nazor Pazin (N=19) and high school students from Grammar School Andrija Mohorovičić Rijeka (GAM) (N=26).

3.2 Instrument and Data Collection

The survey used in this study consisted of 10 statements (Table 2) aimed at capturing different dimensions of students' experiences with the Sudoku-based educational activities. For the participants in Scenario 1, only three statements were used due to their age (Table 1).

Responses were collected using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Each item examined a specific aspect of the learning experience, including interest and enjoyment of participation, clarity of instructions, perceived educational value, motivation for learning mathematics and computer science,

willingness to participate in similar activities and recommend them to others, and perception of integration of such activities into regular classes. Additionally, students were asked to rate the activity on a separate 5-star scale.

Data was collected either via Microsoft Forms, which facilitated digital submission and processing, or via paper surveys when required.

To assess the attitudes of first graders (participants of scenario 1), a simplified three-point scale featuring illustrated faces was used. Students were asked to circle the face that best represented their feelings about each statement (Figure 3).

Figure 3: Scale with drawn faces used in survey for younger students

The collected data was then processed and analysed using descriptive statistics. This allowed comparisons to be made between implementation rounds when multiple rounds were conducted.

4. Results

The results for the first learning scenario, *Orient yourself in Sudoku*, are shown in Table 1. This scenario involved first grade students (N=43) and focused on assessing their general attitude towards participating in the game-based learning activity. The overall results indicate a positive reception of the activity. The highest mean score was for fun (M=2.9, SD=0.37), closely followed by students liking the game (M=2.88, SD=0.44). The results also indicate that students showed a generally positive inclination toward future participation (M=2.77, SD=0.56).

Table 1: Attitudes towards participation in the GBL activity based on scenario 1

Statements - Scenario 1 (N=43)	M	SD
I liked the game.	2.8	0.44
It was fun for me.	2.9	0.37
I want to play such games again.	2.77	0.56

The results for the second learning scenario, *Kangaroo plays Sudoku*, are shown in Table 2. In this scenario, participants (N=17) evaluated their experience of the game-based learning activity using a wider range of statements. The overall results show that the activity was very positively received. High mean scores were achieved for the fun and engagement statements, with the highest scores ranging from M=4.59 (SD=0.77) to M=4.76 (SD=0.55). Participants also rated the clarity of instructions highly (M=4.59, SD=0.84) and gave strong ratings for perceived educational value (M=4.35, SD=0.84). The motivational impact on learning mathematics and computer science was slightly lower, but still positive (M=4.00, SD=0.91). The overall rating of the game was also high (M=4.59, SD=0.60). However, a lower mean score was found for the presence of such activities in the regular curriculum (M=3.47, SD=1.38).

The third learning scenario, *Sudoku in the coordinate system*, was carried out in two rounds with two different groups of students. The overall results show that the scenario was positively received in both rounds, with students in round 2 generally rating all statements higher than students in round 1. In round 1, mean scores ranged from 2.73 to 3.86, while in round 2 they ranged from 3.06 to 4.50. There were significant improvements in the statements about the clarity of instructions and the perceived learning value. For example, the statement on clarity increased from an average of 3.53 (SD=1.09) in round 1 to 4.50 (SD=0.61) in round 2. The overall perception of learning benefit and enjoyment also improved in the second round. Further positive changes were observed in other statements, such as motivation to learn and willingness to recommend the activity. The overall rating of the game rose from 3.73 to 4.24, with lower standard deviations in round 2 indicating a more consistent positive experience.

The results for the fourth learning scenario, *Turtle and Beaver Playing Sudoku*, are shown in Table 3. This scenario was conducted in three rounds with different groups of students. The overall results show that the activity was positively received in all three rounds, with noticeable improvements between rounds. In round 1, mean scores ranged from 2.54 to 4.13, while in round 2 they ranged from 3.33 to 4.18, and in round 3 from 3.53 to 4.53, reflecting a clear upward trend. Over the rounds, mean scores for enjoyment and interest consistently increased. The clarity of instructions fluctuated, but improved significantly in round 3. The perceived educational value

remained high across all rounds. Motivation to learn mathematics and computer science improved significantly from round 1 to round 2 and remained stable in round 3. Willingness to participate in similar activities and recommend them to others also increased. Game rating increased from 3.50 in round 1 to 4.37 in round 3. The relatively higher standard deviations in round 1 indicate more varied responses initially, while later rounds show more uniform positive experiences.

Table 2: Attitudes towards participation in the GBL activity based on Scenario 2 and Scenario 3

	Scenario 2 (N=17)		Scenario 3 R1 (N=22)		Scenario 3 R2 (N=17)	
Statements	**M**	**SD**	**M**	**SD**	**M**	**SD**
I found the game interesting.	4.59	0.77	3.50	0.94	3.88	0.58
I felt good while participating.	4.71	0.57	3.55	1.03	4.18	0.86
I had fun.	4.76	0.55	3.45	1.12	3.88	0.76
The rules of the game were clearly explained to me.	4.59	0.84	3.53	1.09	4.50	0.61
I believe that by playing such games, I can learn something new.	4.35	0.84	3.86	1.06	4.35	0.76
Activities like this motivate me to learn mathematics and computer science.	4.00	0.91	2.73	1.32	3.06	0.87
I would like to participate in similar activities in the future.	4.71	0.46	3.73	1.29	3.59	0.77
I would recommend participation in similar events to other students.	4.71	0.57	3.55	1.12	4.00	0.84
Such games are not sufficiently represented in regular teaching.	3.47	1.38	3.82	0.9	4.24	0.81
Game rating	4.59	0.60	3.73	1.14	4.24	0.81

Additionally, the same scenario was implemented with secondary school students from GAM (N=26). Results showed exceptionally high scores for all statements, with mean scores ranging from 3.92 to 4.77. The highest scores were for overall enjoyment and satisfaction (M=4.77, SD=0.42–0.50). Clarity of instructions and perceived educational value were also rated highly. Compared to elementary students, secondary students gave consistently higher ratings in all dimensions, especially for enjoyment, motivation, and willingness to recommend.

Table 3: Attitudes towards participation in the GBL activity based on Scenario 4

	Scenario 4 R1 (N=24)		Scenario 4 R2 (N=18)		Scenario 4 R3 (N=19)		Scenario 4 GAM (N=26)	
Statements	**AVG**	**SD**	**AVG**	**SD**	**AVG**	**SD**	**AVG**	**SD**
I found the game interesting.	3.3	1.2	4.06	0.7	4.3	0.5	4.7	0.5
I felt good while participating.	3.6	1.2	3.72	0.7	4.0	0.9	4.5	0.6
I had fun.	3.2	1.4	4.06	0.6	4.2	1.1	4.5	0.5
The rules of the game were clearly explained to me.	3.7	0.9	3.33	1.1	4.5	0.6	4.3	0.6
I believe that by playing such games, I can learn something new.	4.1	1.0	4.18	1.0	3.8	0.9	4.3	0.7
Activities like this motivate me to learn mathematics and computer science.	2.5	1.2	3.72	1.1	3.5	1.0	3.9	1.0
I would like to participate in similar activities in the future.	3.0	1.2	3.56	1.1	4.1	0.9	4.4	0.7
I would recommend participation in similar events to other students.	3.5	0.9	3.83	0.8	4.0	1.0	4.5	0.6
Such games are not sufficiently represented in regular teaching.	3.7	1.1	3.89	0.8	3.6	1.3	4.5	0.6
Game rating	3.5	1.1	3.94	0.9	4.3	0.9	4.7	0.4

5. Discussion

The results demonstrate the positive reception and motivational impact of Sudoku-based learning scenarios and suggest that game-based activities can be perceived as entertaining and engaging at an early stage of education and form an important basis for fostering motivation for STEM learning at later stages.

The high scores for fun, engagement, clarity of instructions and educational value indicate that the game-based learning activities were well received across all scenarios and age groups. The improvements observed in repeated rounds of the scenarios, such as clearer explanations and more refined sequences of activities, support the idea that fine-tuning game-based activities can increase their effectiveness. The increasing willingness of students to participate in similar activities and recommend them to others indicates a growing acceptance and enthusiasm for such learning approaches.

The relatively lower score for the presence of game-based activities in the regular curriculum highlights a gap between the potential benefits of these activities and their current integration into the formal teaching. The results also suggest that secondary school students may be better able to recognise the educational aspects of the activity and engage more intensively with the problem-solving elements, indicating the adaptability and effectiveness of the activities across different age groups.

The study has several limitations. Most scenarios involved small sample sizes (less than 30 participants), with the exception of scenario 1, which limits the generalisability of the results. In addition, no control groups were included, which limits the possibility of attributing the observed effects with certainty to the game-based learning activities alone. The analysis was based solely on descriptive statistics (means and standard deviations), which may be less reliable given the small samples and limits deeper statistical inferences. These limitations should be kept in mind when interpreting the results and emphasise the need for future studies with larger participant groups and more rigorous experimental designs.

6. Conclusions and Plans for Future Work

Traditional Sudoku offers several clear advantages that make it a strong candidate for use in the classroom. However, to effectively support educational goals and enhance student motivation, the activity must be thoughtfully designed and implemented. Throughout the development process, teaching scenarios were refined through iterative testing, with final versions receiving significantly higher ratings than earlier prototypes. Student feedback from surveys consistently indicated that the game was fun, engaging, and a valuable learning tool. These findings underscore the importance of iterative design and evaluation in creating effective educational games, especially for teaching complex concepts. Two key conclusions are highlighted below. First, when implementing group-based activities, it is essential to establish clear behavioural guidelines. This includes assigning specific roles such as a team leader or a student responsible for writing on the board and clarifying when and how tasks should be performed. Well-defined roles help ensure smooth collaboration and reduce confusion. Second, students must fully understand the rules of the game before they can successfully engage in independent play and achieve the intended learning outcomes. The younger the students and the more complex the game, the more time and attention should be dedicated to explaining the rules clearly and thoroughly.

Iterative refinements in explaining the rules, organising students into groups and session structure improved engagement and learning outcomes. Feedback from educators showed that they were more confident in delivering these activities independently, emphasising the importance of thoughtful design and support for the successful integration of educational games.

Future work will focus on developing new scenarios tailored for high school and university students. Additionally, a comparative study will evaluate the effectiveness of these teaching scenarios by assessing the results of learning in an experimental group and comparing them to those of a control group, which will receive traditional instruction.

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AI declaration: AI tools were not used in the creation of the paper.

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Creating the Foundation for a Virtual Game-Based Learning Lab to Stimulate Distance Education

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Abstract: Game-based learning has established itself as a student-centred supplementary learning activity in most higher education subjects. Many university campuses are today providing collections of board games available at no cost for self-directing student activities. For universities with a high degree of distance education there is little comparable material available for online courses. There is of course a plethora of digital games available online, but rarely with any alignment to academic subjects and specific courses. For STEM subjects there are several research studies that report on successful initiatives for virtual labs with a mix of tailored simulations and educational games. The aim of this paper is to describe and discuss the requirements for a virtual lab that could provide user-friendly access to simulations and educational games in a wide range of university subjects. In the first phase of this educational development project, the focus is on games for the subjects of History, Pedagogy, and Computer science. The long-term goal is to create a virtual learning lab for all university subjects. Beside the work on finding the appropriate learning games and applications, a large part of this project will be creating a structure for the virtual lab and providing access to different types of games. The research strategy utilizes the Design science framework, with a focus for this paper on the initial phases of 1) Explicating the problem and 2) defining the requirements for the artefact. Data were gathered partly through a literature review, partly through a study of earlier development projects at the university, and partly from discussions with other researchers in the field of game-based learning. Regarding phase 1) To explicate and elaborate on the problem, the findings indicate that the issues of user-friendly access and licenses for commercial games are of primary importance. This leads over to phase 2), which indicates requirements for high usability and user-friendliness in a virtual gaming lab. This means hosting a mix of commercial quality games and educational games developed and tested in earlier development projects at the university. There are also discussions on collaborations with other game developing teachers from outside our university.

Keywords: Game-Based learning, Virtual learning lab, Game-Based learning lab, Educational games, Distance education

1. Introduction

The practice of learning by playing games has a history originating many centuries before it was explicitly discussed as a didactic method in ancient Greece. In Africa and Asia logic and mathematics were trained by playing games such as Mancala or Chess, Checkers and their many precursors. Still practiced today, and according to a recent study by Rimban (2023), chess also has the potential to develop softer and more general skills such as critical thinking, problem-solving, decision-making, patience, and constructivist thinking. In ancient Greece, Plato considered play to be a necessity for education as a first step on a ladder towards what he called true knowledge (Hellerstedt and Mozelius, 2019).

Virtual learning labs for distance education and self-learning is a much more recent concept, devised in the 21st century, with roots reaching into the 1990s. The majority of applications implemented have been simulations in the field of STEM (Forbus, and Whalley, 1998; Qiu, 2007). As found in the study by Heradio et al. (2016), virtual learning labs have certain unique affordances, such as: (a) modifying or simplifying real-world models to make phenomena more visible to learners and adapted to different cognitive levels, (b) performing a wide variety of virtual experiments faster and easier with fast feedback to the students, (c) helping students in the visualisation of objects and processes that normally are hard to perceive, and finally (d) to orchestrate experiments that are too expensive or difficult to carry out with real-world applications In the 21st century, game-based learning (GBL) has established itself as a mainstream student-centred supplementary learning activity in most educational contexts. Collections of board games are available at no cost for self-directing student activities in many universities. For universities with a high degree of distance education there is no digital counterpart, such as a collection of digital games for online courses. Only a small fraction of the wide variety of digital games available online, are aligned to academic subjects, curricula and specific course topics.

In the contemporary digital era, a digital toolbox for distance education should also involve educational games. As highlighted in the study by Celestini (2020), GBL with games that support learning, should be seen as an innovative instructional strategy in higher distance education. The application and use of educational games in higher distance education could, depending on the game design, be aligned to different learning theories such as behaviourism, cognitivism, constructionism, and connectivism. Behaviourism is a part of many games in the sense of rewards such as badges or points to encourage certain behaviour, or to discourage behaviour with a

corrective approach. Cognitivism could be implemented in games through activities such as decision making and problem solving. Constructivism in the sense of knowledge is created by interaction and activities could be stimulated by increasing levels of challenge that require learners to seek new information and test ideas in the gameplay. Connectivism involves the idea that knowledge is formed by the learner as a result of connections between nodes of information in a constantly changing and chaotic game world. (Celestini, 2020) Two other learning theories that are closely aligned to game-based learning are the Flow Theory (Csikszentmihalyi, 2013), and Constructionism (Papert & Harel, 1991).

The aim of this paper is to describe and discuss the requirements for a virtual lab that could provide user-friendly access to simulations and educational games in a wide range of university subjects. In the first phase of the educational development project described in this paper, the focus is on games for the subjects of History, Pedagogy, and Computer science. In the following phases of the project ViSpel, the long-term goal is to create a virtual learning lab for all university subjects where the subject matter experts want to involve GBL. Beside the work with finding the suitable learning games and their applications, this project should also comprise the creation of a structure for deploying and storing games in the virtual lab.

2. Post-Pandemic Distance Education

Virtual learning labs have been around for decades in distance education (Farana et al., 2004), but the COVID-19 pandemic certainly highlighted their value more than ever before. Besides the more expected use in computer science (Ahfaaf, 2023; Czekansky et al., 2023), the concept was also tested in areas such as language learning (Dai et al., 2025), healthcare (Leclerc, 2022), and banking (Knihová, 2021). The barriers for implementing virtual learning labs in new areas during the pandemic were probably not related to specific disciplines, but rather to the ICT skills of teachers and instructional designers.

As highlighted and discussed by Mozelius (2022) and Haywood et al. (2023), many online artifacts created during the pandemic are worth preserving and developing further. The pandemic brought many obstacles for traditional education, but at the same time helped foster open and inclusive course design. The pandemic provided an opportunity to enhance the existing educational architecture and reinforcing the course design by reimagining how, where, and through which mediums teaching and learning occur (Haywood et al., 2023). Moreover, the shortcomings that were revealed during the pandemic could act as a catalyst for further development of pedagogy and technology in distance education (Mozelius, 2022).

3. Method

This study is the first part of a Design science research project aligned with the fivefold process outlined by Johannesson and Perjons (2014). As further discussed in Humble and Mozelius (2023), small scale studies in academia could be carried out with some selected parts of the full five-fold process. The present study mainly involves the two first phases of the process depicted below (Figure 1). In the first phase, the problem was identified and formulated after brainstorming and discussions among the authors. Moreover, the results from the earlier projects HistoTree and SPEDAT were analysed and discussed. Both those projects are described in the next section. In the next phase, requirements were gathered using a combination of a literature review, discussions with colleagues in the HEaD initiative, and previous experiences from other GBL projects.

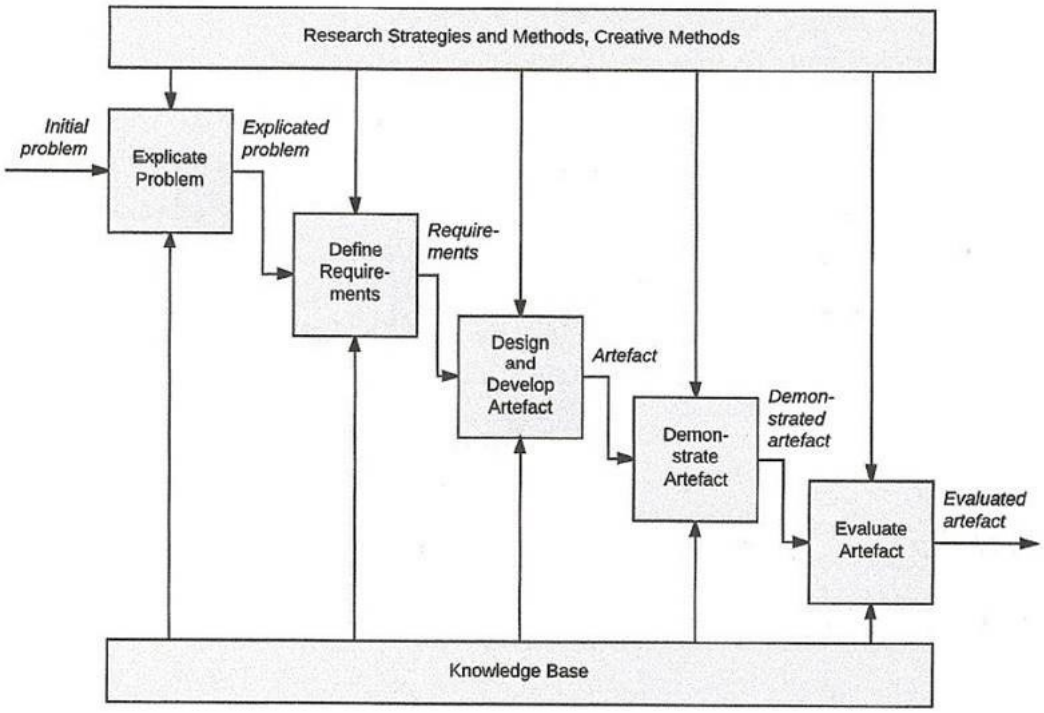

Figure 1: The design science process outlined by Johannesson and Perjons (2014, p. 82)

4. Earlier Development Projects

This study is a part of the project ViSpel, in the HEaD initiative, and builds upon two earlier HEaD projects on GBL, HistoTree and SPEDAT.

HistoTree

HistoTree was a two-year project, the purpose of which was to investigate the potential of using GBL in history education at Mid Sweden university. It aimed to study digital teaching methods and pedagogical tools relevant for the subject of history andthe advantages GBL may bring to students and teachers compared to traditional teaching methods. The technology tree concept was a particular focus. The project included literature studies (presented in Hellerstedt & Mozelius 2023), a survey of students' preferences in gaming (spring 2023; analyzed in Hellerstedt & Mozelius 2024), and a preliminary implementation of a GBL-based assignment written by students in the fall term of 2024.

SPEDAT

The SPEDAT project was a two-year educational development project carried out in a collaboration between Mid Sweden University, and the University of Gävle. SPEDAT is a Swedish acronym that can be translated as 'Games for computational thinking'. The overall aim of the SPEDAT project was to design, develop and evaluate an educational game in which players can learn about computational thinking and fundamental programming. Programming concepts have been implemented without alignment to any specific programming language. The current version of this game, *Programming in Valhalla*, has a Viking theme. Graphics and sound have been created with the use of generative AI. The first preliminary testing results were positive, but the game will undergo through two more test iterations during 2025. In the first round is a large-scale test to evaluate game mechanics and learning outcomes. The second round is a focus group evaluation, to assess the game's gender inclusiveness according to the guidelines presented in Mozelius and Humble (2022). When the described testing is completed, Programming in Valhalla should be deployed as a part of the virtual game lab.

5. Games in History Education

According to our previous findings, two major genres seem to be especially relevant for history education: role-playing games (RPGs) and strategy games. Hitherto, most research on game-based learning in history education has focused on the first category, strategy games. These come in many variations, but most prominent is perhaps the classic *Civilization* series (1991–2025), which in and of itself has attracted a significant number of studies. More generally, the focus has been on 4X games and, particularly, the technology tree mechanic, both of which

are, again, typically associated with *Civilization*. (Hellerstedt & Mozelius 2024; Squire 2003; Slocombe 2019; Ghys 2012) It is clear that such games have a definite number of strengths. They can be very successful in illustrating structural explanations on the societal level, such as the interplay between economy, politics and scientific and technological development. (Wainright 2014; Slocombe 2019; Hellerstedt & Mozelius 2023) Strategy games thus mirror one half of the academic study of history, i. e. social and economic history, with a focus on explanation and causality.

Less attention has been paid to the other important genre in previous research. Our recent study of the gaming preferences of students at Mid Sweden university however, pointed to RPGs as a popular and pedagogically relevant genre. According to our students' responses, such games promise to provide a different, yet complimentary, set of benefits to history education. They argue that RPGs will provide them with the opportunity to experience history, as it were, first-hand. A subjective experience of historical milieux, at best coupled with a focus on interpretation (e.g. of historical documents, in-game) is valuable for learning history in quite a different, but no less important way than the structural understanding afforded by strategy games. (Hellerstedt & Mozelius 2024)

6. Games in Programming Education

What makes GBL in programming special is that there are two different approaches to implementing the concept. One method is to play educational games on programming concepts (Olsson & Mozelius, 2017). In the second approach, students improve their programming skills by building their own designed games (Mozelius & Olsson, 2017). Preferably these two methods could be combined. This may be achieved with having last year students in project courses build the educational games that first year students play in introductory courses. Another often discussed topic of games for programming is about the choice between realism with real-world tasks, and a learning design with stimulating fantasy environments. The PhD thesis by Scott (2015), presents and discusses the idea of an introductory programming lab with fantasy role-play games. The underpinning idea being that fantasy role play can reinforce the real-world identity relating to the activity in the fantasy role.

The opposite is to go for the kind of 'kitchen sink realism' advocated in (Ljungkvist & Mozelius, 2012), with the idea of simulating the type of programming tasks that a student could meet in their future work life. A classic example of a gameplay based on hard and challenging work is the *Human Resource Machine* that was analysed in the study by Heithausen (2020).

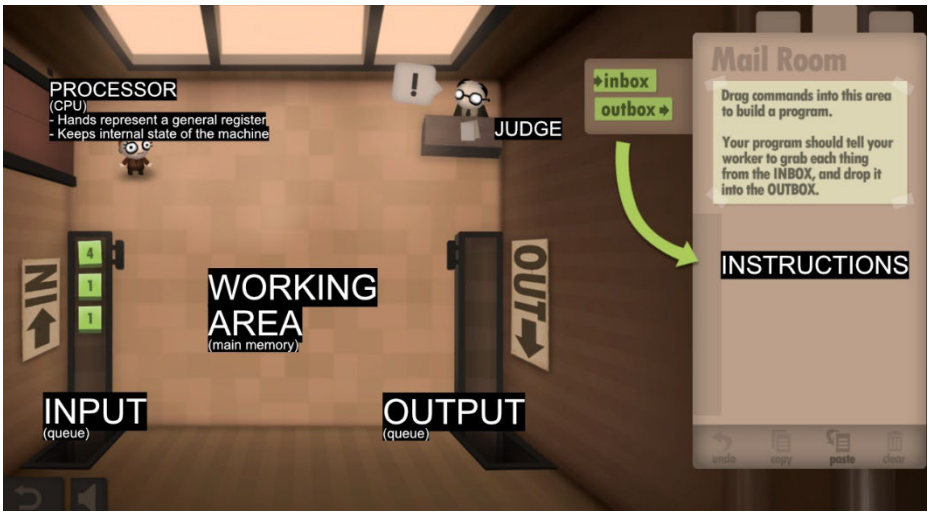

Figure 2: *Human Resource Machine* – a gameplay with concrete tasks and increasing difficulty levels

Moreover, his study discussed how the *Human Resource Machine* game aligned with Seymour Papert's idea of constructionism as a learning strategy. The gameplay has briefly been described as a game where:

> *"The player takes on the role of an office employee assigned with one task per level, 36 of which are included in the game. Each task involves both an input and output conveyor belt, the former supplying numbered or lettered boxes, as well as an assignment as to how the output should be related to the input" (Heithausen, 2020, p. 3)*

With an increasing difficulty and complexity for each level this is a challenging game that also raises the question about how too complex gameplay might scare students from further programming. On the other hand, and to

quote Papert (1998), *"Does easy do it?"*. Looking at the wide variety of educational games on programming and educational thinking there are huge differences in the difficulty levels, ranging from quite childish games such as *Lightbot* (Aedo Lopez et al, 2016) to the complex assembler programming tasks that can be found in the game *TIS-100* (Phipps, 2024). The pedagogical criteria for selecting games here should be the combination of constructionism and engaging games that create flow and an enjoyable learning process. Constructionism in the aspect of selecting games where real-world problems are explored by creative activities. Flow could be stimulated by providing a wide variety of games comprising content from fundamental computational thinking to advanced programming tasks with increasing complexity levels. A combination that is illustrated in Figure 2 where the given input should be processed to a specific output by instructions from the player. Instructions that are easy to put together at the initial levels, but complex and clearly challenging after the first 10 levels.

7. Ideas for a Virtual Game-Based Learning Lab

The ideas of constructionism and how to keep the players in the flow channel presented in the previous section are also valid for other subjects and game themes. While "Easy doesn't do it", a virtual lab must contain games that have a suitable level of challenges for the target group. With the idea of creating flow, motivation and happiness, the games should hit the flow channel in between the boredom of easiness and the anxiety generated by a too high level of difficulty (Csikszentmihalyi, 2013). On the other hand, this should not be based on gaming for the sake of gaming, and the games should have content that is aligned with the content and learning objectives of the courses where they are to be used. Another balance is the one between realism and fiction, that in introductory programming courses could be evaluated with games such as *Human Resource Machine* for realism (Heithausen, 2020), and the fantasy world created in *Code Quest* (Sällvin et al., 2024).

The design idea behind the *Code Quest* game also brings up the question of inclusion and how a game ought to be designed to attract both male and female players. Design factors such as narration, graphics and customization options should be considered. These factors are also important for immersion. The authors expect the high-quality graphics and the detail of the game *The Great Gambit* may contribute to a be successful implementation in history courses. The well-made graphics that could be found in Figure 3 below is a way to create immersion and to make players engage in game worlds with gameplay and content from eras in the past.

Figure 3: *The Great Gambit,* a gameplay set in the pre-World War I era with high-quality graphics and realistic details that stimulates immersion

Based on the principle that the two genres of history games complement each other, it follows that a selection of strategy games should be chosen, together with a selection of RPGs. For strategy games, the *Civilization* series may easily be included, through either use of an older (cheaper and more accessible) edition of the commercial game, or using *FreeCiv*, an open-source alternative with comparable content and game play. Similarly, the *Svea Rike/Europa Universalis* series (as recommended by our students in the previous study) is available in many versions and formats, making it easy to include. The above-mentioned *Great Gambit*, a Swedish-designed learning game for high school students, will complement these games.

For RPGs, the previous study of students' preferences in regard to games for history education (Hellerstedt & Mozelius 2024), has singled out a certain type of historical RPG. We therefore suggest including the commercial game *Pentiment* alongside the non-commercial game *Czechoslovakia 38–39: Assassination*, designed by Cyril Brom of Charles University (Prague). Together, these strategy and RPG games also cover different time periods in a reasonable way (world history, ancient to modern; medieval, early modern, modern).

8. Future Work

More important than the authors' opinions presented in this paper will be the feedback from the students playing the selected games. During the coming year some selected games will be evaluated in different university courses on history, computer science and artificial intelligence. Authors' intention is to present and discuss the

results of these evaluations at the ECGBL 2026 conference. We will also follow the game competition at the conference and include any games with content relevant for our game lab. Game effectiveness will be assessed in a mixed method approach with games involved in teaching and learning activities in various distance courses. Student feedback will be gathered from online gaming webinars, questionnaires and interviews. Quantitative data will be presented with descriptive statistics and qualitative data should be analysed thematically.

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Ethics declaration: This study did not involve any ethical considerations that needed clearance.

AI declaration: No Generative AI tools have been used in the creation of this paper.

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Designing a Role-Play Activity About Social-Emotional Learning for the Indian Context Based on the Integrated Design Framework for Playful Learning

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Abstract: The game design for social-emotional learning (SEL) activities is underexplored worldwide. In particular, there is little research on how to establish best practices for designing SEL games in India. SEL games are vital for children's development, focusing on understanding and managing emotions, building healthy relationships, and making responsible decisions. However, the current state of SEL in India faces several challenges. While a few educational institutions have begun integrating SEL into their curricula, the majority of others remain unaware or lack the resources to implement effective programs. To address this gap, we explored how we can implement game-based learning, in particular, the integrated design framework for playful learning (IDFPL), for SEL in the Indian context. Two pilot tests were conducted with Indian children to assess the appropriateness of such gameplay processes within the cultural context. Six master's students from an Indian university and eighty rural Indian children participated in the game pilot. We conducted four role-play activity sessions by 45 minutes each. The activity included icebreakers, emotional charades, and role-play exercises to encourage the expression and recognition of emotions. A validated Kids Empathy Development Scale (KEDS)-inspired design of this role-play activity in order to engage children to SEL practice and explore the ways to assess their empathy-related skills, including emotion recognition (affective empathy) and ability to understand and explain others' emotions (cognitive empathy). This paper discusses the non-digital design process for Indian rural schoolchildren to teach SEL, lessons learned from designing this game activity, and insights on incorporating affective and sociocultural components of IDFPL into the design process. Pilot tests indicated positive outcomes in enhancing relatedness, observational learning, goal orientation, motivation, interest, and self-esteem among participants. However, hierarchical dynamics between children and adults presented challenges in promoting agency, participatory learning culture, and open social interaction. Additionally, the study emphasizes the need for further empirical research using mixed methods to understand children's engagement with SEL games more deeply. It also suggests developing digital versions of the role-play game, creating a culturally tailored IDFPL for India, and providing guidelines for designing SEL games across diverse cultural contexts.

Keywords: Non-Digital games, Social-Emotional learning, India, Game design framework, Empathy

1. Introduction

Social-emotional learning (SEL) is a crucial aspect of child development. It helps individuals understand and manage emotions, build healthy relationships, and make responsible decisions (Lawlor 2016). There are still challenges with implementing SEL education in school curricula (Jones et al. 2017). Educational game researchers state that games can be used to help teach these skills in effective and engaging ways, using elements like role-play, social interaction, and feedback (Farber 2021). A growing body of research on SEL suggests that games could incorporate the expression of emotions (Nikolayev et al. 2016) to foster self-awareness, social interaction, and resilience. (Shrinivasa et al. 2018; Selman 2003; Hughes 2009; Hormek 2004; Norris 2003; Diamond 2012) Many SEL games include acting, guessing, and expressing emotions (Frey et al., 2019) to build emotional vocabulary and recognition skills (Hoing 1982). Such games may provide a safe space to explore emotions, foster empathy for others, and learn strategies to manage emotions and build relationships (Van Mechelen 2016; Joronen et al. 2011; Walker et al. 2019; Xavier et al. 2022; Craig 2016), which can lead to improving classroom behavior, reducing anxiety, and strengthening friendships (Webster et al., 2004). Indian education is only starting to move toward integrating SEL through playful activities (Chatterjee et al., 2020; Farber, 2021). While India's booming gaming industry holds potential for SEL development (Mukund et al. 2022), the scientific approach to tailoring the educational game design to the Indian context is under-explored. Kam (2009) conducted a study with Indian middle school children and found that the games designed in Western countries failed to match local children's understanding and needed alteration adapted to local social-cultural contexts (Kam 2009). De Jong suggests that there is a cultural impact on the dynamics of game scenarios, communication styles, problem-solving approaches, and emotional expressions. Traditional Indian games like Kabaddi and Ludo have the potential to promote valuable SEL skills through teamwork, communication, and

strategic thinking (Rohit 2013; Khan et al. 2016). This suggests that using culturally relevant game design and incorporating Indian context or art forms can improve engagement and learning (Kumar et al 2010).

Playing games has the potential to develop essential skills like problem-solving, especially for young children entering primary school (Akcaoglu 2014; Artut 2015; Nizaruddin et al.2017) For example, studies have shown success in using non-digital games with frameworks like ProSkiND to improve math skills in preschoolers (Anis et al. 2022). However, the majority of game design frameworks for learning are focused on cognitive aspects of education by considering learning goals, mechanics, and engagement (Martin 2018). In contrast, Plass et al. created a theoretical framework (IDFPL) that incorporates social interaction to enhance the learning experience (Plass et al. 2014). This framework considers cognitive (intellectual challenges), affective (emotions and motivation), and socio-cultural (social interaction and cultural context) aspects of learning. However, it was developed in the US and not in the Indian cultural context. Our paper focuses on addressing the research gap in establishing the practices for designing SEL games for the Indian sociocultural context. This paper shares 1) a description of the design process of a non-digital game for Indian rural school children to teach SEL; 2) lessons learned on designing this game; and 3) insights on how affective and social-cultural components of the IDFPL can be incorporated into such a design process. We specifically addressed the following research questions: 1) How should we design affective and social-cultural elements of role-play game activities to support SEL learning for youth in the Indian context? 2) How can we apply the IDFPL to design SEL games for children in rural India?

2. Methods

Design Process. We used the Integrated Design Framework for Playful Learning (IDFPL) (Plass et al. 2014) because it includes the game design process not only cognitively but also affectively and socio-culturally, which is the focus of our design research. As IDFPL is a flexible framework, we were able to apply it for a nondigital role-play game. Our design process was inspired by the SEL game design process conducted within the USA context by Muravevskaia et al. (2023). We intended to adapt this process to the Indian social-cultural context by engaging children in the co-creation of game scenarios. We chose charades as the primary play pattern, which is commonly known in India. We conducted 2 pilot tests with Indian children, which were facilitated by master's students and professionals from an Indian university. The goal of the tests was to ascertain the appropriateness of the game-play process for the cultural context. We observed participants and then asked them to share their feedback, insights, and potential challenges on how they envision this game being applied in an Indian school context. *In this paper, we focused on the design process and only discussed preliminary observations from the pilot tests; in-depth findings from our study will be discussed in subsequent publications.*

PARTICIPANTS. Six master's students from an Indian university and 10 professionals who worked in our lab participated in our game pilot. Also, there were about 80 rural Indian children who took part.

GAME DESCRIPTION. The game activity includes the following parts. *Part 1: Icebreakers:* This part aimed to establish rapport with the children and to prepare them to express and guess emotions. It included questions on their favorite game and why they like it, how they feel, how they understand how others feel, and the importance of knowing how others feel (Muravevskaia, 2023). *Part 2: Emotional Charades.* This part engaged the children in expressing and guessing emotions. *Part 3: Role-Play***. T**his part expanded emotional charades from a single to a team role-play activity and invited them to think of a scenario and the roles that would represent different specific emotions. After acting out their scenario in front of the audience, the children in the audience are asked to guess the emotions represented by each child, provide the reasons why they think so, and guess the scenario. The questions were inspired by the KEDS (Kids Empathy Development Scale) (Reid, 2013).

3. Design Framework Application and Discussion

To design the activity, we used the aforementioned Integrated Design Framework of Playful Learning (IDFPL) due to its inclusion of sociocultural and affective components, which are relevant to empathy (alongside cognitive components). We used all three parts of IDFPL (i.e., cognitive, affective, and social-cultural). To answer our RQs, we will discuss the affective and social-cultural aspects of the IDFPL, the ways we incorporated them into our game, our lessons learned, and insights on their application in the Indian context. Figure 1 summarized our discussion.

3.1.1 Affective engagement

MOTIVATIONS AND INTEREST. Motivation drives people's desire to play, interact, communicate, and connect with an experience Sparking curiosity and interest for the player can also help lead to better learning outcomes to help engage players; we chose a well-known, popular play pattern: charades. We also chose to engage players by incorporating collaborative aspects. Players needed to work together by acting out to express emotions as well as understanding what others tried to express. For example, we asked children to form a team of two, assigned emotions each of them would be presenting, and asked them to think of the scenario to act out in front of the others.

EMOTIONAL DESIGN (REPRESENTATION AND INTERACTION). Emotional design in IDFPL refers to the learning environment and how sounds, colors, characters, and game challenges help to convey belongingness, support, and camaraderie (Plass et al. 2014). Although a non-digital playful activity may not have established sounds or color palettes, we created emotional design through the tasks we provided. For instance, in the charade activity we devised, we encouraged players to take on characters such as We also established a sense of connection by having players take turns, act and perform for others, and perform as a group, representing a scenario they collaboratively chose.

GOAL INTERACTION. All games have goals and provide the means to reach those goals. Goals are integral to learning because they help us understand what outcome we need to reach and what success looks like. This helps learners continue to strive through challenges. In our game activities, the facilitators worked with the children to set goals (e.g., to show emotion so that others understand, to guess the emotion presented by others, and to be able to explain how they guessed it). We gradually increased the level of difficulty over time from basic to more complicated emotions and from single-player to teamwork-oriented exercises. Facilitators were saying things like, " Would you like to have a harder task to act out?" This helped to engage children by sparking their curiosity and desire to solve the challenges and by providing a space for agency and independent choices. Using the zone of proximal development approach, we gradually increased the difficulty During pilots and study sessions, we observed that students and children enjoyed following the activity. However, local children were only comfortable with the direct instructions on what exactly they should do.

SELF-EFFICACY AND SELF-ESTEEM. Self-efficacy is the sense that a person has that they are capable of learning a topic or skill, and self-esteem refers to an overall sense of worth and competence. Self-efficacy connects not only to one's belief in their ability to succeed, but also research has suggested that it affects whether a person can actually succeed. Higher self-efficacy and self-esteem increase motivation, the assurance that one can handle increasingly complex tasks, and the willingness to take on a novel learning experience. We used a familiar play pattern (charades) to provide an immediate sense of comfort to the students. We used simple to increasingly complex challenges so players would feel a sense of mastery as they progressed through the game. We observed that children enjoyed the challenges and progressed well through the tasks (e.g., nodded to the harder tasks, enthusiastically showed the new emotions assigned, and actively guessed).

3.1.2 Sociocultural engagement

SOCIAL INTERACTION DESIGN. This element focuses on designing a learning environment with positive, caring, and empathetic social interactions. It is important to sustain an empathetic culture so that the players are not only engaged in the play but also meet the learning objectives (i.e., gaining empathy skills). We designed the activity to integrate social interactions, peer support, facilitator support, and collaborative play. The facilitators also encouraged constructive peer-to-peer feedback by first modeling examples and caring words and then kindly prompting students to share their ideas, feedback, and support. Children positively perceived kind words and examples; however, we observed that children did not show support and feedback toward each other. It might be caused by cultural and school norms to focus only on the teacher and not peers. We should further explore how to promote social support among children within an Indian cultural context.

3.1.3 Social context

This element acknowledges that the social context of learning matters and how one learns information, skills, and attitudes affect how one practices them (Plass et al. 2014). It suggests that playful learning contexts help enable players to develop social connections and a sense of belongingness, which helps cultivate a community of practice (Plass et al. 2014). The social context for our playful activity included: 1) encouragement for everybody to sit in the circle (the facilitator and children) without dividing roles so all see each other as equals; 2) encouragement for children to collaborate in pairs on the scenario that they are going to perform for others.

This process was intended to improve social connectedness and collaboration. We observed children being able to collaborate well in pairs; however, we noticed that there still was a sense of hierarchy between children and adults. We plan to continue iterating on the design that better matches our intent while acknowledging existing social constraints.

PARTICIPATORY LEARNING CULTURE. In a participatory culture (cite Jenkins), through direct engagement with a community in different situations, one learns the norms, values, and views of that community. Our intention for the activity was to help players directly engage with each other as well as revise and adapt the game to their own lives, interests, and ideas. The players were invited to be co-designers (e.g., collaboratively decide on new scenarios and ways to present them, communicate while expressing and guessing emotions). However, we observed that there were challenges with establishing collaboration with each other in that children were mainly comfortable communicating through the facilitator only. We plan to explore ways to find culturally sensitive ways to address this, for example, through digital facilitation or increasing the comfort of children around the facilitator.

SOCIAL ASPECTS OF AGENCY. Agency is the ability of a learner to have control and ownership over their learning experience and to decide on how to work together and how to journey through an experience. This helps to give a learner a sense of responsibility and creative control over their learning. Through the activity, we gave learners choices within constraints (e.g., to choose their style and performance in portraying emotions and to tell their own stories). We hoped that children would feel a sense of control over how they wanted to express emotions. However, children only followed the facilitator's commands and did not express readiness to perform independently.

OBSERVATIONAL LEARNING. The keyway to learn is by watching others and observing how they act and engage in different roles and skills, for instance, in how others perform an emotion or express a feeling through dramatic play Watching others gives one insight into how one might also contribute when it is their turn. We had hoped that the facilitators would act as role models and mentor the kids through the game so that children could follow and eventually generate their own ideas. We also had planned that children would observe peers expressing different emotions and learn from each other. Overall, this was effective in that the facilitators provided examples like performing the first expressions of emotion or by sitting on the floor, showing where and how the children needed to sit. The children were also able to see other children acting out different emotions, which provided them with the varied ways we can express emotions. For instance, each child expressed sadness in different ways, which encouraged variations of expression. Also, one child started using body language and gestures, which encouraged other children to do so. Watching others gives one insight into how one might also contribute when it is their turn. We had hoped that the facilitators would act as role models and mentor the kids through the game so that children could follow and eventually generate their own ideas. We also had planned that children would observe peers expressing different emotions and learn from each other. Overall, this was effective in that the facilitators provided examples like performing the first expressions of emotion or by sitting on the floor, showing where and how the children needed to sit. The children were also able to see other children acting out different emotions, which provided them with the varied ways we can express emotions. For instance, each child expressed sadness in different ways, which encouraged variations of expression. Also, one child started using body language and gestures, which encouraged other children to do so.

RELATEDNESS/SELF-PERCEPTION. This concept relates to inclusion and the belongingness we feel in social groups. When a person feels valued by a community and has a sense of belongingness, they are more likely to perform better, feel safer, experiment more, take more risks, and have a greater sense of self-perception and self-efficacy. We aimed to implement this in our role-play game activity by using positive reinforcement (i.e., cheering on players for participating) and team achievements (i.e., inviting reflection and positive self-assessment). We found that this worked well in that the majority of the students were willing to actively participate (i.e., raised hands to ask to act out the next turn; verbally asked to do so; smiled, laughed, and clapped as a way to cheer each other up as a team).

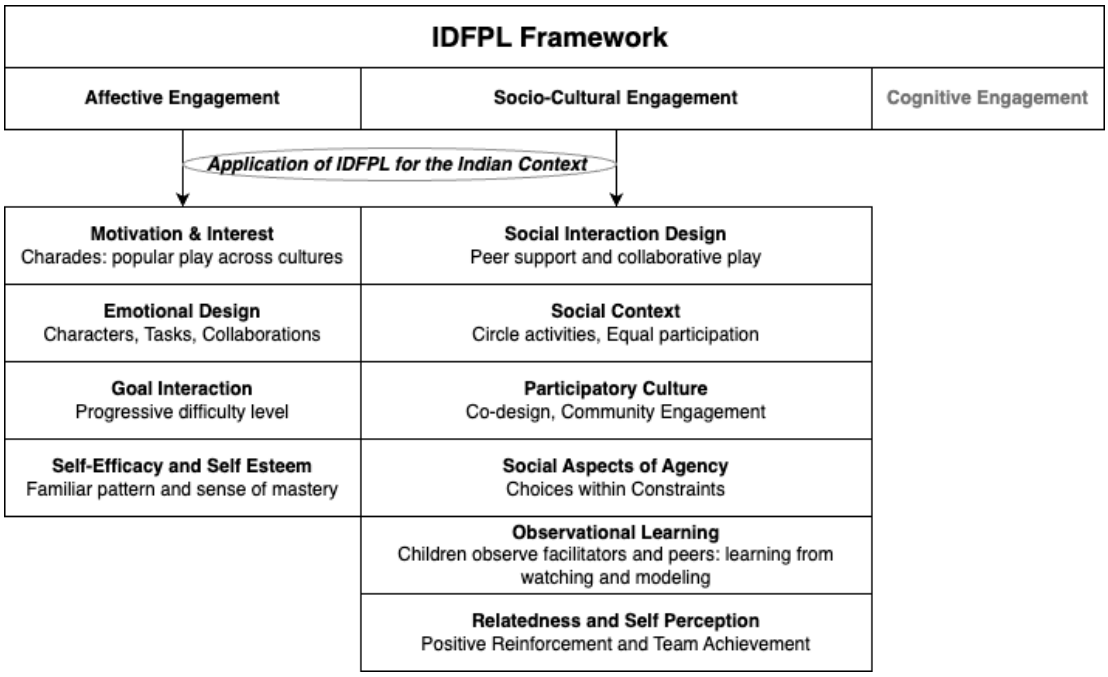

Figure 1: IDFL Framework— Indian Charades Game Application

3.1.4 Design implications

The key design implication from our study for game-based learning researchers and game designers is the importance of culturally responsive and affectively engaging game mechanics when developing SEL experiences. The study demonstrates that integrating familiar play patterns like charades, scaffolding emotional complexity, and fostering peer collaboration can enhance motivation, self-efficacy, and emotional expression. However, it also highlights cultural challenges such as hierarchical classroom dynamics and limited peer-to-peer interaction, which can hinder agency and participatory learning. Therefore, designers should prioritize culturally sensitive facilitation strategies, such as modelling empathetic behaviour and gradually shifting control to learners, to foster a more inclusive and empowering learning environment. Additionally, embedding observational learning and social reinforcement mechanisms can support emotional development and community building, especially in contexts where direct peer engagement is less common. These insights underscore the need for iterative, context-aware design processes that balance structure with learner autonomy.

4. Conclusion

This paper opens the discussion on the current research gaps in design methods of SEL game experiences within Indian cultural contexts. To initiate this exploration, we designed a role-play activity for Indian youth based on the IDFPL framework. In this paper, we described how we applied the affective and sociocultural elements. During pilot tests, we observed some effective aspects of the application (i.e., relatedness, observational learning, goal orientation, motivation and interest, and self-esteem) while also observing challenges with other aspects (i.e., agency, participatory learning culture, and social context). We suggest the following next steps: 1) conducting in-depth empirical mixed-methods studies on children's understanding and engagement with our non-digital SEL role-play game to evaluate further each of the elements (cognitive, affective, social-cultural) and explore the reasons why some aspects are effective; 2) using this to then design digital games based on the emotional charades game in single as well as multiplayer modes; 3) exploring ways to create an integrated design framework for SEL specifically for the Indian context; 4) devising recommendations on considerations for designing and implementing SEL games in different cultural contexts.

Ethics Declaration: Ethical clearance was obtained from the Office of the Institutional Human Ethics Committee (IHEC), with approval number 055_IEC_SSBS_AL-CWEGE-AVV_055.

AI Declaration: This paper was written without using AI tools and grammar check was obtained using Grammarly.

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Evaluating Cybersecurity Awareness in Employees Using Gameplay: Data and Machine Learning Models

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Abstract: Cyber-attacks continue to pose persistent challenges within professional environments. Human error remains a critical vulnerability, frequently leading to security breaches through credential misuse and social engineering tactics. Traditional cybersecurity training approaches often lack effectiveness when not adapted to the dynamic threat landscape. This study presents *CyberEmployee*, a serious game developed to enhance cybersecurity awareness among employees through interactive learning. The objective is to assess employees' awareness levels by analysing gameplay data using machine learning techniques. Data were collected via the game's integrated scoreboard, which tracked user behaviors and performance patterns. The resulting dataset was analysed using multiple machine learning algorithms, including Random Forest, Support Vector Machines (SVM), XGBoost, K-Nearest Neighbors (KNN), and Logistic Regression. Experimental results demonstrated accuracy rates ranging from 86% to 100% and F1-scores from 75% to 100%. The highest performance—100% accuracy and 100% F1-score—was achieved using the Random Forest and XGBoost models. This analysis indicates that ensemble learning methods outperform other classifiers in employee classification. Furthermore, gameplay duration and player score were identified as key predictive features. These findings indicate the potential of serious games combined with machine learning for data-driven cybersecurity training frameworks.

Keywords: Cybersecurity awareness, Cybersecurity training, Gamification, Machine learning

1. Introduction

Cybersecurity threats are becoming complex, posing significant challenges to organisations across various sectors. Despite advancements in technical defenses, human error remains a leading cause of security breaches, often due to social engineering, credential misuse, and poor security awareness (Arif et al., 2025). Traditional cybersecurity training approaches—based on static content such as presentations or videos—have proven insufficient in engaging users and adapting to the evolving threat landscape. These methods lack interactivity, fail to simulate realistic attack scenarios, and often do not promote the cognitive and behavioral changes needed to prevent breaches. This research investigates the effectiveness of modern cybersecurity training methodologies, with a specific focus on serious games as tools for enhancing users' cybersecurity preparedness. The study focuses on the evaluation of *CyberEmployee*, an interactive serious game developed to address the limitations of traditional cybersecurity training approaches. In response to the growing demand for more effective cybersecurity training, organisations are adopting human-centric approaches that emphasize user engagement, behavior modification, and proactive awareness (Deibert, 2018). One such approach is CyberEmployee, a training game designed to enhance employees' ability to detect threats and respond to incidents through simulated cyber scenarios (Nkongolo, 2024). CyberEmployee supports the development of long-term cybersecurity competencies by promoting situational awareness in realistic contexts. Although human-centric training methods show considerable promise, their practical implementation presents several challenges. Organisational readiness, compatibility with existing IT infrastructure, resource constraints, and the need for active stakeholder involvement are critical factors that can influence the success of such training. Growing interest has emerged in the application of various learning theories for cybersecurity training, primarily due to their capacity to provide interactive and engaging learning experiences. These theories form the foundation for designing educational games that enhance user comprehension. These approaches help learners actively construct knowledge through problem-solving, and real-time decision-making. As demonstrated in recent studies, the integration of learning theories not only improves cybersecurity awareness but also supports behavior change and skill acquisition, making them essential for developing effective human-centric training programs. Chattopadhyay, Maschinot, and Nestor (2021) analyse several popular cybersecurity educational games and *Capture the Flag* (CTF) platforms using four key benchmarks: the CSEC2017 guidelines, the Cybersecurity Assessment Tools (CATS), NSA GenCyber concepts, and the NICE framework. Their findings illustrate how each game aligns with curricular domains, core cybersecurity concepts, and specialized skill sets. This analysis offers guidance for educators and practitioners, enabling informed selection of games and supporting gap analysis for curriculum development and training strategies. While the study do not state a specific learning theory, it implicitly supports *constructivisim*. Tempestini et al. (2024) explored a gamified

training program aimed at increasing cybersecurity awareness among young adults. The study is grounded in *cognitive learning* theory, emphasizing mental processes such as problem-solving and decision-making. The tactical gaming approach proved effective in enhancing participants' understanding of cybersecurity concepts. Nevertheless, the study faced limitations, including a small sample size and broad content coverage, which may have diluted the effectiveness in addressing specific cybersecurity topics. In light of the limitations of traditional cybersecurity training methods and the growing need for interactive learning tools, this study explores the potential of CyberEmployee in enhancing cybersecurity awareness. The research is guided by the following question: *How can employee cybersecurity awareness be effectively evaluated through gameplay data using machine learning models?*

2. Related Work

Tokmak (2023) evaluated cybersecurity awareness among students using machine learning. After applying descriptive statistics, several models were used to classify awareness levels as low, moderate, or high. Most students showed moderate awareness, with limited knowledge of phishing attacks. Gender differences were minimal, though female students showed greater concern for data integrity. IT students displayed higher awareness due to their coursework. Multilayer Perceptron (MLP) and Support Vector Machine (SVM) achieved the best classification performance, demonstrating the effectiveness of machine learning in assessing cybersecurity awareness. Rismayanti (2024) conducted a study to predict online gaming behavior using machine learning techniques. A dataset from *Kaggle* containing player demographics and in-game metrics is employed to forecast player engagement levels. The study utilised the Gaussian Naïve Bayes (GNB) algorithm within a supervised learning framework and evaluated model performance using accuracy as the primary metric. Results demonstrated the GNB effectiveness in predicting player engagement, but the study acknowledged limitations related to resource constraints, including limited access to technology and lack of technical expertise. Kuna (2024) explored the application of machine learning techniques to predict the popularity of video games by analysing patterns in player data. The study employed the K-Nearest Neighbors (KNN) algorithm to forecast player trends, aiming to improve user experience (UX). Although it followed a supervised learning approach, the evaluation metrics were not specified. Smerdov et al. (2023) investigated an AI-enabled approach to predicting *eSports* player performance using data collected from sensors. The study employed Convolutional Neural Networks (CNNs) with regression metrics used for evaluation. The results indicated strong potential for using sensor data to forecast in-game player performance. Nevertheless, it lacked detailed information on specific algorithms used, as well as comprehensive evaluation metrics, which limits the ability to fully assess the model's reproducibility (Table 1). Syed et al. (2020) developed a video recognition system based on a CNN model to digitize the *blackjack* game by detecting players in real-time, with the goal of constructing accurate player profiles. The system, rooted in supervised learning, achieved approximately 97% accuracy. Despite these promising results, the difficulty of replicating the variability of real-world settings within a controlled environment impacted the model's performance. Table 1 shows a comparative analysis of various studies that explore the integration of machine learning and gamified approaches in cybersecurity training.

Table 1: Comparative analysis of studies on gaming and cybersecurity training

Author	Algorithm	Metrics	Results	Limitations
Syed et al. (2020)	CNN	Accuracy	95% Accuracy	May not reflect real-world variability
Smerdov et al. (2023)	CNNs	Regression	Strong prediction	Lack of evaluation results
Tokmak (2023)	SVM, MLP	Accuracy	98% MLP Accuracy and 95% SVM Accuracy	Dataset limited to university students
Kuna (2024)	KNNs	Not specify	UX understanding	Limited comparative analysis
Rismayanti (2024)	GNB	Accuracy	Effective player prediction	Ressource constraints
Nkongolo, Sithole, and Sewnath (2025)	Random Forest	F1, ROC	100 % ROC AUC	Replayability
This Study	XGBoost, SVM, Random Forest	Accuracy, Precision, Recall, F1, ROC	100% XGBoost Accuracy	Limited generalizability

The most widely applied approach in gaming analytics is machine learning, which has been employed in numerous studies to predict player engagement, analyse game popularity, and assess in-game performance (Table 1). Some of these studies utilise sensor data to evaluate player behavior, while others rely on demographic and in-game metrics to classify engagement levels. For instance, *DotaGame* demonstrates the effectiveness of machine learning models in outcome prediction, though its findings may not be generalizable (Akhmedov and Phan, 2021). Similarly, the controlled experimental conditions used in Ghazali et al. (2023) ensured high accuracy but limited the ability to capture the variability of real-world contexts. Each study employed different methodologies, algorithms, and evaluation metrics—some achieving high accuracy using deep learning techniques, while others lacked sufficient methodological transparency, making direct comparisons difficult (Table 1). This study builds on earlier work by Nkongolo, Sithole, and Sewnath (2025), which showed that gamification effectively improved students' cybersecurity awareness. The current study extends Nkongolo, Sithole, and Sewnath (2025)'s research by focusing on employees rather than students, offering more practical insights into how the game can enhance cybersecurity skills in real workplace settings. Rather than examining isolated gameplay metrics in controlled environments, the research analyses employees actions within dynamic and uncontrolled real-world scenarios. The proposed approach incorporates a wider range of gaming data and employee behavior indicators, making it more applicable to machine learning analysis (Table 1).

3. CyberEmployee Gameplay

The CyberEmployee game is played over 13 rounds on a virtual board (Figure 1). Let $B = \{b_1, b_2, b_3, \dots, b_{13}\}$ represent the sequence of rounds in the game. In each round b_t (where t ranges from 1 to 13), both players make a move: $m_t^A \in A$ denotes the attacker's chosen token at round t, and $m_t^D \in D$ represents the defender's response token at round t. Each round is represented as a pair: $b_t = (m_t^A, m_t^D)$. And the judging agent (J) evaluates the effectiveness of each move pair using a reward function (1).

$$J(m_t^A, m_t^D) \rightarrow (r^A, r^D) \quad (1)$$

where:

$r^A \in \{0,1\}$ is the reward for the attacker and $r^D \in \{0,1\}$ is the reward for the defender. These rewards are assigned as (1, 0) if the attacker's move is successful and the defender fails to counter. (0, 1) if the defender's move successfully counters the attacker, and (0, 0) if neither player selects an optimal move (Table 2). The total score for each player is computed by summing their respective rewards across all rounds (2):

$$R^A = \sum_t J(m_t^A, m_t^D)_1 \quad (2)$$

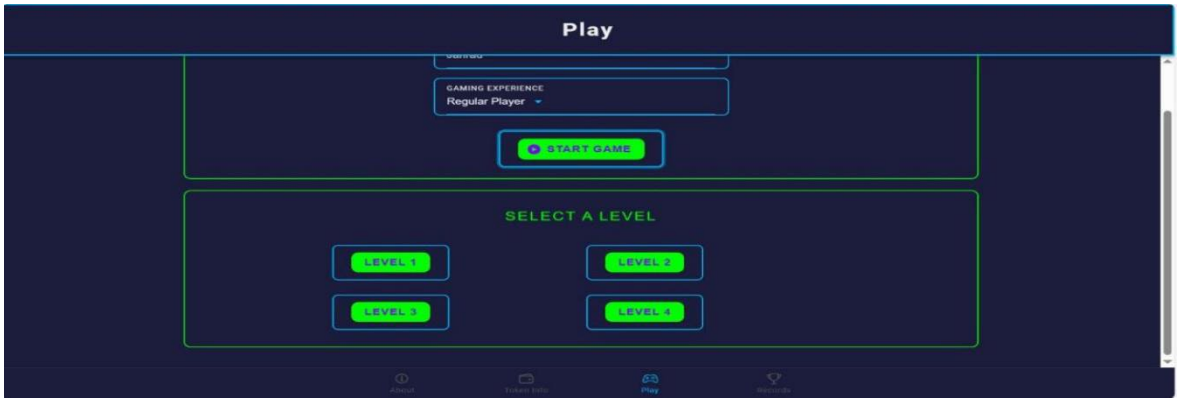
$$R^D = \sum_t J(m_t^A, m_t^D)_2 \quad (2.1)$$

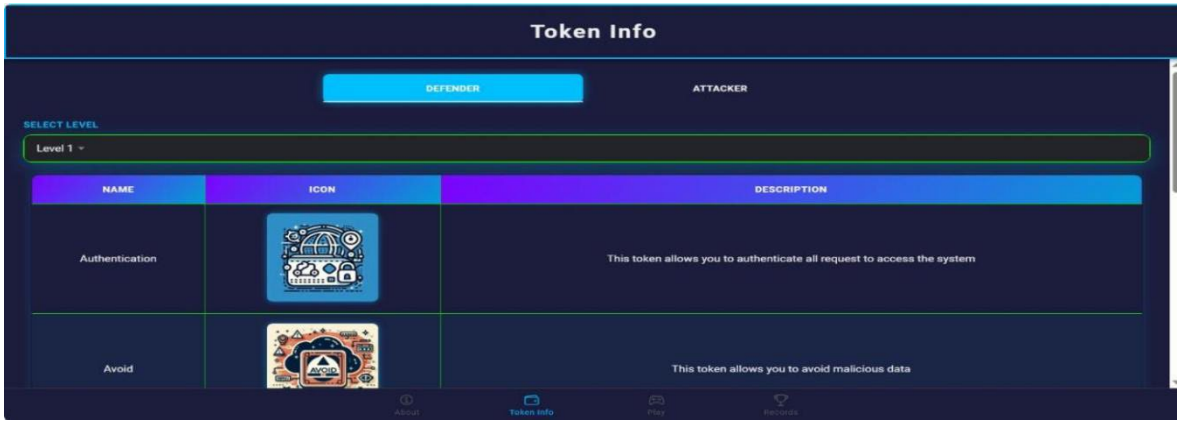
where $J(m_t^A, m_t^D)_1$ and $J(m_t^A, m_t^D)_2$ denote the attacker's and defender's rewards respectively for round t.

Table 2: Token pair scoring matrix

Attacker Token	Attacker Strategy	Defender Token	Defender Strategy	Score (A:D)
A1 - Email	Malicious e-mail	D1 - Denying	Block/deny access	0 : 1
A2 - Phone	Malicious phone call	D2 - Identification	Verify identity	0 : 1
A3 - Password	Stolen password	D3 - Upload	Upload controls	1 : 0
A4 - Click	Phishing link	D4 - Avoid clicking	Refuse to click unknown links	0 : 1

The game ends when all 13 pairs of tokens have been placed on the board. The final outcome is determined as $R^A > R^D$ if the attacker wins, $R^D > R^A$ if the defender wins, and $R^A = R^D$ if the game is a draw (Figure 1).


Play
GAMING EXPERIENCE
Regular Player
START GAME
SELECT A LEVEL
LEVEL 1
LEVEL 2
LEVEL 3
LEVEL 4


Token Info
DEFENDER
ATTACKER
SELECT LEVEL
Level 1
NAME
ICON
DESCRIPTION
Authentication
This token allows you to authenticate all request to access the system
Avoid
This token allows you to avoid malicious data

Token Info
DEFENDER
ATTACKER
SELECT LEVEL
Level 1
NAME
ICON
DESCRIPTION
Data
This token represents malicious data
Email
This token represents malicious email

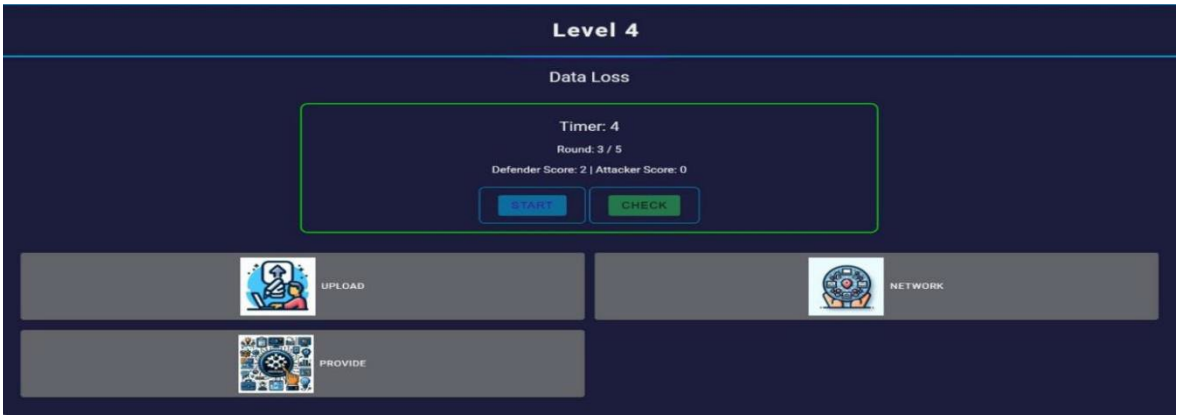

Level 4
Data Loss
Timer: 4
Round: 3 / 5
Defender Score: 2 | Attacker Score: 0
START
CHECK
UPLOAD
NETWORK
PROVIDE

Figure 1: Overview of CyberEmployee level selection interface, token information, gameplay snapshot (Level 4, Round 3 of 5), and corresponding scoreboard records

Each player chooses a strategy that determines the sequence in which they place their tokens. Let $\sum^A$ be the set of all permutations of attacker tokens and $\sum^D$ be the set of all permutations of defender tokens (Figure 1). A strategy is defined as a function $\sigma^A: \{1,2,\ldots,13\} \rightarrow A$ or $\sigma^D: \{1,2,\ldots,13\} \rightarrow D$ where each token is used exactly once. An optimal strategy σ^* maximizes a player's expected cumulative score against an opponent's strategy. Each attacker strategy (A_i) has an ideal defending strategy (D_j) mapped based on common cybersecurity best practices. The CyberEmployee game unfolds over 4 levels, each denoted L_i for $i = 1, 2, 3, 4$, with each level consisting of 5 rounds, totaling 20 rounds (Figure 2). Each round is determined by a reward function $J(m_t^A, m_t^D) \rightarrow (r^A, r^D) \in \{0,1\}\, x\, \{0,1\}$. As levels progress, the number of effective (i.e., winning) defender tokens decreases while attacker options increase (Figure 2). Let $W^{D(i)}$ denote the number of winning defender tokens and $W^{A(i)}$ the number of winning attacker tokens at level L_i. Then, the transition obeys (2.2).

$$W^{D(1)} > W^{D(2)} > W^{D(3)} > W^{D(4)} >, and\ W^{A(1)} < W^{A(2)} < W^{A(3)} < W^{A(4)} < W^{A(i)} \quad (2,2)$$

This reflects a growing asymmetry, where $|D_i|$ decreases and $|A_i|$ increases, adding pressure on the defender (Figure 2). Each strategy is a bijection $\sigma^A: \{1,2,\ldots,20\} \rightarrow A$ and $\sigma^D: \{1,2,\ldots,20\} \rightarrow D$, where players select tokens without repetition. The reduction in $W^{D(i)}$ across levels reduces the defender's available counter-strategies, making optimal play increasingly difficult.

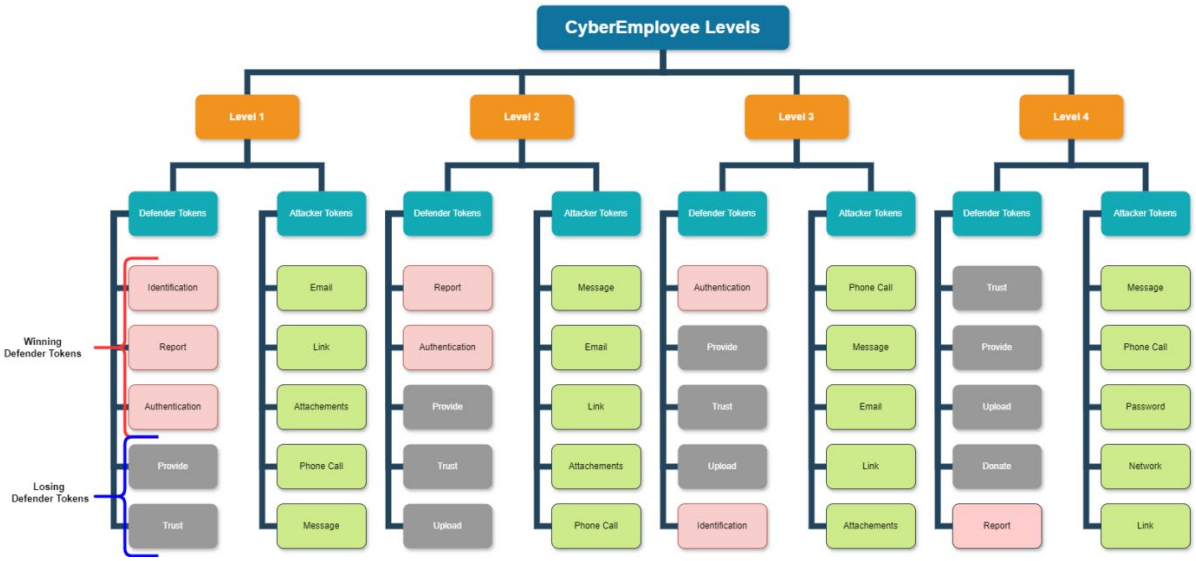


Figure 2: CyberEmployee Levels

4. Methodology

The study frameworks are illustrated in Figure 3 and Figure 4. The process begins with the data collection phase, in which employees play the CyberEmployee game to generate data (Figure 3). Participants from an IT organisation voluntarily engaged in gameplay after signing informed consent forms. Ethical clearance was obtained from the affiliated institution prior to data collection.

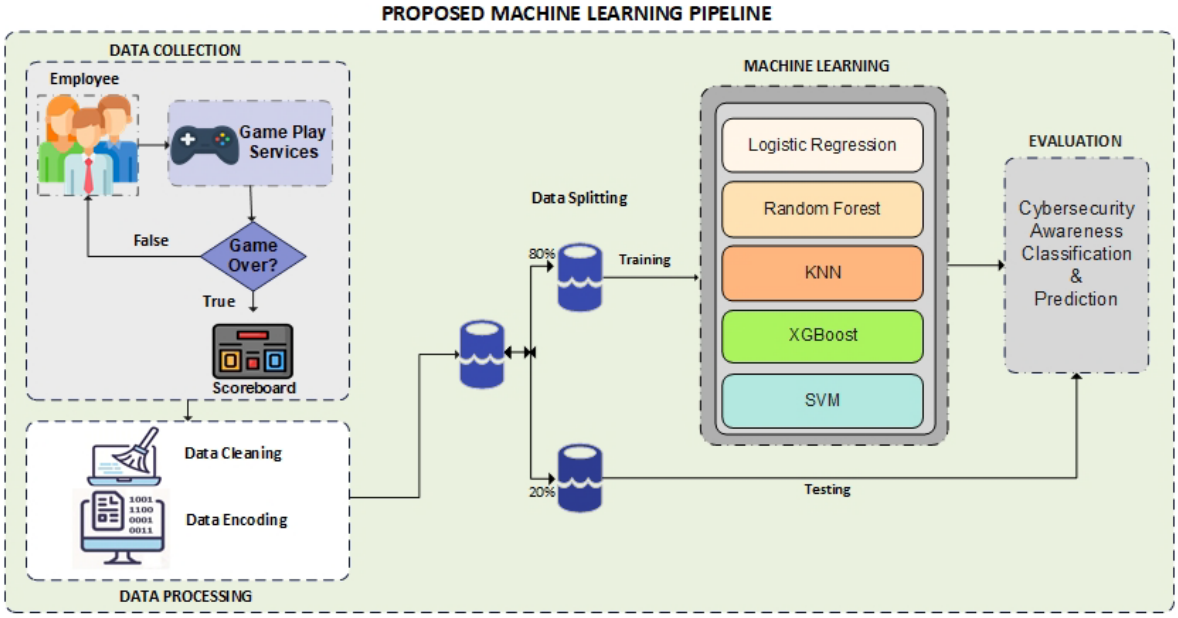


Figure 3: The proposed machine learning pipeline

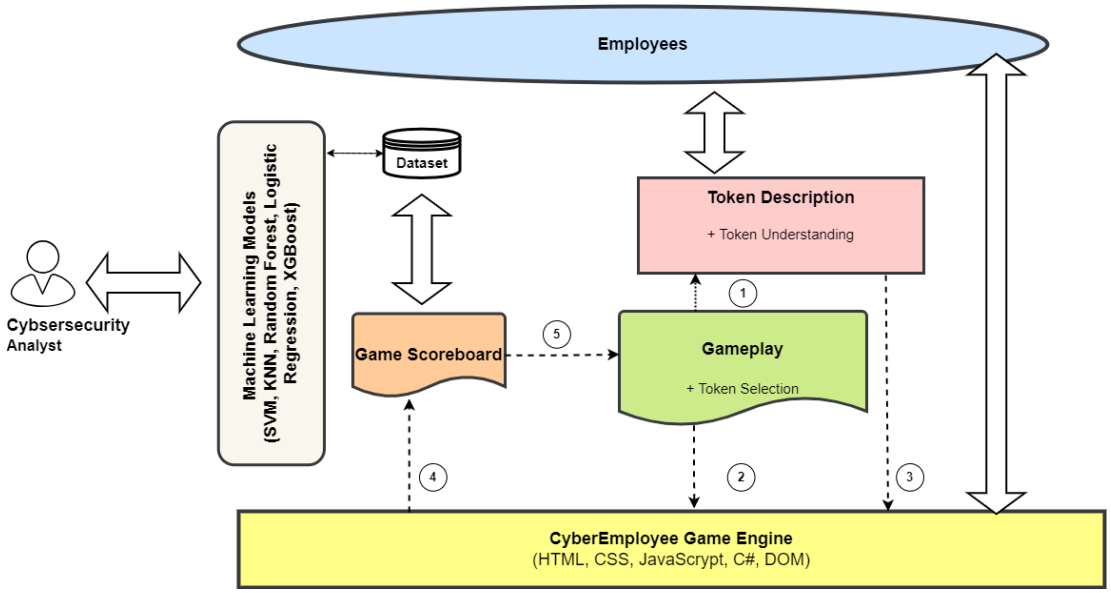


Figure 4: Data collection steps

Upon completion of the game, participant performance levels were automatically classified into beginner, intermediate, and expert tiers, as recorded on the CyberEmployee scoreboard (Figure 1). This data is exported in CSV format for further processing (Figure 4). The second phase involved data pre-processing to ensure data quality. In the third phase, the dataset is encoded using *One-Hot Encoding* to convert categorical variables into a machine-learning-friendly format (Figure 4). The resulting dataset is then split into training (80%) and testing (20%) subsets (Figure 3). Five supervised machine learning algorithms—Random Forest (RF), Support Vector Machines (SVM), XGBoost, K-Nearest Neighbors (KNN), and Logistic Regression (LR) (Figure 4)—were trained and evaluated to classify and predict employee cybersecurity awareness levels (Horvat and Job, 2020). Finally, the performance evaluation phase compared the models using metrics such as accuracy, precision, recall, F1

score, and receiver operating characteristic (ROC) curves (Horvat and Job, 2020), with the goal of identifying the most effective algorithm.

5. Results

In this experiment, the defender (employee) competed against the attacker (a computer program). A comparative analysis of machine learning models revealed that the Random Forest classifier accurately identified 56 instances as defenders patterns and classified only 1 gameplay as a draw (Figure 5). Moreover, this algorithm effectively predicted cybersecurity skill levels, classifying 53 employees as beginners, 32 as experts, and 15 as intermediate (Figure 5). These results suggest that employees in this organisation demonstrate strong cybersecurity awareness. In contrast, other algorithms—such as KNN exhibited higher rates of misclassification in both defender identification and skill level prediction (Figure 6). Figure 7 illustrates the key features influencing the model's predictions. The game outcome (Winner) and the employee identifier (Nickname) exhibit minimal impact on the classification results. In contrast, the most influential factors are the employee's performance score (DefenderScore), the duration of gameplay (Time (sec)), and the computer's performance (AttackerScore). These features play a central role in shaping the model's ability to accurately predict cybersecurity skill levels of the employees (Table 3 and Figure 8). This suggests that the game is capturing meaningful behavioral signals that reflect employee's decision-making quality and situational awareness during gameplay. The low importance of superficial features like Outcome (Winner) and Identifier (Nickname) reinforces that the model is not biased by outcomes or identity, but by in-game behavioral metrics (Figure 7).

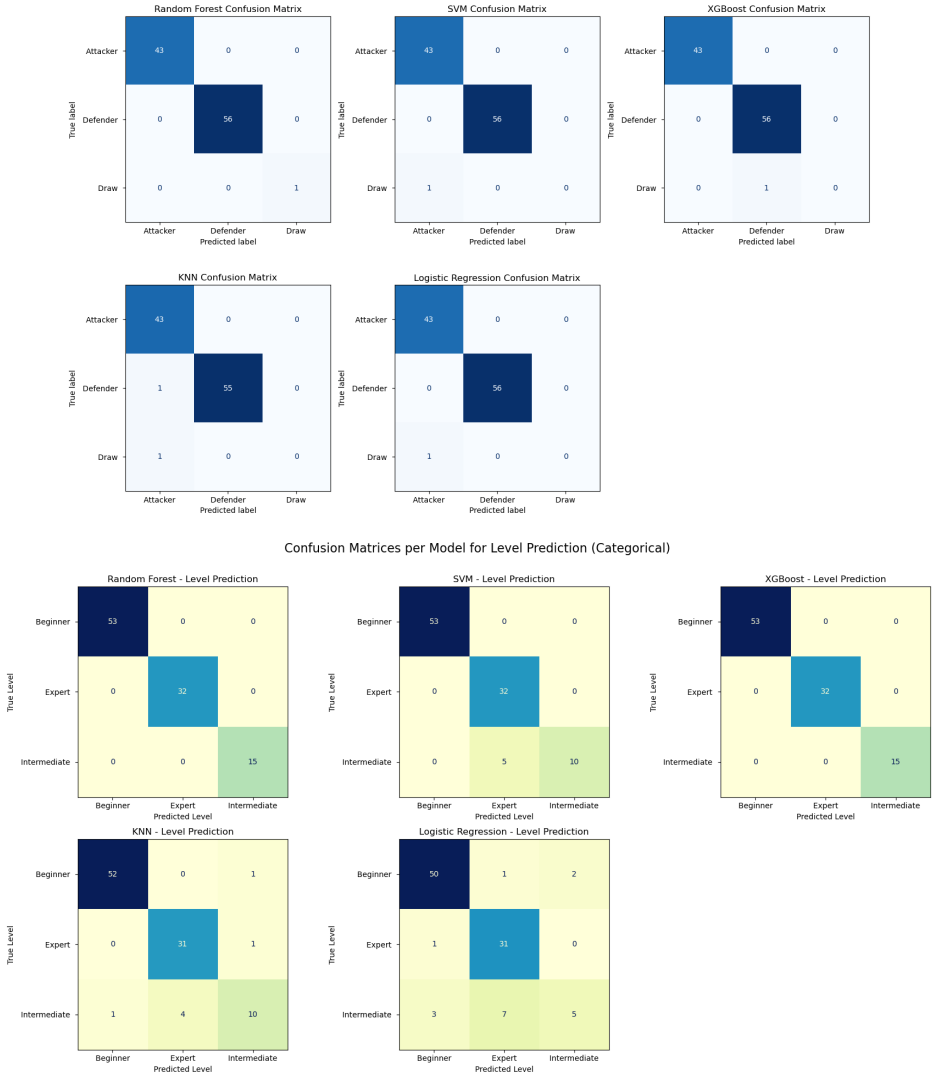


Figure 5: Overall machine learning results

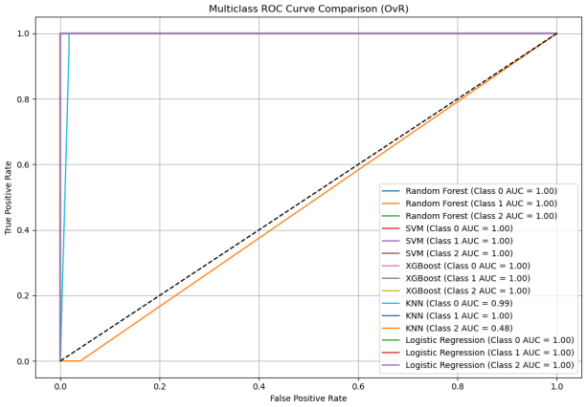


Figure 6: The ROC curve at various threshold settings

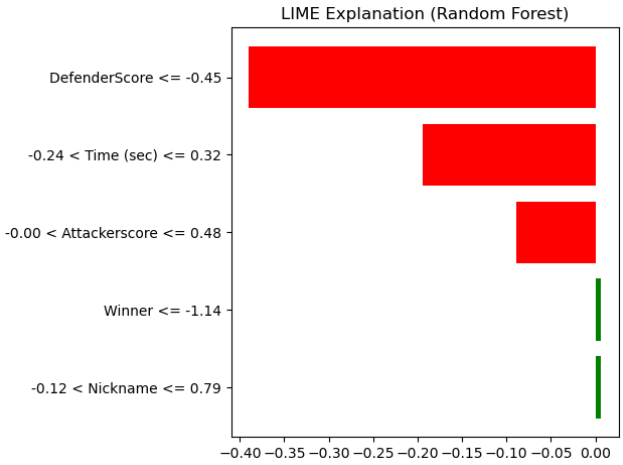


Figure 7: Features influencing the model's prediction

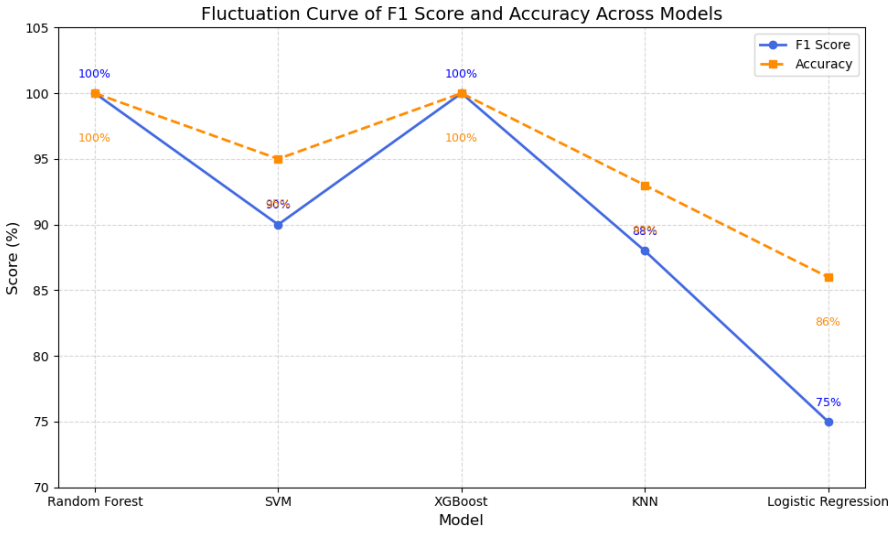


Figure 8: Each model's performance

Features such as DefenderScore, Time, and AttackerScore are the most influential, reflecting genuine cognitive and strategic engagement during gameplay. This supports the game's role as both an assessment and training tool, validating CyberEmployee as a practical approach to reducing human-centric cybersecurity risks.

Table 3: Comparative analysis of machine learning models

Model	Accuracy	Precision	Recall	F1 score	ROC AUC
Random Forest	100%	100%	100%	100%	100%
SVM	95%	95%	88%	90%	99%
XGBoost	100%	100%	100%	100%	100%
KNN	93%	90%	87%	88%	98%
Logistic Regression	86%	81%	74%	75%	97%

Figure 9 illustrates the overall distribution of participant responses across all cybersecurity awareness categories in the CyberEmployee game survey. The chart highlights that a majority of participants responded with "Strongly Agree" and "Agree", together accounting for over 80% of total responses. This positive feedback demonstrates the effectiveness of CyberEmployee in promoting key human-centric cybersecurity skills such as threat awareness, problem-solving, and self-reflection (Figure 10). Conversely, negative responses such as "Disagree" and "Strongly Disagree" were minimal, reinforcing the game's positive impact on employee cybersecurity awareness.

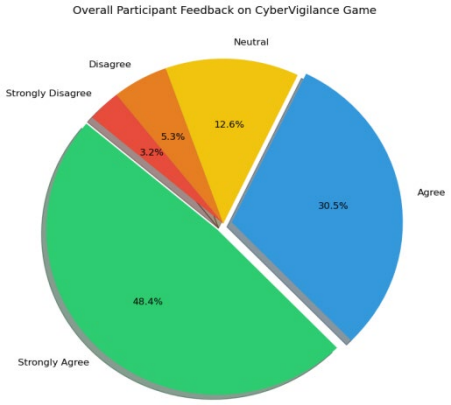


Figure 9: Overall survey response

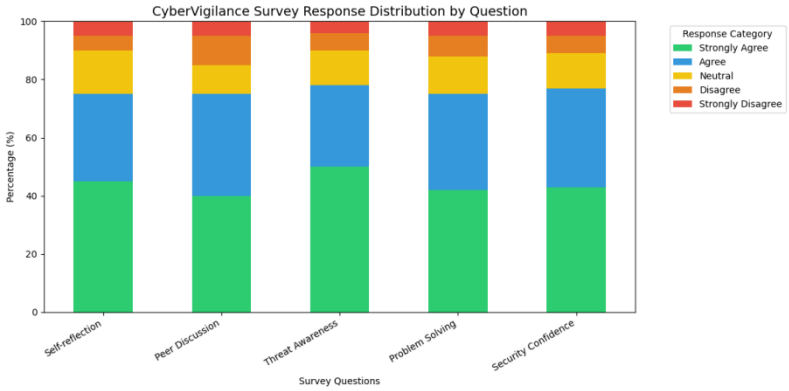


Figure 10: Survey response by question

6. Conclusion

Human error remains a leading cause of cybersecurity breaches, yet traditional cybersecurity training often fails to adequately prepare employees for the evolving threat landscape. To address this gap, the present study introduces CyberEmployee, a digital card game designed to evaluate and enhance employee awareness in realistic cybersecurity scenarios. Findings from the study indicate that the game offers an interactive learning environment that replicates real-world attack dynamics. The effectiveness of CyberEmployee is further supported by post-game survey responses. Employees reported a notable improvement in their understanding of cybersecurity risks, with many highlighting how the game encouraged critical reflection and peer discussion. In conclusion, the study demonstrates that gamification is a powerful tool for advancing cybersecurity awareness

through experiential learning. The research makes a strong case for shifting from passive cybersecurity training to dynamic, and scenario-based models. Future work will explore adaptive gameplay tailored to individual risk profiles.

Ethics declaration: Ethical approval was duly obtained prior to the commencement of the study. The dataset used is publicly available at: https://www.kaggle.com/dsv/9480976

AI declaration: Artificial Intelligence (AI) tools were used to assist in generating illustrative tokens. Bing AI was used for assistance in this regard: https://www.bing.com/chat. The use of AI was supplementary and did not replace original scholarly work or analysis.

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Conceptual Understanding and Systems Thinking Skill in Carbon Neutralization in Farming Role Play Board Game for Science Teacher Professional Development

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Abstract: Carbon Neutralization play the important criteria for the global air pollution problems, and it is the one of the sustainable development goals about air quality. The Carbon Neutralization concept is about the amount of Carbon dioxide (CO_2) absorption should equal the amount of CO_2 emission depending on the activity in any areas. The Farming Role Play Board Game was design for learning in Carbon Neutralization concept including activity card in theme color for CO_2 emission items in red, CO_2 absorption items in blue, and special items in green. Each item shows the amount of CO_2 from 10- 100 ppm and price from 10 – 500 coins. The participants were the 15 science teachers who teach in grade 7-9 in science subject in the western school area of Thailand. The group players, 3-4 teachers, role play to be a farmer who can produce plants, fruit and animals for buying and selling goods. At the game started every group received a budget 2,000 coins to buy any items in the board game. After that they had to play and learn by a random 9 events/rounds which occurred in the concept to calculate in balanced carbon and wrote the number in an activity's worksheet. A winner should balance well in the amount of CO_2 in the last round. The board game engaged the teachers to learn the conceptual understanding in Carbon Neutralization. They reflected about the fundamental system thinking skills that the boardgame need the players to plan the number of plants, animals, alternative or clean energy effected to the amount of CO_2 in ppm, and they need to relate the component of absorption and emission activities. The events were the lesson to practice the system thinking skills, identify the farming problem, finding and feedback the relationship between absorption and emission. Furthermore, they need to be aware dynamic events that effect in every farm that reflect the responsibility for making the better place for the air quality.

Keywords: Carbon neutralization, Systems thinking, Board game, Science teacher professional development

1. Introduction

Climate change, driven largely by human-induced carbon emissions, poses a significant threat to the global environment and human health. Among the many strategies proposed to address this crisis, carbon neutralization has emerged as a vital approach to reduce net carbon dioxide (CO_2) emissions and improve air quality. Carbon neutralization refers to achieving a balance between CO_2 emissions and CO_2 absorption through human and environmental activities. This concept is strongly aligned with the United Nations Sustainable Development Goals (SDGs), particularly those focused on climate action and sustainable resource use. For effective climate education, it is essential that science teachers possess a deep conceptual understanding of carbon neutralization and the interconnected processes that influence it. However, teaching and learning about complex environmental systems remains a challenge in many educational contexts. Traditional instructional methods often fail to promote holistic thinking or to engage learners in understanding the dynamic interactions between human activities and natural systems. As a result, there is a growing need for innovative, experiential approaches to science teacher professional development that foster both conceptual understanding and systems thinking.

One promising approach is the use of educational games, which provide interactive and meaningful learning experiences. Role-play board games can simulate real-world systems and allow participants to explore cause-effect relationships, feedback loops, and the consequences of decision-making in a safe, engaging environment. This study explores the use of a Farming Role Play Board Game specifically designed to teach the principles of carbon neutralization and promote fundamental systems thinking skills among secondary school science teachers in Thailand. The aim of this research is to examine how the board game supports science teachers in developing a conceptual understanding of carbon neutralization and in practicing key systems thinking skills such as identifying components, analysing interactions, recognizing feedback, and responding to dynamic changes. By integrating game-based learning into professional development, this study contributes to a more effective and engaging model for teaching complex environmental concepts in science education.

2. Theoretical Framework

2.1 Carbon Neutralization Concept and Extended in Daily Life

Carbon neutrality, also known as carbon neutrality, refers to achieving a balance between greenhouse gas (GHG) emissions produced and the equivalent amount removed or offset from the atmosphere (IPCC, 2021). This concept plays a key role in global efforts to mitigate climate change and is consistent with international frameworks such as the Paris Agreement, which aims to limit the increase in global temperatures to well below 2°C above pre-industrial levels (UNFCCC, 2021). The basic principle can be expressed through the following equation: Emission = Reductions + Offsetting. This theoretical model provides a foundation for understanding how individuals, organizations, and systems, including agricultural ecosystems, can contribute to net-zero carbon (Fankhauser and Gennaioli, 2021). The process of becoming carbon neutral involves three main strategies: 1) Reducing emissions at source through improved practices and technologies, 2) Increase carbon sequestration, such as through reforestation, soil carbon sequestration, and regenerative agriculture. And 3) Offsetting remaining emissions through investment in carbon credits, renewable energy projects, or other verified emission reduction projects. These strategies are not only essential for achieving national and international climate goals but also serve as a framework for educational interventions aimed at promoting sustainability literacy among educators and learners (Wills et al., 2022).

2.2 Role-Play Board Game on Agricultural and Carbon Neutrality

The design of the Farming Role-Play board game, which focuses on carbon neutrality in agriculture for the professional development of science teachers, is consistent with many existing educational board games that focus on sustainability and environmental literacy. However, this board game stands out by incorporating carbon accounting mechanisms, stakeholder dynamics in role-playing, and targeted applications in teacher education. Another relevant example is The Carbon Footprint Game, developed by researchers at the University of Milan (Sartori et al., 2021). The game introduces players to everyday choices that affect their personal carbon footprint through scenario-based gameplay. Although both games use carbon labels and tracking mechanisms, Farming Role Play Board Game extends this concept by incorporating systemic trade-offs and long-term planning around emissions, sequestration, and offsetting—a level of complexity does not present in The Carbon Footprint Game, which focuses more on decisions about urban lifestyles than agricultural practices. A third related game is Changing the Game – Neighborhood, an EU-funded board game designed to engage communities in local energy transitions (Bouwmeester et al., 2022). The game uses creative mechanics, such as excess energy management and “comfort coins,” to model a society’s acceptance of green technologies. These elements are in line with the Farming Role Play Board Game’s ethos of balancing productivity and ecological impact. However, Changing the Game – Neighborhood focuses on urban energy systems, while Farming Role Play Board Game applies similar systems thinking to rural and agricultural contexts, offering a new way to expand the framework. Finally, MainKassandra (Hoffmann & Rennings, 2021), a business-focused climate risk simulation, uses role-playing to teach resilience and adaptation strategies. While useful for professional training, it does not directly focus on carbon neutrality or integrate agricultural practices.

In summary, board games address issues of sustainability, carbon awareness, and role-playing, but Farming Role-Play uniquely combines all these elements within an agricultural context, specifically designed for science teacher development. The combination of realistic carbon metrics, collaborative decision-making, and systems thinking make this board game a new and impactful tool in the growing field of sustainability education.

2.3 Science Teacher Professional Development in Systematic Thinking

Systems thinking is increasingly recognized as an important skill for science educators, particularly in the context of sustainability education (Wiek et al., 2021). Systems thinking enables teachers to understand and teach the complex, dynamic, and interdependent relationships within environmental and socioeconomic systems, a skill that is essential to addressing global challenges such as climate change and biodiversity loss (Boyes & Stanisstreet, 2020). In response, professional development programs are turning to experiential and simulation-based learning formats, which promote deeper intellectual engagement and systems understanding among educators (Papagiannopoulou et al., 2022). One important recent finding is that traditional professional development workshops often fail to instill systems thinking, due to their reliance on theoretical teaching and discrete content delivery (Morrison, 2022). In contrast, participatory and interactive learning approaches, such as role-playing, board games, and scenario-based learning, have been shown to be more effective in developing this skill. For example, Sipos et al. (2020) found that experiential learning

environments encourage teachers to explore cause-and-effect relationships, feedback loops, and the long-term consequences of decisions. This is a key component of systems thinking.

A growing body of research highlights the value of role-playing and game-based learning in supporting teachers' development in systems thinking. As Hadjichambis et al. (2021) state, these methods allow teachers to assume from multiple perspectives, simulate interactions between stakeholders, and navigate trade-offs between economic, ecological, and social dimensions of sustainability, which is consistent with the instructional design of the Farming Role-Play board game, which allows teachers to immerse themselves in agricultural decision-making scenarios related to carbon neutrality, resource allocation, and environmental impact assessment. Furthermore, reflective thinking exercises after playing the game have been identified as an important mechanism for enhancing systems thinking skills (Sterling, 2021). Structured debriefing sessions allow teachers to articulate, evaluate decision-making strategies, and apply insights to real-world teaching contexts. This reflective thinking process not only enhances individual understanding but also enhances their ability to design classroom activities that promote student-centered inquiry-based learning about sustainability topics (Papagiannopoulou et al., 2022).A recent meta-analysis further indicated that integrating systems thinking into teacher education improves curriculum design. Interdisciplinary integration and student engagement (Reydon et al., 2023). Teachers who develop strong systems thinking skills are more likely to create lessons that emphasize complexity, interdependence, and long-term planning, which are key characteristics of effective sustainability education (Wiek et al., 2021).

3. Methodology

The participants were the 15 science teachers who teach in grade 7-9 in science subject in the western school area of Thailand. The group players, 3-4 teachers, role play to be a farmer who can produce plants, fruit and animals for buying and selling goods on the Farming Role Play Boardgame. The qualitative research was used. The data collecting instruments were an opened interview conceptual understanding of Carbon Neutralization and the obervation for engagement and feedback on the Farming Role Play Board Game.

3.1 The Farming Role Play Board Game

The design of the Farming Role Play board game, which focuses on carbon neutrality in agriculture for the professional development of science teachers, is consistent with many existing educational board games that focus on sustainability and environmental literacy. However, this board game stands out by incorporating carbon accounting mechanisms, stakeholder dynamics in role-playing, and targeted applications in teacher education. The Boardgame was structured around nine progressive scenarios, each representing a real-world environmental, economic, and social challenge faced by farmers. The scenarios are designed to promote systems thinking, encourage collaborative decision-making, and deepen understanding of carbon neutrality principles among science teachers participating in the professional development program. Each scenario introduces new variables, such as climate change impacts, policy interventions, or market volatility, that affect the outcome of the game and require players to adjust their strategies accordingly. For clarity and consistency, the key elements of each scenario are summarized in Table 1 below.

Table 1: The nine scenario of the board game and its environmental and economic impacts.

Scenario No.	Description	Environmental Impact / Gameplay Mechanics
1	Government regulation on carbon dioxide emissions	Each farm must reduce CO_2 by at least 100 ppm through compensatory planting or adoption of alternative energy sources. Teams must make at least one purchase during this scenario.
2	Increased tourism demand for local produce	Farmers are encouraged to sell cabbage, oranges, and pork to a central distribution point to meet high tourist demand.
3	Industrial development increases local CO_2 emissions	Each farm receives an additional 100 ppm of CO_2 due to nearby clothing factory operations. The government offers to buy plants or livestock from farms up to a maximum of 200 coin per farm.
4	Unusually cold winter season	Cold weather prompts increased demand for wool and cotton for winter clothing production. Farms unable to supply these materials incur an additional 50 ppm of CO_2.
5	Heavy rainfall and flooding damage crops and livestock	Damaged crops (e.g., water spinach, taro) and livestock (e.g., shrimp, fish) result in decomposition-related emissions: 10 ppm CO_2 per crop plot or livestock unit (per species).

Scenario No.	Description	Environmental Impact / Gameplay Mechanics
6	Introduction of renewable energy technologies	Renewable energy representatives offer equipment that reduces carbon-emitting energy use. Farms may purchase these tools to lower emissions.
7	Government financial support for young farmers	Each farm receives 500 coins in funding and must make at least one purchase to invest in sustainable practices.
8	Outbreak of Foot-and-Mouth Disease (FMD) affecting livestock	Livestock mortality (cattle, chickens, ducks) requires burial, resulting in decomposition emissions: 10 ppm CO_2 per livestock unit or coop (per species).
9	Farmer networking and resource-sharing initiative	Farms may exchange or trade agricultural goods (crops, livestock, tools) based on negotiated agreements to promote collaboration and sustainability.

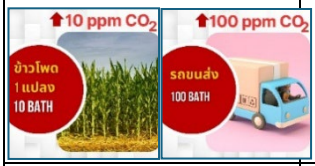
Through these transformative scenarios, participants will experience first-hand how individual agricultural decisions impact the wider ecosystem. For example, Scenario 5 models the impacts of extreme weather on agricultural yields, while Scenario 6 promotes investment in renewable energy solutions. The final scenario promotes community-level collaboration and resource sharing, reinforcing the importance of collective action in achieving sustainability goals.

For the game rules and paly, the players are divided into a team of 3–4 members each. Each team assigns internal roles for farm management including Farm Manager, Carbon Emission Controller Purchasing and Accounting Officer. Each team must play the game according to 9 predefined scenarios. Throughout the gameplay, teams are required to manage carbon dioxide (CO_2) emissions on their farm to achieve carbon neutrality, meaning that the amount of CO_2 emitted should equal the sum of compensation and emission reductions. The CO_2 quantities are calculated based on carbon labels provided for each item.

At the beginning of the game, each team receives an initial budget of 2,000 coins to establish their farm. Teams must use this budget to purchase items from a central marketplace based on carbon-labeled products, under the following conditions: Field Crops and Livestock Group: 20 plots total, with at least 5 different crop types. Livestock Group: At least 5 types of livestock animals and Perennial Plants Group: Exactly 5 trees. A minimum of 1,000 coins must be spent to establish the initial farm setup. In-game Purchases: During gameplay, each team may purchase new items at the beginning of every scenario. Before starting each new scenario, each team must calculate the total CO_2 emissions generated by their farm based on the carbon labels and record it on the Farm Management Score Board. This step is essential for planning purchases and managing CO_2 levels effectively. Once all teams have completed setting up their initial farms, the game begins with the first scenario and continues through the nineth scenario. Throughout the scenarios, each team must manage and operate their farm to complete the assigned tasks.

At the end of the game, the winning team is the one that successfully manages its farm to achieve carbon neutrality, where the total amount of CO_2 emissions equals the sum of carbon compensation and emission reductions.

Table 2: The character and CO_2 activities of the cards

Emitted Card	Offset Card	Reduce Card	Special Card
			
The Field Crops and Livestock Group can be purchased in every scenario. Upon purchase, the associated carbon dioxide (CO_2) emissions are calculated immediately in every scenario. If spoilage occurs, an additional CO_2 emission value equal to twice the original amount must be accounted for.	The Perennial Plants Group can be purchased in every scenario. Once purchased, the associated carbon dioxide (CO_2) emissions are accounted for starting in the following scenario and can be applied toward CO_2 management in all subsequent scenarios. If fruits from perennial plants are bought or sold, the trees remain on the farm.	Renewable energy items can be purchased in every scenario. Once purchased, the associated carbon dioxide (CO_2) value begins to take effect in the following scenario and can be applied toward CO_2 management in all subsequent scenarios.	Carbon reduction technology can be purchased in any situation. Once purchased, it can be immediately applied to reduce carbon dioxide (CO_2) emissions, but the technology's effects are only effective in the current situation.

4. Results

4.1 The Conceptual Understanding of Carbon Neutrality

For the observation and interview, teachers could gain an understanding of the principles of carbon neutrality through gameplay during the fourth round, in which the scenario tiles are revealed. In each round, the game gradually builds foundational knowledge regarding processes of carbon dioxide emissions, absorption, and reduction resulting from agricultural activities and the transportation of agricultural products. Upon completing the game, teachers were able to conclude that the amount of carbon dioxide emitted must equal the amount absorbed. Therefore, teachers formulated a simple mathematical equation and attempted to select various activities that would result in the total sum of emissions, absorption, and reduction of carbon dioxide equating to zero.

4.2 Teachers' Engagement and Feedback on the Farming Role Play Board Game

Teachers were able to engage with the game in their assigned roles, although some expressed a desire to take on multiple responsibilities, acting as moderators of decisions both within and between groups. This behavior reflected emerging leadership tendencies in some participants, particularly in the initial scenarios (Scenarios 1–3), where teachers followed structured game play activities and gradually developed an understanding of the specific characteristics of each card type. Overall, teachers provided constructive feedback indicating that the scenarios could benefit from greater variety in agricultural challenges and constraints. They suggested that agricultural purchases and sales occur in smaller quantities, such as 1–2 items per round, to allow for more informed decision-making, which would reduce the cognitive burden associated with simultaneously monitoring residual carbon levels and managing financial budgets for subsequent rounds. In addition, several teachers noted that the initial capital provided at the beginning of the game was relatively high, which reduced the urgency or need to strategically procure crops or livestock for trade with other groups, and as a result, the economic stresses and resource scarcity in the game were less pronounced.

Despite these observations, most teachers reported enjoying the process of selecting crops, livestock, and transportation methods that minimized carbon emissions. They found these aspects interesting and educationally valuable in understanding the trade-offs between yield and sustainability. However, they also noted the difficulty of measuring the impact of unexpected events, such as crop failure or livestock death. These elements do not generate income but rather increase carbon emissions. These elements elicit emotional reactions related to loss and uncertainty, which, while reflecting the risks of real-world farming, are challenging to measure within current game structures.

5. Discussions and Conclusions

Integrating role-playing board games into the professional development of science teachers has emerged as an effective approach to foster systems thinking, particularly in the context of sustainability education. A farming role play board game, designed to model agricultural systems and carbon neutrality strategies, provides teachers with an experiential learning environment that promotes holistic understanding, interconnected decision-making, and long-term strategic planning, all of which are essential components of systems thinking (Wiek et al., 2021). Systems thinking involves recognizing how different elements within a system are interconnected and influence each other (Sterling, 2021), a skill that is essential for teaching complex topics such as climate change and sustainable agriculture. In the game, teachers assume roles such as farm manager, carbon controller, and buyer/seller, each responsible for different aspects of the farm operation. As teachers deal with environmental and economic scenarios such as extreme weather, policy changes, or market fluctuations, teachers begin to see how individual actions (e.g., the use of synthetic fertilizers) can have ripple effects on soil health, emissions, and profitability. This mechanism supports the development of thinking models that reflect real-world complexity, helping teachers understand agriculture not only as a production system, but also as part of a broader ecological and socio-economic network. (Papagiannopoulou et al., 2022) A key feature of systems thinking is the ability to identify feedback loops, lags, and non-linear relationships (Boyes & Stanisstreet, 2020). Game designs require players to track cumulative CO_2 emissions over multiple rounds, forcing them to anticipate the long-term consequences of their choices. For example, planting trees may reduce emissions in future rounds but also reduce cropland in the short term. Similarly, purchasing renewable energy equipment may reduce emissions in the long term, but requires upfront investment. These dynamics encourage teachers to think outside the immediate outcomes box and consider trade-offs in the system, reinforcing the idea that environmental decision-making often involves balancing conflicting priorities, a skill essential for effective teaching of sustainability topics. Role-playing is an important mechanism by which

games promote systems thinking. By assigning different roles with conflicting goals (e.g., maximizing output versus minimizing emissions), games simulate the interactions of stakeholders encountered in real-world sustainability challenges. Teachers must negotiate, collaborate, and compromise. This skill reflects the interdisciplinary and collaborative nature of climate action (Sipos et al., 2020). This aspect of game play helps educators understand the complex nature of problems that involve multiple perspectives, enhancing their ability to teach sustainability as a systems-based discipline rather than a set of isolated facts. After playing the game, a structured debriefing session allows teachers to reflect on their experiences, discuss decision-making processes, and explore how lessons learned can be applied to classroom teaching. This reflective practice is essential to embedding systems thinking into their teaching practices (Morrison, 2022). Such reflective teachers often design lessons that emphasize cross-disciplinary connections, real-world problem-solving, and student-led inquiry, which are essential characteristics of effective sustainability education. Overall, the Farming Role Play Board Game is an effective tool for science teacher professional development, particularly in promoting systems thinking skills through its simulation of agricultural ecosystems, its focus on long-term planning, its promotion of perspective-taking, and its support for reflective learning. The board game provides teachers with an understanding of the concepts and practical tools needed to teach complex environmental topics. As Thailand continues to prioritize the green economy transition, the game will play an increasingly important role in preparing science teachers to lead sustainability education in the 21st century.

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Ethics and AI Declaration: This research adheres to the highest standards of academic integrity and ethical conduct throughout its design, implementation, and reporting. All data collected from participating science teachers during the development and testing of the Farming Role Play Board Game were obtained with the consent of interested teachers to participate in the project and will be used solely for educational research purposes. Participants were fully informed of their rights, including the ability to withdraw from the study at any time without consequence. Anonymity and confidentiality of all responses were maintained in strict accordance with the ethical guidelines for educational research involving human participants. In addition, the authors wish to disclose that artificial intelligence (AI) tools were used to assist in drafting, editing, and formatting this manuscript. These tools were used solely to improve clarity, grammar, and structure, and all content was reviewed, edited, and approved by the human authors. The use of AI did not affect the conceptual development, interpretation of the data, or conclusions presented in this research.

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Beyond the Game: Identity, Ethics, and the Transformative Power of Role Play in Business Simulations

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Abstract: Role play and game-based learning are reshaping higher education by fostering deeper engagement, motivation, and practical skill development through immersive, interactive experiences. This paper explores the pedagogical potential of role play as a core game mechanic embedded within the business simulation platform – *SimVenture Evolution*. By assigning learners executive roles such as CEO, Marketing Director, or Finance Lead, the simulation creates a team-based environment in which students collaboratively navigate strategic and operational challenges across a virtual start-up lifecycle. Findings indicate that role play enhances learner engagement, confidence, and applied business skills. More notably, students reported increased ethical awareness and the emergence of professional identity, reflecting on the moral complexity and personal growth that arise through simulation-based decision-making. Reflective narratives revealed that the experience supported collaboration, metacognitive development, and values-driven leadership – suggesting that role play contributes not only to technical competence but also to behavioural and ethical formation. The paper advocates for the intentional integration of role-based mechanics in simulation learning, underpinned by onboarding, feedback, and structured reflection. These insights highlight the transformative potential of role play to cultivate analytical, interpersonal, and ethically grounded capacities in business education.

Keywords: e-Learning, Simulation, Higher education, Game-Based learning, Interactive learning, Role play, Simventure evolution

1. Introduction

Gamification has emerged as a transformative force in education, offering new ways to engage learners by incorporating game mechanics into teaching and assessment (Hidalgo-Cajo et al., 2022). The increasing digitalisation of higher education, accelerated by the COVID-19 pandemic, has further propelled the adoption of gamified learning environments (Bai et al., 2020). Within these environments, role play serves as a bridge between theoretical knowledge and real-world application, fostering deeper learning through active participation and simulated experiences.

SimVenture Evolution, a business simulation platform, exemplifies this integration by assigning learners specific professional roles (e.g., CEO, Operations Manager) and guiding them through entrepreneurial decision-making processes. This exploratory study situates role play within the literature on gamification, game-based learning, and business simulation, drawing from recent empirical studies and educational theory to explore its pedagogical value.

While gamification has shown considerable promise in increasing motivation and learner engagement, its true pedagogical potential lies in cultivating deeper learning outcomes, including *ethical reasoning* and the *formation of professional identity*. This paper examines how role play, embedded within a business simulation, not only enhances applied business skills but also supports the emergence of ethical awareness and identity development. By doing so, it contributes a distinctive analytical perspective to the literature on game-based learning – one that foregrounds the human, reflective, and developmental dimensions of simulation pedagogy. In this study, we distinguish between *gamification*, understood as the application of game elements (e.g., role enactment, feedback loops, progression) to non-game contexts (Deterding et al., 2011), and *game-based learning*, where an entire game – such as SimVenture Evolution – is used as the core learning environment. Within this context, role play is examined as a specific game mechanic embedded in the simulation design. When intentionally integrated into a gamified learning environment, role play can move beyond surface-level engagement to foster critical thinking, collaboration, ethical reflection, and identity development.

This study responds to the growing need for pedagogical models that prepare students not only to know, but to think, lead, and adapt. It explores how role play within a gamified simulation can cultivate these capabilities by fostering engagement, applied skill development, ethical awareness, and the formation of professional identity. Specifically, it asks: *How does role-based learning within a business simulation influence learners' engagement, skill development, ethical awareness, and the formation of professional identity?*

2. Gamification in Higher Education

Gamification is an educational approach that integrates game elements and principles – such as points, challenges, levels, feedback loops, and progress tracking – into non-game contexts to increase engagement, motivation, and learning outcomes (Deterding et al., 2011; Caponetto et al., 2014). In higher education, gamification has been employed across disciplines to improve knowledge retention, promote learner autonomy, and encourage active participation (Looyestyn et al., 2017; Hidalgo-Cajo et al., 2022).

A growing body of research supports the value of gamification in fostering intrinsic motivation when it aligns with psychological needs for autonomy, competence, and relatedness (Ryan & Deci, 2000; Luarn et al., 2023). For instance, learners are more likely to engage deeply with tasks when given a sense of agency, personalised feedback, and the opportunity to collaborate in structured environments. These factors make gamification particularly suited to the development of soft skills, problem-solving, and adaptability in complex, uncertain situations – attributes central to business and management education (Beatty et al., 2021).

However, it is important to distinguish gamification from game-based learning (GBL). While gamification applies selected game mechanics to conventional learning activities, GBL involves the use of full-scale games designed with educational intent (Plass et al., 2015). In GBL, the game itself is the learning environment, not just a motivational overlay. This study is situated within a game-based learning context, utilising SimVenture Evolution – a simulation that immerses students in entrepreneurial decision-making. Within this context, elements of gamification, such as progress tracking, feedback, and functional roles, are embedded into the gameplay to enhance the learning experience.

Meta-analyses indicate that the most effective gamified systems are those that offer meaningful learning experiences and are closely aligned with course objectives (Li, Ma & Shi, 2023). Rather than using superficial game features (e.g., badges or points), effective implementations prioritise cognitive and emotional engagement, reflection, and challenge (Koivisto & Hamari, 2019; Plass et al., 2020). In this paper, we explore how role play – a core mechanic embedded within a business simulation – contributes to these deeper learning processes.

3. Role Play as a Pedagogical Tool

Role play is a longstanding instructional strategy that invites learners to adopt specific identities or responsibilities within a scenario, encouraging them to respond to problems or dilemmas from that character's perspective. Rooted in constructivist learning theory (Vygotsky, 1978) and experiential learning (Kolb, 1984), role play creates space for learners to construct meaning through interaction, experimentation, and reflection. In higher education, role play has been effectively applied in disciplines ranging from law and nursing to business and political science (Witherspoon et al., 2023; AlMubarak, 2022). It promotes the development of transferable skills such as strategic thinking, emotional intelligence, negotiation, and ethical reasoning – skills that are difficult to cultivate through traditional lecture-based methods. According to Schön (1983), role play helps learners become "reflective practitioners," capable of acting and thinking simultaneously while navigating uncertainty.

When embedded within digital environments, role play further benefits from the structure and interactivity provided by technology. Recent studies have shown that digital role play can increase engagement and collaboration while enhancing the authenticity of learning experiences (Ciani & Laus, 2023; Lin et al., 2024). Students who inhabit executive or leadership roles in simulated environments often demonstrate greater levels of confidence, teamwork, and professional identity development.

However, the effectiveness of role play is not automatic. It depends on thoughtful scenario design, clear role expectations, scaffolding for decision-making, and opportunities for reflection and feedback. Without these supports, students may experience confusion, disengagement, or reinforcement of existing hierarchies within teams (Zepke, 2020). Reflective debriefs – both written and verbal – play a critical role in consolidating learning by helping students process their actions, understand their assumptions, and consider alternative strategies (Moon, 2013).

In this study, we focus on role play not as an isolated method, but as a game mechanic embedded within the SimVenture Evolution simulation. This mechanic enables students to inhabit executive functions within a virtual start-up, taking on responsibilities that require strategic decision-making, financial oversight, marketing planning, and human resource management. The structured roles create cognitive anchors that support focus,

collaboration, and self-regulation. We examine how this form of embedded role play contributes to learner development across cognitive, emotional, and identity dimensions.

4. Research Approach

Business simulation games are representations of real business situations in a virtual environment/world. Business simulation games enhance learning experiences by providing a context in which students *learn by doing*, providing them with the opportunity to apply theory to practice (Silva & Silva, 2014). The simulation game used for this study is SimVenture Evolution (see Fig. 1), which requires logical reasoning to unravel many complex scenarios, while at the same time enabling students to monitor their progress through appraisals, as well as saving and loading various simulated situations.

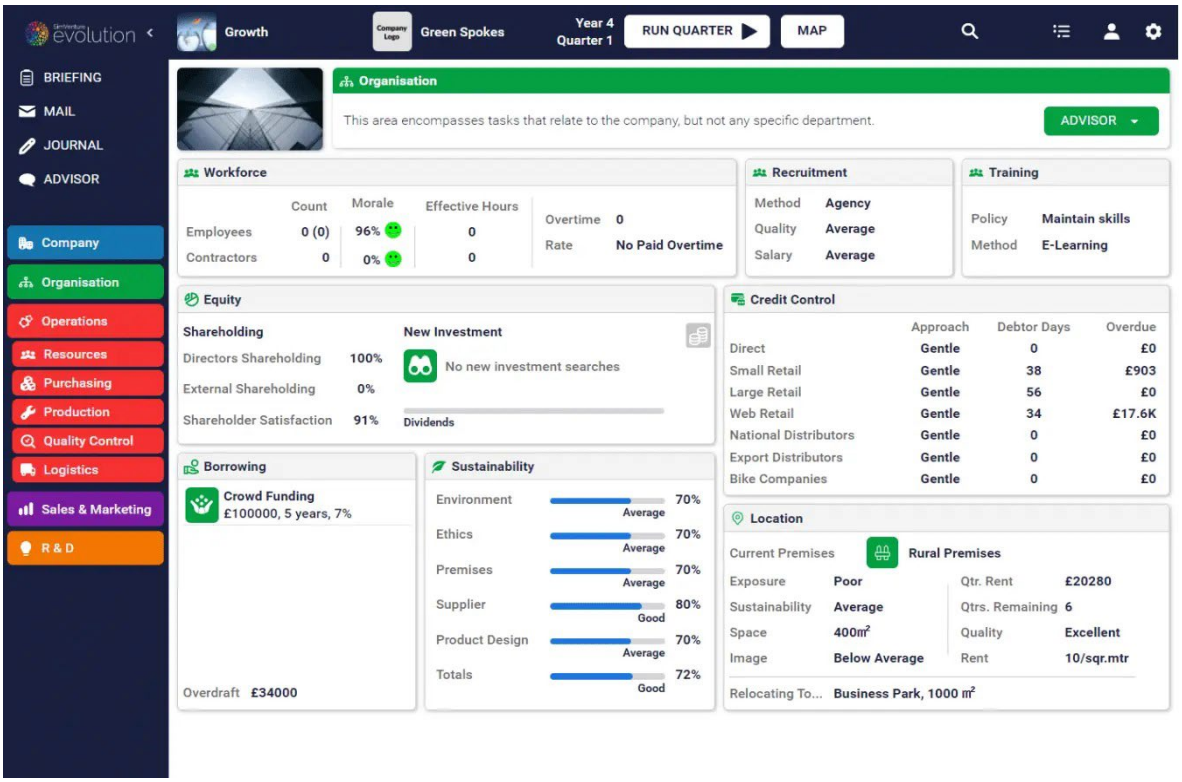

Figure 1: SimVenture Evolution Interface

SimVenture Evolution stands at the intersection of simulation, gamification, and role play. It immerses learners in a realistic entrepreneurial environment where they are tasked with managing a virtual start-up. Players assume functional roles within a team (e.g., CEO, finance director, operations manager) and work collaboratively to make decisions on product development, budgeting, marketing, and human resources. Instructors facilitate rather than teach to foster an inquisitive, creative and analytical mind-set, building students' self-confidence, and promoting teamwork. The game allows users to establish and run a virtual company, testing their knowledge of the various functions of running a business.

Previous studies have found that role-playing within SimVenture Evolution enhances learner engagement and motivation by situating abstract business concepts in a realistic context (O'Brien & Costin, 2022; O'Brien & Costin, 2023; Costin, O'Brien & Hogan, 2024). Learners report greater confidence in financial forecasting, strategic planning, and risk analysis after participating in SimVenture Evolution-based modules. The simulation also supports multidisciplinary learning, integrating marketing, operations, and finance into a single decision-making environment.

Research by Baruah and Ward (2022) underscores the role of SimVenture Evolution in facilitating authentic assessment through problem-based learning and ongoing feedback. Their study revealed that many students perceived the platform as enhancing their creativity and problem-solving abilities. Participants also reported that the simulation promoted effective teamwork, with the interactive nature of the platform encouraging active engagement in assigned group assessments, thereby making the learning experience more enjoyable and productive. Nonetheless, the inherent complexity of the simulation - designed to reflect the ambiguity and

unpredictability of real-world business scenarios – necessitates structured scaffolding. In the absence of sufficient preparation, students may encounter challenges such as frustration, decision fatigue, or disengagement.

The following sections present the study's context, highlight key challenges and pedagogical design considerations, and describe the methods used for data collection and analysis.

4.1 Context of the Study

The Business Simulation module is a (thesis-replacement) capstone module designed for postgraduate students completing a taught MSc degree in Business Analytics. Many of these students come from non-business backgrounds. The module reflects the challenges of entrepreneurial start-up and business growth, and emphasises the development of critical thinking, data analytics, decision-making, and collaborative skills.

To support team formation and encourage diverse working styles, students completed a brief online personality assessment using the 16 Personalities platform, based on the MBTI framework. While not a research variable, this profiling served a pedagogical function – helping allocate students to complementary teams and align them with simulation roles (e.g., R&D Director, Operations Lead). It enhanced mutual understanding and confidence in responsibilities.

It is worth noting, however, that the Myers-Briggs Type Indicator and its derivatives have been subject to critique regarding their psychometric reliability and predictive validity (Pittenger, 2005). In this context, the tool was used not as a diagnostic measure but as a light-touch, pedagogical aid to support team composition and initiate reflective discussion around roles and working styles.

4.2 Challenges and Pedagogical Design Considerations

Although gamified role play offers significant educational advantages, several challenges require attention:

- *Role ambiguity* can limit engagement if learners are unclear on responsibilities.
- *Group dynamics* may impact outcomes if team members dominate or disengage
- *Cognitive overload* may arise in complex simulations without sufficient scaffolding (Plass et al., 2020).
- *Assessment alignment* must ensure that simulation tasks support intended learning outcomes and are evaluated fairly (Wood & Drew, 2025).

To mitigate these risks, the module design incorporated structured onboarding, role briefing sessions, formative assessment opportunities, and reflective journaling. Debriefing activities after each simulation cycle helped learners make sense of their decisions and connect outcomes to academic theory. These strategies helped manage workload, promote metacognitive reflection, and support learners in developing analytical and interpersonal competencies across the simulation experience.

4.3 Data Collection and Analysis

Grounded in constructivist and experiential learning theories, this small-scale exploratory study sought to examine how role-based gamification facilitates critical thinking, decision-making, and reflective practice in a postgraduate business simulation capstone module. The primary data source comprised reflective journals submitted by students during the final week of the module. These journals formed part of the summative assessment and invited students to articulate their experiences of role enactment, strategic decision-making, team collaboration, and personal development across the simulation. Reflections typically ranged from 2,000 to 2,500 words and encouraged students to connect their experiences with broader business concepts, team dynamics, and their own learning trajectories.

A total of twenty reflective narratives were analysed, representing the full cohort of students who consented to participate in the study. All were enrolled in the MSc in Business Analytics programme and had engaged in the simulation as a capstone module. Ethical approval was obtained from the university's research ethics committee, and informed consent was collected in advance of data analysis.

Thematic analysis was employed to interpret the data, following the six-phase framework developed by Braun and Clarke (2006). This approach was chosen for its flexibility and alignment with an interpretivist lens, allowing for the emergence of meaning from student narratives without imposing pre-existing coding structures. The analysis involved six iterative steps: (1) familiarisation with the data through repeated reading; (2) generation of initial codes through inductive, open coding using NVivo software; (3) identification of preliminary themes by clustering related codes; (4) review and refinement of themes for coherence and

distinctiveness; (5) definition and naming of themes to capture their core essence; and (6) integration of themes into the broader analytic narrative.

To ensure rigour and trustworthiness, the first author maintained a reflective log to document analytic decisions and emerging insights. Peer debriefing sessions with a co-author were conducted to challenge assumptions, support reflexivity, and refine thematic structure. Additionally, member checks were undertaken with a small number of students, who confirmed that the themes accurately captured their experiences and perspectives.

This process led to the identification of five dominant and interrelated themes: experiential anchoring, motivational engagement, cognitive regulation, ethical awareness, and identity formation. These themes, presented in the next section, illuminate the cognitive, emotional, and developmental impacts of role-based gamification within the simulation environment.

5. Research Findings

Thematic analysis of the twenty student reflections revealed five interrelated themes that illustrate how role play within a gamified business simulation shaped learner experience. These themes – experiential anchoring, motivational engagement, cognitive regulation, ethical awareness, and identity formation – illuminate the cognitive, emotional, and developmental dimensions of role-based gamification. Each theme is supported by illustrative quotes and interpreted in relation to relevant pedagogical frameworks.

5.1 Role Play as Experiential Anchor

Students consistently described role play as the mechanism that transformed theoretical concepts into lived experience. By assuming functional roles such as CEO, Marketing Lead, or Finance Director, learners moved beyond abstract understanding to engage with authentic decision-making processes. These roles served as cognitive and emotional anchors, situating learners within Kolb's (1984) experiential learning cycle. One student reflected, *"I wasn't just learning about business – I was running one. The mistakes we made early on taught me more than any lecture."* Another student shared, *"Being the Finance Lead meant I had to really think like a decision-maker, not just a student trying to get a grade."* A third noted, *"Once we made a major pricing mistake and watched our sales drop, the lesson stuck with me more than any lecture ever could."*

Such reflections suggest that role enactment enabled meaningful engagement with the simulation's complexity, reinforcing the value of experiential, scenario-based learning environments. Notably, many students framed failure within the simulation not as a setback, but as a valuable learning opportunity. Missteps such as over-investing in R&D, underestimating staff requirements, or setting inappropriate pricing strategies were frequently cited as moments of insight. These experiences supported what Kolb identifies as the transformation of experience into knowledge through reflection and adaptation.

5.2 Motivation Through Role Engagement

Learners reported high levels of motivation linked directly to their role assignments and team responsibilities. Drawing on Self-Determination Theory (Ryan & Deci, 2000), the simulation appeared to support core psychological needs: autonomy, competence, and relatedness. Autonomy was fostered through the ability to choose or rotate roles, while iterative decision-making cycles allowed students to build competence through feedback and trial-and-error. Relatedness emerged through collaborative team structures that relied on cross-functional coordination.

One student wrote, *"I felt responsible for our company's direction. My role gave me purpose, and I knew my input mattered."* Another commented, *"We built on each other's strengths. Everyone had something to bring to the table."* Additional reflections reinforced these insights. *"Taking ownership of our marketing strategy made me feel like I was actually contributing something real – not just ticking a box,"* wrote one participant. Another noted, *"We weren't just doing tasks; we were running a company together. That made me show up with a different mindset."*

These narratives suggest that role-based collaboration contributed to a sense of shared ownership and psychological investment in the simulation's outcomes, supporting previous findings on engagement in gamified learning (Luarn et al., 2023; Beatty et al., 2021).

5.3 Cognitive Regulation Through Structure and Scaffolding

While some students initially expressed feelings of overload due to the simulation's complexity, many noted that role assignment and structured onboarding helped reduce extraneous cognitive load. This aligns with Sweller's (1988) Cognitive Load Theory, which emphasises the importance of managing mental effort in learning environments. The simulation's interface, dashboards, and pacing supported learners in managing tasks specific to their roles, allowing them to focus attention on relevant problem-solving and decision-making processes. One student remarked, *"At first it was overwhelming, but once we understood our roles and who was responsible for what, it became manageable – and even enjoyable."* Other participants echoed this experience. *"The dashboards helped me focus on my area without being overwhelmed by everything else going on,"* shared one learner. Another added, *"At first, I was lost. But once we divided responsibilities, I could concentrate and actually enjoy the experience."* The division of labour through role play enabled deeper domain expertise, while shared team planning tools and logs supported cross-functional integration.

5.4 Ethical Reasoning and Strategic Trade-offs

A recurring theme in the reflections was the tension between business performance and ethical decision-making. Many students described facing dilemmas involving sustainability, employee wellbeing, or reputational trade-offs. These moments often prompted reflective questioning of what constituted 'success' within a simulated business environment. One participant shared, *"We hit our profit targets, but failed on the sustainability score. That made me question what kind of business leader I want to be."* Another reflected on the discomfort of approving layoffs for financial gain, stating, *"It felt wrong, even if it was a logical choice."* Other students echoed these concerns. *"Cutting staff to meet targets made sense on paper, but it didn't sit right with me – I kept wondering how that would feel in real life,"* noted one. Another wrote, *"It forced me to think beyond profit. Is a decision still 'successful' if it goes against your values?"*

These examples suggest that role play facilitated engagement with values-driven decision-making, echoing Schön's (1983) notion of the reflective practitioner and reinforcing findings by Zepke (2020) on the importance of surfacing ethical tensions in higher education learning environments.

5.5 Identity Formation and Role-Based Confidence

Perhaps the most transformative dimension of the experience was the development of professional identity. Students expressed that role enactment helped them envision themselves in future business contexts, providing what Ibarra (1999) terms "provisional selves" – trial identities shaped through practice in low-risk environments. Learners frequently described a shift in self-perception, as captured in statements like, *"I finally feel like a business analyst,"* or *"This helped me discover the kind of leader I want to be."* Additional reflections reinforced this theme. *"By the end, I wasn't pretending to be a CEO — I actually felt like one,"* shared one student. Another wrote, "*I've never thought of myself as a leader before this, but now I'm considering it seriously."* These identity shifts were linked to growing confidence, enhanced communication, and greater awareness of individual strengths. Although personality profiling was not analysed as a variable, its use in role allocation and team formation may have contributed to students' sense of role fit and self-efficacy. Several reflections highlighted how role alignment supported trust, clarity, and performance within the group dynamic.

Taken together, these five themes offer insight into the cognitive, emotional, and developmental impacts of role-based gamification. The following section interprets these findings in light of existing literature, drawing out implications for pedagogy, limitations of the study, and opportunities for future research.

6. Discussion and Conclusion

Taken together, the five themes identified in this study – experiential anchoring, motivational engagement, cognitive regulation, ethical awareness, and identity formation – provide insight into how role play within a gamified business simulation can support personal and professional development in postgraduate learners. In this section, we interpret these findings in relation to existing literature and educational theory, while also acknowledging the methodological limitations of the study and outlining directions for future research.

A central contribution of the simulation experience was its capacity to transform abstract knowledge into meaningful, embodied learning. By stepping into authentic executive roles, students engaged in iterative decision-making processes that mirrored the complexities of real-world business practice. This finding aligns with Kolb's (1984) experiential learning theory, which emphasises learning through concrete experience and reflective observation. The integration of role play within the simulation created a space for active

experimentation and conceptualisation, supporting similar outcomes observed in recent studies on digital role enactment in business education (Ciani & Laus, 2023; Lin et al., 2024). As students navigated successes and failures, they built not only cognitive skills but also emotional resilience – an important, though often underexplored, dimension of experiential learning.

Motivation was another key dimension of the learner experience. The structure of the simulation, which allowed students to choose or rotate roles and engage in real-time strategic planning, fulfilled core components of Self-Determination Theory (Ryan & Deci, 2000): autonomy, competence, and relatedness. These motivational drivers were evident in the way students expressed ownership of their roles, confidence in decision-making, and respect for diverse perspectives within their teams. This echoes the work of Beatty et al. (2021) and Luarn et al. (2023), who emphasise the motivational potential of gamified learning environments when they are thoughtfully scaffolded and role-driven.

Despite the perceived complexity of the simulation environment, learners reported that the structure provided by role clarity and onboarding materials helped regulate their cognitive load. This supports findings from Plass et al. (2020) and Sweller's (1988) Cognitive Load Theory, which stress the importance of scaffolding in high-demand learning contexts. Learners appeared to shift from initial overwhelm to strategic planning once task ownership and team coordination were established. The simulation's design – gradually introducing complexity while offering domain-specific dashboards – enabled students to manage information more effectively and engage with deeper cognitive processes.

One of the more unexpected findings was the emergence of ethical reflection as a result of role enactment. When faced with trade-offs involving profit, sustainability, and employee wellbeing, students began to question not only what decisions were effective, but what decisions aligned with their values. These moments of ethical tension mirror Schön's (1983) concept of the reflective practitioner and Zepke's (2020) argument that authentic learning environments should surface moral and social complexity. Role-based simulation appears to create the conditions for such reflection, particularly when supported by structured debriefs and performance metrics that go beyond financial outcomes.

Perhaps the most transformative impact of the simulation was in the area of professional identity development. Students described how playing a defined executive role helped them envision themselves in future leadership positions and make sense of their capabilities and aspirations. These reflections resonate with Ibarra's (1999) concept of "provisional selves" – the idea that identity is developed through low-risk experimentation with different roles. The combination of role responsibility, reflective journaling, and team collaboration supported learners in developing a stronger sense of self-efficacy, adaptability, and professional purpose. Although not a formal variable in this study, the use of personality profiling for role allocation and team composition may have enhanced this outcome by helping students feel more attuned to their responsibilities and team dynamics.

While this exploratory study offers valuable insights, several limitations should be noted. The sample size was small and limited to one postgraduate cohort in a single institution, which constrains the generalisability of the findings. The study drew primarily on reflective journals, which provided rich subjective insights but may benefit from triangulation in future work. The analysis, though systematic and reflexive, was interpretive and based solely on self-reported data. Future research could strengthen the validity of findings through data triangulation, incorporating additional sources such as facilitator observations, simulation performance metrics, or learning analytics. This would provide a more holistic view of learner engagement and development, complementing the subjective insights provided by student reflections.

In conclusion, this study suggests that when thoughtfully integrated into a gamified, game-based learning environment, role play can enhance experiential learning, cognitive regulation, ethical reasoning, and professional identity development. These outcomes are not solely attributable to the simulation technology itself, but to the surrounding pedagogical design – scaffolding, team formation, structured reflection, and role clarity – that enables deeper learning. As business education continues to evolve in response to technological change and shifting workplace expectations, simulation-based role play represents a promising, adaptable strategy for cultivating reflective, adaptive, and ethically grounded graduates.

Ethics Declaration: This study involved human participants in the form of student engagement, and formal ethical approval was obtained from the university's ethics committee prior to data collection. All participants were informed about the purpose of the study and provided informed consent in accordance with ethical guidelines. Participation was voluntary, and confidentiality and anonymity were maintained throughout.

AI Declaration: Artificial intelligence tools were used during the development of this paper to support tasks such as proofreading, language refinement, and idea clarification. All intellectual contributions, critical analysis, and final content decisions were made by the authors.

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Megagames as a Methodology to Foster Learning in Higher Education

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Abstract: Megagames are large-scale collaborative games with elements of role-playing and board games. Players need to solve wicked problems together and explore multiple solutions. When applied to higher education, megagames create opportunities for learners to work in multidisciplinary teams solving ill-structured problems, and in this way prepare learners to deal with complex social processes and different actor's interests. Despite the promising potential of megagames, there is limited research on the use of megagames in education. The project 'Megagames as a Methodology to Enhance Global Awareness' (MEGA) involved a multidisciplinary team of teachers, researchers and game designers and its aim was to investigate the potential of megagames as methodology for higher education to address global problems, which cannot be simply solved from a fragmented disciplinary approach. In this paper we present and discuss insights gathered during the MEGA project. The guiding research question was: How can megagames be used in higher education to create immersive learning experiences that foster learning about global issues? We addressed the research question through phenomenological research because we wanted to capture the players' experience. Phenomenological research emphasizes the importance of direct experience for understanding the essence of a phenomenon. Within this methodology we developed and piloted a megagame centered on AI and Ethics, a relevant global issue for our university's students and faculty and investigated players' experience. The game event took about 4 hours, and it was open to students, faculty staff and other professionals. Thirty people participated in the game. We investigated participants' learning and personal experience and how they envisioned the implementation of megagames in education through open questionnaires and semi-structured interviews. In this paper we focus on the results from the twenty-eight participants who answered the questionnaire. The data was analyzed qualitatively. Results reveal dimensions in the participants' megagame experience that are valuable for preparing students to deal with complex situations and global problems. In particular, experiences that were connected with moral values and social skills, which are increasingly needed to prepare students for a democratic society. The megagame approach can help meet this need by offering immersive learning experiences.

Keywords: Megagames, Game-Based learning, Artificial intelligence, Higher education, Wicked problems, Serious games

1. Introduction

1.1 Megagames in Education

Megagames are large-scale collaborative games with elements of role-playing and board games. The number of players can vary from several to hundreds of people who are organized into teams and taking specific roles (Ludert et al., 2023). Players need to solve wicked problems together and explore multiple solutions. The megagame format creates a context where players come together in a process and explore solutions, thus making different perspectives visible. Megagames share some features of board games such as rules, rounds, and objectives which provide a framework for the player to act (Moreno & Melgoza, 2024). However, while board games have clear rules and goals, the megagame format has few rules with freedom for the players to define their own goals (Ludert et al 2023; Uhrqvist et al, 2021). Also, while board games involve typically a few players around a single table, a megagame involves several teams of players competing and/or collaborating with each other.

1.2 Research on Educational Megagames

Research on educational megagames has shown that megagames increase students awareness of social global issues, such as sustainability (Ludert et al, 2023; Uhrqvist et al, 2021), can be designed for increasing students' motivation for learning (Ludert et al., 2023), and are a method for gathering empirical data about different groups' knowledge and perspectives about social global issues. One example of a megagame for education is the Climate Change megagame conducted in 2020 at Linköping University. This game aims to encourage discussion about Climate change and what strategies to follow. Players are engaged in real-life experiences and role-play; they must negotiate the use of limited resources while considering different needs and interests. Findings from this study (Uhrqvist et al, 2021) showed that the megagame raised the awareness of the participants for climate adaptation and mitigation.

Research on megagames can also provide valuable guidelines and insights for designing and adapting them for educational purposes (Ludert et al., 2023). A review of the literature identifies several dimensions of the megagame format that make it interesting for education. One such dimension is *immersion*. Game elements contributing to this include narrative, secrecy, role-playing, high levels of interaction, and a context that resonates with participants (Uhrqvist et al., 2021; Moreno & Melgoza, 2024).

Another key dimension is *collaboration*. The large number of participants requires strategic thinking and alliance-building, as it is not feasible to communicate with everyone (Uhrqvist et al., 2021). Additionally, the presence of *multiple perspectives and stakeholders* enables participants to adopt multidisciplinary and holistic approaches to address complex, "wicked" problems—challenges that cannot be effectively solved through fragmented, discipline-specific strategies (Ludert et al., 2023; Uhrqvist et al., 2021; Kossoff & Irwin, 2021).

Megagames also support *experiential learning* by allowing players to actively engage with events and experiment with different perspectives, solutions, and outcomes that are often absent in traditional educational settings. Finally, because megagames involve participants adopting specific roles and foster empathy by encouraging them to view problems from other stakeholders' perspectives, they create a *safe environment* for discussing real-world issues. This setting helps facilitate the exchange of conflicting views and opinions in a constructive manner—conversations that might otherwise provoke defensiveness, argumentation, or entrenchment (Fleming et al., 2020).

However, research on educational megagames remains limited and existing studies on the use of megagames provide little insight into how learning unfolds during the megagame experience or how educators can effectively integrate this format into their practice. Our research addresses these gaps by focusing on the investigation, design, and implementation of educational megagames within higher education contexts.

In this paper we present a megagame developed in a project and results from the pilot of the game, which involved thirty people playing. Our guiding research question was: How can megagames be used in higher education to create immersive learning experiences that foster learning about global issues?

2. Context of the Research

2.1 MEGA Project

The MEGA (Megagames as a Methodology to Enhance Global Awareness) project explores the use of megagames in higher education to address social issues. By participating in a megagame, students and faculty engage with global challenges, gaining insight into the motivations of different stakeholders and reflecting on their own agency. The project focuses on a megagame about AI and Ethics—a timely and relevant topic—and investigates how participants learn through this format.

2.2 The Megagame Age of Intelligence

"Age of Intelligence" simulates a near-future world where nations and corporations negotiate AI technologies while confronting global crises and ethical challenges. Designed for 25-50 players, the game emphasizes the complex interplay between technological advancement, ethical considerations, and societal impact.

Players were assigned to one of four faction types with distinct missions **Nations** (2-3 people in each team, the main mission was improving trust with citizens), **Corporations** (2-3 people in each team, with the mission of developing and selling AI technology for profit), **Press** (2 people reporting news to maintain audience trust), and **Activists** (1 person promoting ethical AI use). Each player received at the start of the game a sheet folded in half and sealed to hide the exact details of achieving his/her character and faction goals. The activities created tensions between and within factions, compelling players to negotiate ethical dilemmas while pursuing conflicting objectives. **Control players** (one per team Nation or Corporation) facilitated gameplay, adjudicated actions, and ensured narrative coherence, with a **Master Control player** overseeing the game while individual Controls supported specific factions.

The setup included tables for nations, corporations, a research forum, and a world council. Each **faction table** featured a map with a "trust track" that visually represented the faction's standing with their constituents (citizens for nations, shareholders for corporations). An example is provided in Figure 1. These spaces facilitated nations managing their resources and internal policies, and corporations developing AI technologies and applications; **the research table** provided access to AI knowledge for a resource cost, by presenting an overview of possible AI applications for various application domains, the core technologies required to develop them, their potential benefits, costs, and associated ethical issues; and the **world council** handled global crises affecting

multiple factions. Movement between spaces was regulated to simulate real-world communication constraints, with press and activist players having greater mobility to fulfill their watchdog roles.

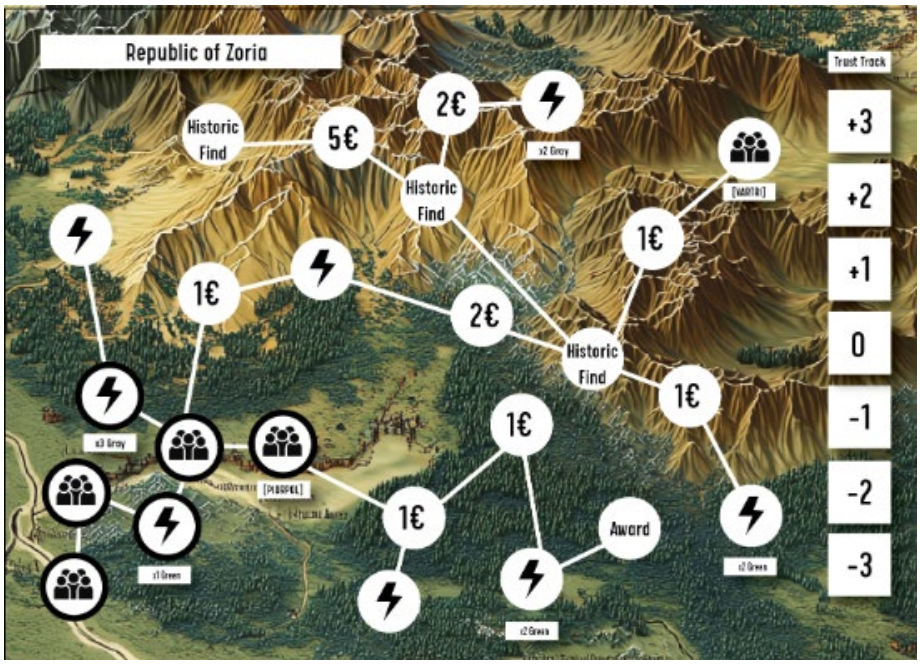

Figure 1: Map of Republic of Zoria

Resources in the game included both tangible assets (money, people, energy) and abstract concepts (data, advantages, complications), all represented by physical cards that players collected, traded, and spent during gameplay. Examples of these cards are presented in Figure 2. This resource economy was designed to encourage negotiation and create interdependence between factions, as players physically exchanged these cards when making deals or investing in technologies.

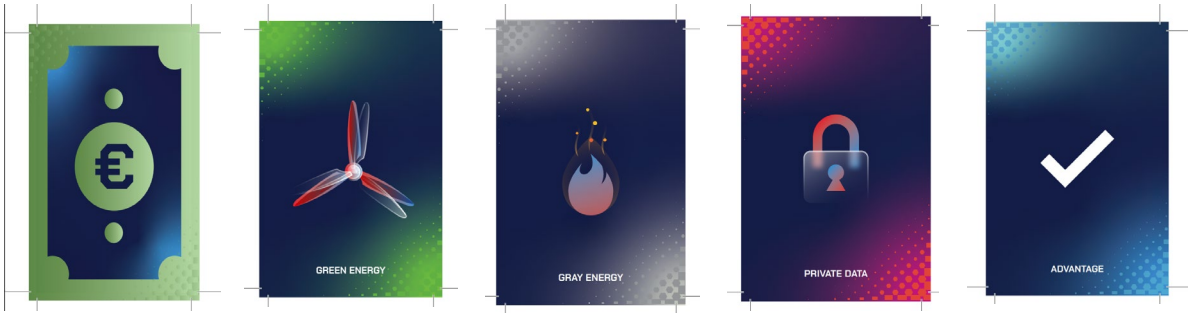

Figure 2: Resource cards

The game ran for nine rounds, from 1 to 5 pm, with mandatory faction meetings on alternate rounds. Control players served as both facilitators and arbiters who evaluated the quality and plausibility of player actions. Rather than rigid rules, the game relied on Control players' judgment to assess players' narratives, role alignment, and resource allocation when resolving actions. Action resolution followed a structured process where players described their intended actions to Control players, who evaluated the quality of their plans and resource allocation before determining outcomes through dice rolls. This mechanism rewarded thoughtful planning and role-appropriate behavior while maintaining an element of uncertainty. Although factions had goals to strive for, there were no explicit winning conditions to be achieved, and the end of the game was determined by the Master Control player.

Learning outcomes were of two types: (1) application of 21st century skills such as negotiation, critical thinking and collaboration for solving global issues in practice; and (2) learning about AI and ethics, in particular awareness of ethical principles, risk categories, and mitigation strategies. The descriptions of ethical issues and risks were informed by the European Commission's seven ethical principles for trustworthy AI (European

Commission HLEGAI, 2019) and the EU AI Act's risk categories (European Commission, 2024), stimulating players to engage with these frameworks within the context of their roles and objectives.

To illustrate how the different game elements combine, consider a nation faction facing rising healthcare costs due to an aging population. One or more business factions negotiate with this nation about AI healthcare applications and, using the AI research table, arrive at a solution: *AI-powered remote health monitoring*. Developing this requires two core technologies: Internet of Things (IoT) for data collection and Machine Learning for health pattern analysis. The company already possesses one core technology, and invests money and other resources (data and energy) to develop the second and build the AI application. This offers potential benefits to the nation—early health issue detection and reduced costs through preventive care—but also raises two ethical concerns: (1) Privacy and Data Governance, involving consent and potential data breaches, and (2) Technical Robustness and Safety, where data collection errors could endanger patients. The business faction must explain how they plan to address these concerns to a control player, who evaluates the plan and determines outcomes using dice to reflect uncertainty. At some point, the master game controller announces that the next round will include a check on the use of personal data, triggering additional costs. This prompts factions to either switch to anonymized data or develop AI applications that support data anonymization.

3. Method

3.1 Participants

To investigate the way megagames enact learning we applied phenomenological research because this method is suitable to capture peoples' experience. Phenomenological research emphasizes the importance of direct experience for understanding the essence of a phenomenon, in this case, the megagame. The pilot of the megagame was open to students, faculty staff, and other professionals and took approximately four hours. Participants' learning and personal experience and how they envisioned the implementation of megagames in education were investigated using open questionnaires. Of the thirty people who participated in the game, twenty-eight participants answered the questionnaire.

3.2 Questionnaire

The questionnaire contained 22 questions, addressing participants' background (age, function, workplace, motivation to play the game), participants' satisfaction and overall learning experience, what they liked and disliked, when they were engaged and disengaged, participants' perceived learning about AI and Ethics and how participants envisaged application of megagames in their work or school practice.

3.3 Data Analyses

Following a phenomenological approach, the qualitative data was analyzed per participant (horizontalization) and across participants. The whole dataset was coded and from the codes, categories and overarching themes were created. Through the processes of horizontalization, comparison and reduction, the themes were tested against the original data. These themes describe players' experience with the megagame and provide answers to the first part of the research question (how people learned). Perceived learning about AI and Ethics was measured with multiple-choice questions that asked to what extent participants learned specific content. Quantitative analyses of participants' answers provided answers to the second part of the research question (what they have learned about the global issue in question).

In qualitative data analysis, some methodologists question the relevance of intercoder agreement, given the interpretative nature of the process (Saldaña, 2015). In this study, we employed extensive team discussions and achieving consensus as a primary agreement strategy. During the initial phase of analysis, two researchers independently coded a portion of the data to establish inter-coder reliability. Any discrepancies were addressed through discussion and resolved by consensus. After this step, the first author completed the full dataset coding, while the third author acted as a critical reviewer, thoroughly auditing the coding process to ensure consistency and transparency (Saldaña, 2015).

4. Results

4.1 Characterizing Players' Learning Experience With the Megagame

4.1.1 Immersive

The theme Immersive entails players' feelings of joy, pleasure or displeasure in their megagame experience. Playing the megagame felt very immersive for some players. For instance: "I had a blast! The experience was very immersive" (P10); "Special! I've never done anything like this before, so it was educational and entertaining" (P26). "I was continuously motivated and engaged" (P06).

Other players experienced fun, enjoyed the role-playing and the story unfolding (*fun or interesting*) and one player was slightly disappointed (*disappointed*), feeling that it took too long to step into the game.

4.1.2 Learnful

Learnful refers to the educational potential of the megagame. It includes aspects related to learning activities, learned knowledge or skills enacted during the gameplay. People recognized its educational value and relevance for learning about AI and ethics *(relevant and educational*). For instance, one player noticed that it was "easy to see the relevance" (P20). Playing the game gets people "thinking about AI" (P18) and provokes thinking about positive and negative consequences of its use (*fostered critical thinking*): "Coming up with positive negative consequences regarding the actions or innovations of the players" (P18).

Players were exposed in a fun way to complex learning which involves multiple and diverse perspectives, different points of views, and shifting priorities / urgencies (*multiple perspectives*): "It was a fun way to learn about different perspectives" (P06). This experience was complex and nonlinear, sometimes described as "chaotic because of many perspectives and shifting priorities / urgencies. But in a good way" (P27). It was also connected with reality as players experienced the complexity of the world. They found the resources largely corresponded with reality and the role play realistic *(connection with reality*): "[I liked] how the resources largely corresponded with reality" (P18); "the role play was realistic" (P14).

Players felt most engaged when doing research, creating proposals or designing products ("when we did some research and ended up with a great proposal", P07); when negotiating and making deals with other teams. For instance, player P12 stated: "When dealing with the press and negotiating with companies, I had to really break things down to what benefitted my country most and enter the character. In thinking about how something would affect millions of people"; when persuading others or discussing about tradeoffs ("Making the argument for a plan before control. Then all of the things you discussed and discovered need to make sense and be convincing.", P27) (*engaging discussions, negotiation, design*).

4.1.3 Collaborating, communicating and connecting with others

Collaborating, communicating and connecting with others referred to the social interaction enacted during the gameplay and ways that it supported and motivated players through the gameplay. Interaction and collaboration with others was the most engaging factor of the megagame experience. During the game people met new people ("I got to know new people", P16) and collaborated intensively with other players within the team and across the teams (*interaction and collaboration*). For instance, player P01 liked the "collaboration, see how we were all sort of dependent on one another", and player P17 was most engaged when "cooperating with other countries to prevent war" (P17).

People felt also strongly engaged when talking to other people, other teams and the press and talking about their plans (*Interacting and talking with others): "*When I made 'a bond' with the journalists. I just like to work together and make fun with each other" (P16).

People felt connected during the megagame, which led to engagement (and probably immersion). Working and having fun or being in a story together, seeing people getting into their role and seeing that everyone is involved, enthusiastic and participating (*sense of closeness and belongingness*).

Players were also explaining and helping each other and people felt very engaged when feeling that they could help the team (*helping others*). Player 23, who was a control-player, felt most engaged when "shifting from explaining the game rules and thoughts to guiding the table to participate more in the story, and suggests 'story development options'". For this player "it was all great fun that got even better the longer we played".

Conversely, people felt disengaged in situations where interaction was missing, as in the case of the control players when players were away from the table to negotiate with other teams: “The even rounds, where the players went in all directions to discuss and I just came up with ideas and did the administration” (P18).

4.1.4 Experiencing and dealing with complex situations

Complexity refers to the state of feeling difficulty to understand or find a solution to a problem, which cannot be solved through linear methods, and it involves multiple paths or perspectives. Creating the experience of complexity was one of the reasons to use megagames and we were curious to see how players experienced this in their game-experience. We saw this theme emerging from participants descriptions in three main forms: complex, increasing complexity and high workload. Players experienced the game as chaotic but in a good way, they related with joyful feelings although also overwhelming (*complex*). For instance, player 13 describes his/her experience as ‘nice but a bit overwhelming and too much".

Players felt that negotiation became difficult while the game was going on (*increasing complexity).* For instance, player P01 felt disengaged "when things were becoming too overwhelming" and "negotiation becomes difficult".

Mostly, players experienced some kind of difficulty and workload before and during the game. They need preparation (you need to read the role before the game); it is difficult to be a control player: "I was control. It felt like quite a heavy job to steer the group in the right directions" (P24). Stepping into the game was considered difficult. Many players referred to the difficulty in understanding the rules, determining priorities and develop the first products: “In the beginning it was quite hard to figure out what I had to do" (P09); “I also sometimes found it difficult to understand the rules and determine the priority” (P26).

4.1.5 Freedom, uncertainty, progress and trust

The open character of the megagame evoked divergent feelings among the participants. There were players who experienced and appreciated it and liked the freedom to come up with alternatives. This was the case for player P03, who liked “the freedom and the amount of background information provided” the most, and player P12 valued the “liberty to come up with alternatives that aren’t guarded by a strict rule set”. The absence of winning conditions was noticed and appreciated by some players. Player P25 stated “it was also nice not knowing the specific goals but having a general idea of the goal as we were going. This meant that the end felt satisfying seeing that you did make choices that awarded something at the end without knowing if you were doing the right thing". Player P10 enjoyed that “everyone had different goals”.

There were also players who felt out of comfort zone, too much freedom, unprepared, didn't know what to do and felt insecure when rules were not clear, or when feeling not having enough knowledge on AI: “Too much freedom, not clear what the options are. Everything can be done but that blocks me sometimes” (P19). This player commented that the use of scaffolding and examples would work better for her/him. Player P03 experienced as unpleasurable the game’s “complexity and not knowing how you progress”. This player suggested adding a dashboard to the game.

Starting to understand the game and accomplishing particular tasks and goals were turning points and allowed players to gain trust: "I think I was engaged around the middle part to the end, I gained some trust and figured out what my role was" (P09). Player P07 got engaged when feeling progress and accomplishment: “I finally had the feeling like I was starting to understand the game."

4.2 Learning about AI and Ethics

The majority of the 28 participants reported having learned something about AI and Ethics (n=11) or a little (n=10). Some players reported that they didn’t learn (n=7) and none reported having learned a lot about this topic. Nineteen participants gave more detailed answers, mentioning having learned about specific topics such as data concerns, complexity and multifaceted character of the problem, difficulty to match ethics and production, influence of the press, resources and consequences, risks of corruption, and perspectives on implementation [of AI] in the energy sector.

We also asked players whether they had learned specific knowledge related to AI and Ethics from the game, or whether they already had this knowledge. An overview of these issues and the participants’ answers is presented in Table 1.

Table 1: Knowledge on AI and Ethics in the megagame

To what extent do you agree with the following statements? After participating in the megagame:	Agree	Disagree	I already had this knowledge
I can describe an example of an AI application that addresses a societal problem	25%	25%	50%
I can explain a benefit and a disadvantage of AI adoption from different societal perspectives	39%	14%	46%
I can describe an ethical issue related to human agency and oversight	32%	29%	39%
I can describe an ethical issue related to technical robustness and safety	32%	21%	46%
I can describe an ethical issue related to the environment	39%	7%	54%
I can describe an ethical issue related to privacy and/or data governance	36%	7%	57%
I can describe an ethical issue related to diversity, non-discrimination, and/or fairness	21%	36%	43%
I can describe an ethical issue related to transparency	43%	21%	36%
I can describe an ethical issue related to accountability	25%	39%	36%
I can explain and justify solutions that might mitigate the different ethical risks associated with the application of AI	21%	46%	32%

Participants shared additional reflections on their learning, including: "how many different interests various parties can have, especially regarding data safety and regulations" (P11), and "the importance of the government's possession of personal data"—not just avoiding misuse, but "but keeping it safe in the first place." (P13).

4.3 Megagame Application to Education or Workplace

We investigated how participants would use (or not) megagames in their learning, teaching, research, or other educational practice and why. People who would use megagames (n=6) would do it for the following reasons: to foster awareness and/or introduction to the world of AI and Ethics, as well as an active learning activity or icebreaker or to learn about gamification. For instance, one professional from a Tech company "would use it to work with companies that are looking to adopt AI - as a fun engagement in parallel to the base case definition workshops". A teacher would use the megagame format as a whole class activity as an example of gamified learning.

The majority of participants (n=16) had doubts about whether they would use it in their educational practice or workplace. The three main concerns related to its application in education were the difficulty of adapting it to one's own context, the time that it takes to play, and the effort or resources needed to organize it: "I think that it requires a lot of time and resources to manage and the return is a bit low". One teacher doubted about the use of the megagame with students: "For my students it might be too difficult as it was played today. I think modeling 2 rounds in a video or something would help".

The participants who would not use megagames (n=6) did not have a role in education or were teaching in secondary education. Also, one teacher would not use it because "It takes many people and a lot of time to play it, we don't have the opportunity to do that in our teaching environment".

5. Conclusion and Further Research

The findings highlight various aspects of participants' megagame experiences that help prepare students to navigate complex situations and global challenges. Understanding how and why megagames can be used for learning in higher education is essential for lecturers and researchers aiming to apply this format effectively. Based on these findings, we propose the following working definition of learning through educational megagames in higher education, offering insight into their educational value:

"In a megagame learning involves feelings such as joy, pleasure or displeasure and in some cases playing the megagame can be very immersive. Players are exposed in a fun way to complex learning that involves multiple and diverse perspectives, different points of view, and shifting priorities and urgencies. People learn about the topic and other people's views through discussions, negotiation and design. The social interaction enacted

during the gameplay, which involves communication, collaboration and connection, motivates players to keep playing, develop critical thinking and knowledge and feel connected. The gameplay takes time which is needed to experience and overcome less pleasure experiences"

The definition above aligns with previous research on learning through megagames. For example, in studies by Ludert et al. (2023) and Moreno and Melgoza (2024), players reported feeling immersed in the game, engaging in experiential learning, collaborating, and sharing multiple perspectives. The megagame format has also been shown to create a safe environment for learning through experimentation and dialogue (Fleming et al., 2020).

However, other aspects of our definition—such as feelings of joy and fun, a sense of belonging, and personal and moral dimensions—are less frequently discussed in the existing literature on megagames.

Many of the elements included in the above definition are also present in other educational game formats, so what distinguishes learning within the megagame format? We believe it is not a single feature, but rather the combination of several elements—such as the openness of the game's goals and the high level of interaction among players. Together, these factors significantly expand the range of possible solutions, participant perspectives, game scenarios, and learning outcomes, resulting in a more immersive and dynamic learning environment compared to more traditional and predictable formats.

Additionally, the extended duration of gameplay appeared to be a crucial factor for participants in our study. It allowed them time to fully immerse themselves in the experience, engage meaningfully with the gameplay, and work through moments of confusion or frustration.

Implementing megagames in practice involves resources and organization that are usually not available in traditional higher education. In addition to play the game in another setting requires effort and expertise to adapt it to a new environment and its specific problems. Especially teachers see possibilities for using the megagame format for awareness and introduction to a topic, but not much beyond this. Follow-up research is needed to better understand the particularities of learning with megagames and to develop ways to support teachers who are interested in using them in practice.

Ethics declaration: Ethics declaration was not required for the research.

AI declaration: No AI tools were used for the creation of this paper besides for correcting writing. The main language of the authors is not English.

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Analogue Games and Digital Literacy: The NetSmart Case Study with Older People

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Abstract: In an era where digital proficiency is increasingly vital for full societal participation, older adults remain disproportionately underserved by digital literacy initiatives. Addressing this gap, the present study investigates the impact of *NetSmart*, a custom-designed analogue board game aimed at improving digital literacy among older adults. Developed through a participatory approach, *NetSmart* engages players in collaborative gameplay centred around digital safety, mobile device usage, and online interaction. The study employed a quasi-experimental pre-post design involving 42 participants aged 60 to 89, all previously introduced to foundational digital skills through local lifelong learning programs in Lisbon, Portugal. Participants attended a six-week intervention comprising guided gameplay sessions structured to promote reflective learning, skill reinforcement, and social interaction. Digital literacy was assessed through a 22-item questionnaire administered before and after the intervention. Quantitative analysis using the Wilcoxon signed-rank test revealed significant improvements in key areas: the ability to download and install applications ($p = .015$), update operating systems ($p = .037$), and understand the role of games in learning ($p = .020$). Additionally, post-intervention responses showed increased self-efficacy in educating others on digital safety and greater engagement with online gaming ($p = .033$ and $p = .013$, respectively). These findings underscore the potential of analogue Game-Based Learning (GBL) not only as a tool for developing digital competencies, but also as a means of enhancing older adults' autonomy, social engagement, and confidence in navigating digital environments. This aligns with a broader recognition of play as a dynamic and effective medium for adult learning—especially when educational approaches are sensitively adapted to the cognitive and emotional dimensions of aging. While the case study's context-specific nature and absence of a control group limit generalizability, the results nonetheless offer meaningful insights into how GBL can inform digital inclusion strategies for older populations. To build on these insights, future research should incorporate performance-based assessments alongside self-reported data and explore diverse settings to strengthen external validity.

Keywords: Older people, Game-Based learning, Digital literacy, Analogue games

1. Introduction

The increasing digitalization of services, social interactions, and everyday life has widened the generational gap in how people access and engage with technology. Older adults often face a combination of technological, cognitive, and emotional barriers that make it difficult to fully participate in today's digital society. In this context, digital literacy is more than a technical skill – it's a key to social inclusion, autonomy, and active participation in later life (Ng, 2012; Helsper and Van Deursen, 2017).

Although many programs aim to bridge this digital divide, traditional teaching methods often fall short in meeting the needs of older learners. These approaches may not align with their learning preferences or engage them meaningfully. In response, educational research has increasingly explored Game-Based Learning (GBL) to boost motivation, foster autonomy, and support skill development among adult learners (Romero et al., 2017; Hsiao et al., 2024). Games create safe and engaging environments for practice, feedback, exploration, and collaboration – key ingredients for effective learning.

While GBL has been widely studied among younger populations and in formal educational settings, its use in teaching digital literacy to older adults has received far less attention – especially from a quantitative standpoint. There is a growing need for solid evidence on how structured game-based interventions can support older adults in developing digital skills (Zou et al., 2021; Costa et al., 2022).

This study seeks to address that gap by examining the impact of *NetSmart,* a custom-designed board game created to enhance digital literacy in older adults. Using a pre and post evaluation design, we assess changes in participants' skills and perceptions after five guided sessions with the game. Our quantitative approach offers a clear lens into how playful, structured learning can benefit older adults in the context of lifelong learning and digital inclusion.

2. Theoretical Foundations

2.1 Lifelong Learning, Aging, and Social Participation

Lifelong learning is essential for keeping older adults engaged, independent, and connected in today's fast-changing digital world. As emphasized by UNESCO (2016), continuing to learn throughout life supports well-being, adaptability, and civic involvement. Yet, many older adults encounter real barriers when returning to learning environments—ranging from reduced self-confidence and negative age-related stereotypes to anxiety about using unfamiliar technologies (Formosa, 2014; Charness and Boot, 2022).

These challenges are often made worse by inequalities in access to education and digital infrastructure. To address them, educational practices need to be inclusive, empathetic, and meaningful. Aging also brings natural changes in memory, attention, and processing speed. As a result, effective learning environments for older adults should respect cognitive diversity and allow learners to move at their own pace (Czaja et al., 2019).

Approaches that encourage active participation, foster social interaction, and create emotionally safe spaces are more likely to succeed in keeping older adults engaged and motivated to learn. By nurturing not just intellectual but also social and emotional engagement, such environments support learning that is both meaningful and sustainable.

2.2 Digital Literacy in Later Life

Digital literacy goes beyond knowing how to use a computer or smartphone. It includes the ability to find, evaluate, understand, and apply digital information in meaningful and critical ways (Ng, 2012). For older adults, this often means more than acquiring technical skills – it's about building confidence, feeling that technology is useful in their lives, and developing a sense of autonomy in digital environments.

These aspects are shaped by personal histories, the level of support from friends or family, and emotional comfort with technology (Lee and Coughlin, 2015). Many older adults face psychological and practical barriers to digital engagement, such as low self-efficacy, fear of making mistakes, or inaccessible instruction (Neves et al., 2018; Helsper and Van Deursen, 2017).

Overcoming these challenges requires learning environments that are welcoming, user-friendly, and tailored to the needs of older users. When digital literacy education is rooted in empathy and respect for learners' experiences, it has the potential to empower older adults—not just to use technology, but to engage with it meaningfully and confidently.

2.3 Game-Based Learning and Older Adults

GBL is an approach that uses the structure and elements of games – like rules, feedback, and goals – to support meaningful learning. Unlike gamification, which adds game-like features to traditional content, GBL is centred on learning through play. It fosters engagement, reflection, and motivation by creating immersive and interactive experiences (Plass et al., 2015).

Although often associated with younger learners, GBL is increasingly being recognized as a valuable tool in adult education, including programs for older adults (Perim et al., 2024). For those with limited experience using digital tools, GBL offers a low-pressure way to explore new skills. It creates space for experimentation, where failure is safe and part of the process. This is especially important for older adults, who may face anxiety or self-doubt when learning new technologies.

Recent research has explored GBL with older populations in a range of settings. For instance, cognitive games have been shown to support memory, attention, and executive functioning (Kueider et al., 2012; Bercovitz et al., 2020). Other studies have used games to teach health management skills, improve health literacy, and encourage behaviour change (Vázquez et al., 2021; Guimarães et al., 2023). Still others have focused on promoting intergenerational learning and reducing social isolation through collaborative games (Voida and Greenberg, 2021; De Schutter, 2023).

Across these diverse applications, games do more than support skill-building—they enhance emotional well-being, build self-efficacy, and create a sense of belonging. These are crucial ingredients for improving quality of life in later years, and they make GBL a promising approach for digital literacy education with older adults.

3. Methodology

This study uses a quantitative, *quasi*-experimental pre and post design to assess how a GBL intervention impacts digital literacy among older adults. This design is appropriate for evaluating educational interventions where random assignment is not feasible but pre- and post-measures allow for within-group comparison (Campbell and Stanley, 1963; Creswell and Creswell, 2018). The study builds upon a prior qualitative investigation conducted with the same participants (see Perim et al, in press), institutions, and pedagogical tools, offering a valuable opportunity to compare results and deepen understanding of how older adults engage with technology-focused learning in both experiential and reflective dimensions (Creswell and Plano Clark, 2018)

3.1 Participants and Context

The study involved 42 older adults aged 60 to 89 (*M* = 74.14; *SD* = 7.08), 38 females (90.5%), and four males (9.5%), recruited from community centres and lifelong learning programs in the Greater Lisbon area. These institutions promote active aging and educational inclusion through participatory pedagogical approaches (Formosa, 2014; Loos, 2020). All participants voluntarily consented and had previously completed introductory digital literacy programs, providing a shared baseline that enabled more experiential learning through game-based educational models (Ng, 2012; Romero et al., 2017).

From the gathered data, it is relevant to note that most of the participants (97.6%) reported being able to make or receive phone calls. Regarding digital media habits, 68.3% used their phones to search for information, 70.7% for updates, and 51.2% for entertainment. Nearly half of the participants (48.8%) indicated they used their phones to play games, and 50% reported using them to access services. In contrast, only 19.5% reported having access to streaming services.

3.2 The NetSmart Game

The intervention was centred around *NetSmart: Discover Your Digital Literacy Level!*, a custom-designed educational board game developed specifically for this study. The game was conceptualized based on principles of GBL and inclusive adult education, promoting critical digital skills in a collaborative, hands-on, and motivational environment (Plass et al., 2015; Whitton and Langan, 2019).

NetSmart consists of a flexible vinyl game board (120 cm × 80 cm), 100 multiple-choice question cards in four levels of difficulty, 100 answer cards, a die, and coloured tokens for scoring. The layout features Wi-Fi-style icons that simulate increasing digital complexity, encouraging a scaffolded learning experience. Topics include identifying scams, creating secure passwords, adjusting privacy settings, recognizing fake links, and using email and messaging apps – selected based on known challenges among older digital users (Lee and Coughlin, 2015; Helsper and Van Deursen, 2017). Figure 1 illustrates the *NetSmart* game board along with its components, as they were used during the intervention sessions.

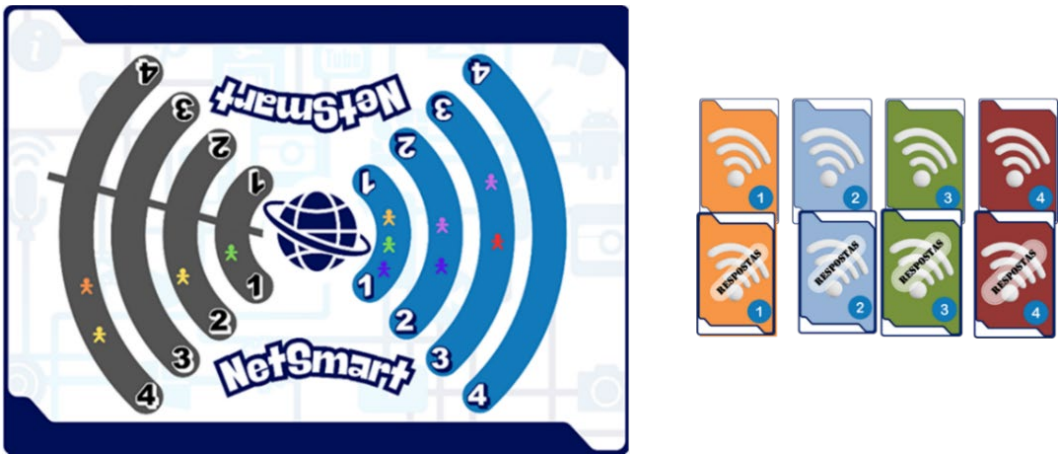

Figure 1: *NetSmart* board and components

Gameplay involves small groups (3 to 5 participants) who roll the die to select categories, collaboratively discuss answers, and reflect on outcomes. Correct answers earn team points; incorrect ones award points to the board, representing the "challenges" of the digital world. This game mechanic supports social learning, critical thinking, and emotional safety – features identified as essential for older adult learners (Gee, 2020; De Schutter, 2023).

Accessibility was a priority: all cards were printed in large format (12cm × 8.5 cm), laminated for reusability, and designed with removable adhesive labels for continuous content updates.

3.3 Intervention Procedures

The intervention occurred over six weeks (from January to February 2025), with weekly in-person sessions lasting from 75 to 80 minutes. Each session followed a three-phase structure: (1) a brief conceptual introduction; (2) group gameplay; and (3) a facilitated discussion. The first session was a full-group demonstration. From the second week onward, participants were split into smaller groups for structured, turn-based play.

Facilitators guided the experience by reading questions aloud, encouraging discussion, clarifying concepts, and supporting reflection. Their role aligns with research emphasizing the importance of pedagogical mediation in GBL settings – especially where adult learners exhibit diverse cognitive, motivational, and emotional profiles (Munoz et al., 2019; Whitton and Langan, 2019).

At the end of each session, scores were shared, and informal feedback was gathered. These post-session reflections contributed to a broader understanding of learning engagement and group dynamics.

3.4 Data Collection and Analysis

Participants completed a digital literacy questionnaire before and after the intervention. The survey measured self-perceived confidence and ability in performing digital tasks aligned with the game content. Such instruments are widely used in older adult digital inclusion research, as they capture both competence and affective dimensions (Kueider et al., 2012; Zou et al., 2021). It was composed of 22 items and based of previous approaches to measure media and digital literacy, developed with different populations (Costa et al., 2018), while adapted for the characteristics of older adults. Table 1, in the results section, presents the 22 items gathered both in pre- and post-GBL intervention with *NetSmart* (see columns "Item no." and "Item text"). Those were answered through a 5-point Likert scale.

Prior to participation, all individuals were informed about the objectives, procedures, potential risks, and benefits of the study. Written informed consent was obtained from all participants in accordance with ethical research standards.

Due to the ordinal nature and non-normal distribution of the data, the Wilcoxon signed-rank test was applied to evaluate significant differences in pre- and post-intervention scores. These tests and descriptive statistics were computed using JASP (Version 0.19.3).

4. Results

As explained above, a first exploratory step of the statistical analysis expressed that all the variables of the questionnaire with potential significant differences had a non-normal distribution – through Shapiro-Wilk testing ($p < .05$) – Wilcoxon signed-rank test was adopted to test differences between pre- and post- intervention, as well as medians for descriptives statistics. This procedure was, therefore, calculated for the 22 variables in the study (see Table 1 items). The full results are presented in Table 2.

Table 1: Full questionnaire items and results from the Wilcoxon signed-rank of the pre- and post-intervention questionnaire (*N* = 42)

Item	Item text	Pre-Intervention Median	Pre-Intervention Median	W	Z	p
1	Browsing the internet for information.	4.0	5.0	12.0	-1.580	.112
2	Downloading and installing apps on your mobile phone.	3.0	4.0	4.5	-2.344	.015
3	Use social networks such as Facebook, Instagram or Tik Tok.	4.0	4.0	38.5	-0.039	1.00
4	Create and use secure passwords.	3.0	3.0	56.0	-1.285	.190
5	Identify fake or dubious news.	2.0	3.0	45.5	-0.439	.677
6	Use an email to send and receive messages.	4.0	5.0	6.0	-1.680	.098

Item	Item text	Pre-Intervention Median	Pre-Intervention Median	W	Z	p
7	Play online games.	3.5	4.0	32.0	-1.287	.199
8	Using WhatsApp to send messages or make calls.	5.0	5.0	7.5	-1.099	.301
9	Understand what cookies and terms of conditions are on websites.	2.0	3.0	24.0	-1.177	.241
10	Protect my devices (computer and mobile phone) with secure passwords.	2.0	3.0	35.5	-1.067	.288
11	Configure basic settings on my mobile phone, such as Wi-Fi or volume.	4.0	4.0	33.0	-0.471	.644
12	Identify and not share fake news.	1.0	3.0	23.5	-1.821	.067
13	Send emails with attachments.	4.0	5.0	7.0	-1.540	.138
14	Educate friends and family about good online safety practices.	2.0	3.5	27.0	-2.120	.033
15	Use games as a tool to learn new things.	1.0	3.0	16.0	-2.291	.020
16	Organise documents and digital files in folders on my computer or mobile phone.	2.0	2.5	22.0	-1.642	.098
17	Update applications and operating systems to keep my devices safe.	2.0	3.0	7.0	-2.090	.037
18	Use cloud storage services (such as Google Drive or OneDrive) to store documents.	2.0	3.0	23.0	-1.255	.208
19	Make secure passwords.	3.0	3.0	56.0	-1.285	.190
20	Recognise and avoid fraudulent links, messages and emails.	2.0	4.0	48.0	-1.034	.303
21	Play video games on the internet.	2.0	4.0	13.5	-2.448	.013
22	Connect online (social networks) with people who like the same things as me.	3.0	3.0	15.5	-1.556	.126

The obtained results, although not uniformly, show the potential impact of *NetSmart* in some specific skills and aspects of older adults' digital literacy. First, item two ("Downloading and installing apps on your mobile phone") showed significantly higher values from the pre-questionnaire (M = 2.68; SD = 1.36) to the post-questionnaire (M = 3.40; SD = 1.19); W = 4.5, Z = -2.344, p = .015. Item fourteen ("Educate friends and family about good online safety practices") also presented impact from the *NetSmart* game-based intervention with significantly higher results between the pre-intervention (M = 2.22; SD = 1.34), and the post-intervention (M = 3.08; SD = 1.38); W = 27.0, Z = -2.120, p = .033. Moreover, also item fifteen ("Use games as a tool to learn new things") presented similar results, with significantly higher values of self-perceived ability in post-intervention (M = 2.83; SD = 1.34) than in pre-intervention (M = 1.87; SD = 1.27); W = 16.0, Z = -2.291, p = .020.

Two more pairs of pre- and post-intervention variables presented significant differences. Item 17 ("Update applications and operating systems to keep my devices safe") presented significantly higher values between the pre-GBL intervention moment (M = 2.16; SD = 1.29) and the post- GBL intervention moment (M = 3.00; SD = 1.45); W = 7.0, Z = -2.090, p = .037. Similarly, item 21 ("Play video games on the internet") also showed significantly higher values from the pre-questionnaire (M = 1.84; SD = 1.18) to the post-questionnaire (M = 3.08; SD = 1.44); W = 13.5, Z = -2.448, p = .013.

For the remaining items of the questionnaire no statistically significant differences were found.

5. Discussion

The present study intended to address the potential of *NetSmart* in promoting the digital literacy of older adults, through the development of a case study. Through this quasi-experimental approach, it is possible to highlight its impact in some of the self-perceived skills of the target audience's digital literacy and related aspects, although not I all the tested items. Most specifically, this analogue game presented a relevant impact in enhancing how older adults perceive their ability to keep their own devices' safety settings, through updates, and through their ability to install the required apps. Moreover, the findings suggest a potential multiplier effect of the *NetSmart* game, as participants reported a significantly increased ability to educate and support their friends and family on safe online practices following the intervention. This perceived shift indicates that such interventions may extend their impact beyond individual learning, fostering knowledge transfer within participants' social networks. Notably, this outcome aligns with existing research highlighting the role of GBL in promoting intergenerational interaction and communication between older adults and their family members (Wu et al., 2020), as well as supporting cross-generational learning dynamics (Perim et al., 2024).

The remaining results of this study further emphasise the relevance of games and playfulness in the life contexts of older people, and how GBL can capitalise on this. Firstly, after the game-based intervention with *NetSmart*, participants felt more able to use games as tools to learn new things, which highlights a certain notion of process transferability to other games and even contexts. Moreover, the differences found on their perceived ability to play video games on the internet after the intervention also show how analogue and digital games common environment – "the magic circle" (Huizinga, 1949) – also reinforces a certain transferability of their interest in playfulness from analogue through digital environments. By feeling safer playing and more digital literate, they also felt more able to play other types of games, which might assume a relevant role in their free time occupation.

5.1 Limitations and Future Directions

Although the study presents relevant findings, it is a bounded system approach (case study), emphasizing the context dependency and difficulty generalizability of those. Moreover, the adoption of a *quasi*-experimental research design – with no control group – and the lack of transversal impacts in all assessed skills are also worth mentioning.

Future studies should target these issues, while also triangulate the players' self-perceived skills, respective impacts, and actual skills assessments, through task completion and knowledge tests.

The team is currently working in the final mixed-methods results of this research, which will also explore in-depth the gaming sessions, the players behaviours and performance, as a path to explain the different impacted skills, as well as the ones without significant differences.

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Ethics Declaration: This study did not require formal ethical clearance. However, it was conducted in accordance with strict ethical standards to ensure the protection of participants' rights and privacy. Informed consent was obtained from all participants after clear communication of the study's objectives and potential risks. Participant anonymity was maintained through data anonymization, and appropriate accommodations—such as visual aids and flexible pacing—were offered to support individuals with cognitive or physical limitations.

AI Statement: This article was proofread and edited for language clarity using Grammarly and Generative AI tools. These tools were employed solely for linguistic enhancement, with no impact on the content, arguments, or conclusions. The authors, for whom English is not the primary language, retain full responsibility for the work's intellectual integrity.

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Managing Resources and Reducing Greenhouse Gas Emissions Through Game-Based Learning to Achieve Zero Emission Farms

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Abstract: Farming and agriculture have been identified as a major contributor to greenhouse gas emissions. Climate calculators have been developed to help farmers assess the amount of greenhouse gas emissions for specific activities. Despite the possibilities to calculate emissions and concerns about climate change and reduction of emissions, there is a knowledge gap in understanding the trade-offs related to specific resources and taking specific actions. More importantly, there is a need to understand the impacts of taking a specific action, resource use and how to manage emissions over time to achieve zero emission farming. In this paper, we describe two game concepts based on a climate calculator that is used to teach students in an agriculture school. The aim of the games is to engage students and to enhance the understanding of the consequences of actions in farming and agriculture, and to manage the resources to achieve zero emission farms efficiently. The learning goal for the first game is to understand the greenhouse gas emissions and the consequences of taking an action or a combination of actions. The learning goal of the second game is to manage the greenhouse gas emissions in a farm over time through the use of available resources. The game mechanic virtual currency is used as points that the player has to manage, and it aims to encourage players to learn trade-offs in managing a farm and the available resources. Both game concepts use cards to represent actions and the consequences of actions are calculated as greenhouse gas emissions using a climate calculator. Both games are designed as digital games, in collaboration with an expert and a teacher from an agriculture school. The game concepts have been evaluated by the expert.

Keywords: Zero emission farm, Climate calculator, Simulation games, Game-Based learning, Expert evaluation

1. Introduction

The drive to create zero emission farms is important as farming contributes to 11% of global Green House Gas (GHG) emissions (Food and Agriculture Organization of the United Nations (FAO), 2020). Reducing the emissions in agriculture with integrating new technologies through carbon sequestration, renewable energy sources, smart grids and heat recovery along with new farming methods such as agrivoltaics, precision livestock farming and manure gasification can be used to reduce emissions. Design thinking, innovation and digital technologies are used to create innovative solutions and improve production (Berntzen and Florea, 2022 , Florea et al., 2023). Furthermore, climate calculators have been developed to help the agricultural services to evolve to a more sustainable future (Colomb et al., 2012).

Educational games have become an important part of adult education and games are perceived as more engaging and effective than traditional coursework. Games also provide a safe environment to fail and develop both critical thinking and gain a diverse set of experiences (Oliveira et al., 2013, Petersen and Ekambaram, 2012). Educational theories argue that people learn better when placed in authentic contexts and are given the opportunity to make decisions and interact in the virtual world within the game.

Farming games engage several adults as it promotes a certain culture that goes beyond farming skills (Sutherland, 2020). Digital farming games shape public perceptions of agriculture by offering both educational and recreational experiences. Educational games can promote the understanding of sustainable farming practices and long-term decision making. Most games that focus on agriculture focus on the crop farming aspect of agriculture and many focus on a limited version of livestock. Many farming games lack the educational aspect and focus on reducing GHG and zero emission technologies and creating a more sustainable agricultural sector. Even fewer of them focus on agricultural students and how they can be motivated and engaged in using Game-based Learning to learn the relevant concepts. Our work therefore seeks to fill the gap in knowledge by creating digital games for learning about farming, and investigates how these impact agriculture students' learning abilities, motivation and engagement with regard to sustainability and zero emission technologies.

Despite the possibilities to calculate emissions and concerns about climate change and reduction of emissions, there is a knowledge gap in understanding the trade-offs related to specific resources and taking specific actions. More importantly, there is a need to understand the impacts of taking a specific action, resource use

and how to manage emissions over time to achieve zero emission farming. One of the main challenges in learning about farming is that, in real life, actions and measures taken on a farm take time before their consequences could be determined. This can make it hard for students to understand the knowledge. Financial resources also play a factor in achieving change in a farm. There is a growing need for future farmers to deal with these challenges. In this paper, we describe two game concepts based on a climate calculator that is used to teach students in an agriculture school. The aim of the games is to engage students and to enhance the understanding of the consequences of actions in farming and agriculture, and to manage the resources to achieve zero emission farms.

This work is based on two Masters students' projects and the main aim is to obtain a proof of concept for games to implement the knowledge captured in a climate calculator and convey that to students studying agriculture and farming. The basic game concepts and game mechanics have been designed and implemented for both games to obtain a proof of concept. This paper describes the overall game concepts and their design process. An expert evaluation confirms that the games are aligned with the learning goals for the students, and they have the potential to engage and support learning.

2. Farming Games for Learning

Simulation games on farming are designed for entertainment and education purposes. "Stardew Valley" is a computer game for simulating farm life. Players take the role of a character who inherits their grandfather's farm. It is an open-ended game where players manage a farm by clearing land, growing seasonal crops and raising animals (2025). It can be played as a single or an online multiplayer game and includes several achievements to enhance engagement (Sijabat and Grahita, 2021). Another simulation game is "Farm Together" that allows the player to create a farm by selecting the plot of land to start the farm, select crops, plant and harvest them. This is a multiplayer game aimed to promote fellowship. It incorporates the aspect of real time by making the players wait for some time before their plants grow. Another game that supports farming is "Plant Tycoon", and engages players through achievements from caring for their plants (Sijabat and Grahita, 2021). These video games lack the complete picture of farming, the pedagogical aspects and they do not address sustainability issues such as GHG emissions.

A suite of interactive farm simulation computer-aided games that is used in the education of farming systems is "Risky Business" (Stewart et al., 2000). An issue, such as a farm affected by salinisation, is presented to the players and they have to solve them. While there are several entertainment games that are based on farms and agriculture, e.g., Farmville, the game "Roots of Tomorrow" appears to be the only one that addresses sustainable farming. It is an educational game to raise awareness and teach the general public about the strategic management of farms and about sustainable agriculture (Botadkar, 2022). The objective of the game is to transform the farm within ten years by upgrading and balancing the farmland's economic, environmental and social scores, and this is done by the players conducting farm related activities.

3. Method

The overall approach for designing the two games have been exploratory, iterative and using expert guidance. Both the games used the "gameplay loop" system, which builds upon the idea that a game has a series of loops that can be repeated and this idea was used for incorporating several rounds in the game. One of the games used the LEAGUÊ game design framework (Tahir and Wang, 2020a, Tahir and Wang, 2020b) more explicitly in the design of the learning goals and the cards used in the game. LEAGUÊ is a method of using ideation cards to design and identify elements of a learning game. The framework is split into different activities, which supply cards with suggestions on how to define different aspects of the game. The LEAGUÊ framework provides a means to analyse, design and evaluate the game.

An expert has been consulted throughout the design and implementation phases. The role of the expert is invaluable as the game designers are not knowledgeable about the domain of application, i.e. zero emission farming. At the beginning of the projects, advice was sought to help us understand the domain of application. Then, a consultation was done to ensure that the design concepts made sense and that the climate calculator, on which the games are based, has been interpreted correctly. Altogether three meetings were conducted with the expert, two of which were face to face meetings. These meetings followed the pattern of asking the expert questions that had come up while working on the games for clarifications, showing the game design ideas and getting feedback and sometimes suggesting alternatives and asking advice as well as alternative approaches that may be relevant.

An expert evaluation has been conducted for both the games to obtain feedback on the knowledge content and to improve the design (Klas, 2012). The expert is also the designer of the climate calculator and the climate game and is also a teacher at the Agriculture School. The evaluation was conducted by presenting the game to the expert, followed by a discussion. The game was presented using a shared screen. A white board and large sheets of paper were used to support the discussions and ideas for new ways to visualise the content. The discussions were captured as notes during the evaluation and processed to identify recommendations for future improvements of the games.

3.1 Climate Calculator

The climate calculator is central to our game as it is the basis for the numbers and calculations used to show how measures and practices impact agriculture within the game. Hence, the climate calculator that is used by the agriculture school, that is designed for the relevant climate zone, was selected (Grønt kompetansesenter Mære og Skjetlein). When the users select an action in the game, the consequence of the action in terms of productivity or Carbon Dioxide equivalent (CO2e) emissions are calculated using the climate calculator. Thus, both the games include a component within the game that reflects the climate calculator; see Figure 1. The interface component of the game submits values to the climate calculator component, which provides the new values for the next state of the game. The interface component then structures the quantitative data and visualises it to the player in a manner that is easily understood by the player.

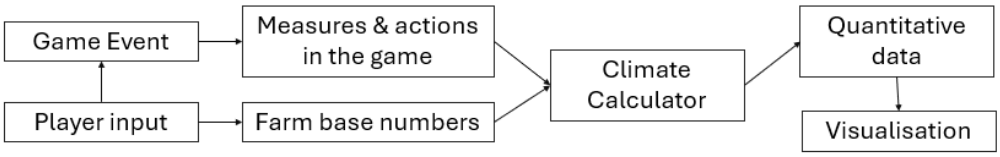

Figure 1: Climate calculator in the game

The current versions of the games do not use the full capabilities of the climate calculator as only a limited number of measures have been implemented in these prototypes. Emissions are calculated as CO2e rather than specific GHG as this is simpler.

4. Game Design

The main learning goal for both the games is to enhance the understanding of the consequences of actions in farming and agriculture, and to manage the resources to achieve zero emission farms. Hence, both games aim to support learning of actions or measures that could be taken on a farm that would help to reduce emissions and achieve a sustainable farm. Action cards have been used to support this learning goal, and these are designed from real life measures, and the players can see the consequences of individual actions instantaneously through a simulation based on the climate calculator. The target user group is the students of the agriculture school. The game is intended as a learning resource that could complement currently available resources and activities.

Both games are designed as single player games and are based on the climate calculator that has been developed by the Agriculture School, which calculates the emissions (Grønt kompetansesenter Mære og Skjetlein). The current versions of the games support the Norwegian language.

4.1 Game Concept 1 – Actions to Reduce GHG

The learning goal for this game is to learn about the different real-life measures, or actions, that could be taken on a farm to reduce the amount of GHG emissions and to understand the consequences of each action. In real life, many of the measures that could be taken would take time before their consequences are noticeable. Experimenting with the different measures and the possibility to see the consequences immediately within a game could enhance the learning possibilities. The goal of the game is to select actions representing real-life measures on a farm, in order to make the farm as environmentally friendly as possible.

A core pillar of the game concept is the “gameplay loop” system, which builds upon the idea that a game has a series of loops that can be repeated, typically with a reward towards the end of the repetitions. This game utilises cards to create a gameplay loop of “analysing cards, choosing a card, witnessing the effects of the action represented in the chosen card and repeating the process. Cards get shuffled and redrawn between

each loop; see Figure 2. A significant aim for making the loop system function properly is making sure it engages the player to continue playing.

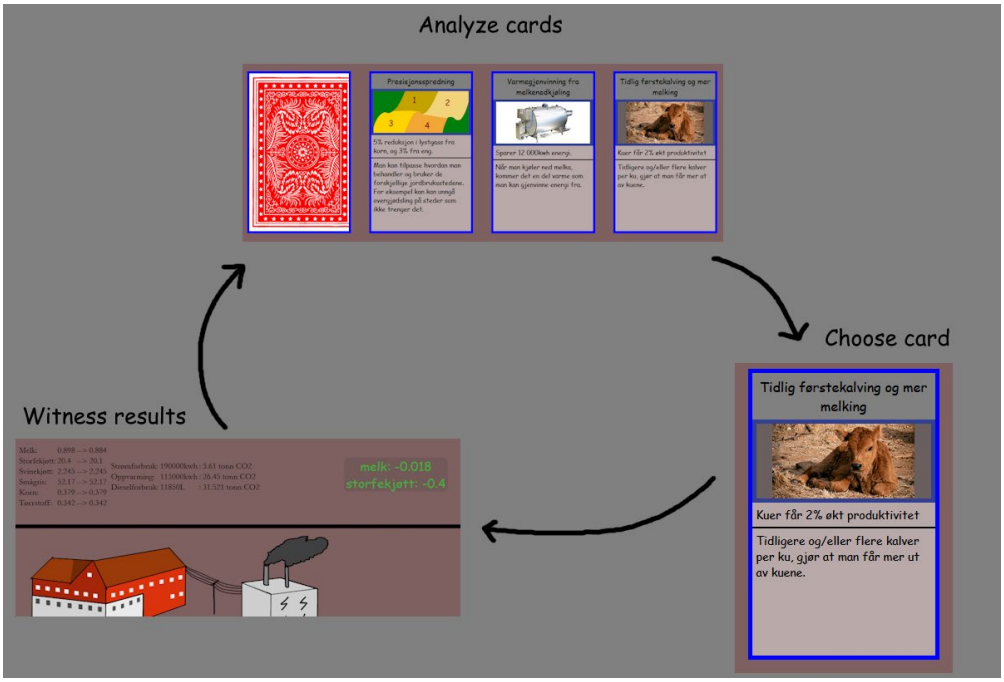

Figure 2: Core idea of Game 1

The game is played by selecting an action card which starts a loop, or a game round. Currently, a maximum of ten rounds are available in each game session, and each round includes a selection of a single action. This is intended to reflect that measures in real life are not free and implementing several or everything is difficult. Cards can primarily be picked to enhance the farm and make it more efficient. Secondly, they can affect the game loop itself by altering one of the loop areas. Players are able to see how many rounds and actions they have used and are remaining within each game round. Throughout this process, by utilising the loop system and encouraging multiple attempts at the game, the intention is that the player will retain the knowledge after playing.

Each action is represented as a card, which is divided into sections which provide different information about the specific action: a title, an image, a gameplay description and a description of what the action does in practice; see Figure 3.

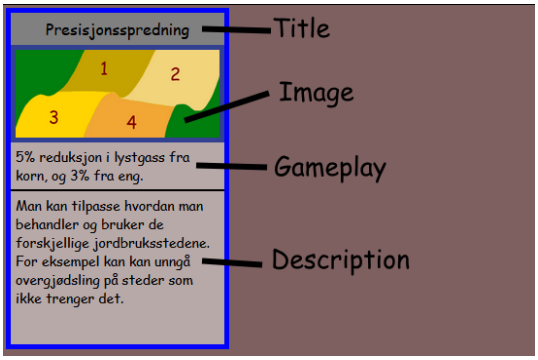

Figure 3: Design of an action card

As shown in Figure 2, a player gets three action cards to select from, referred to as “analyze cards”. A player could select 10 cards in each game. Once the player selects an action card, e.g., early first calving and more milking, the consequences of the action are shown as “Witness results”, which consists of two parts: a visual indication and quantitative data to indicate production and emissions; see Figure 4. The quantitative data, shown on the left hand side of Figure 4, indicates the change due to the action using an arrow, e.g., the top value shows that the milk (“Melk”) production has dropped from 0.898 to 0.884. The data shown in the middle

column shows emissions from energy consumption (“Strømforbruk”), heating (“Oppvarming”) and diesel consumption (“Dieselforbruk”), in tons of Carbon Dioxide Equivalent (CO2e).

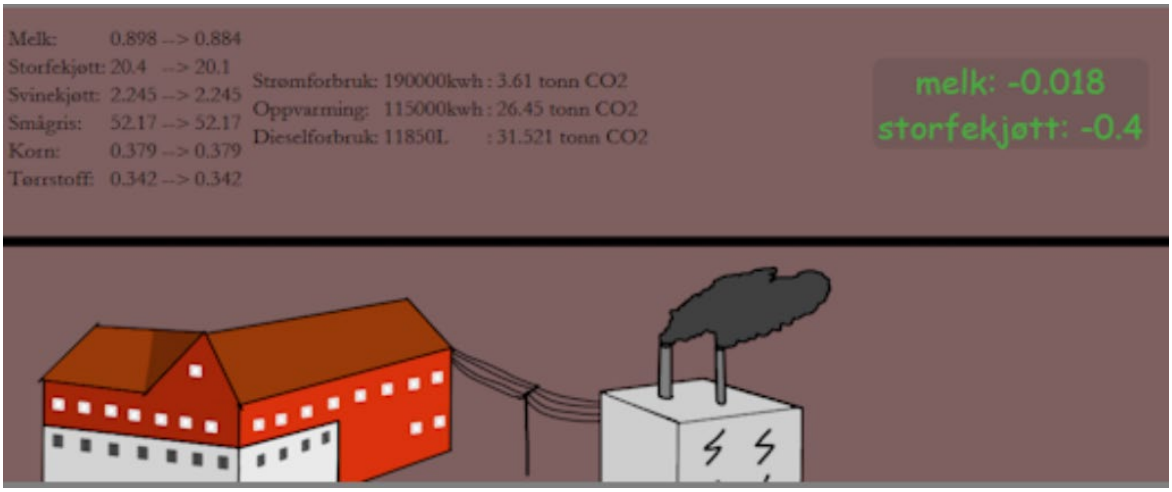

Figure 4: Consequences of an action shown as quantitative data and graphics

The current state of the game does not include scoring and one of the challenges in designing the scoring for the game is to value each action and determine which actions are better than others and how.

4.2 Game Concept 2 – Managing a Farm

The learning goal for this game is for agriculture school students to learn about zero emission technologies and practices in the agricultural landscape. The goal of the game is to reduce emissions while increasing production, creating a balance where the player must both increase their farm’s production and decrease emissions. The core idea in this game is on managing the available resources, depicted in the game as points, to find a balance between investing in increasing production, e.g., more cattle, and decreasing emissions, e.g., through new technologies such as renewable energies. The points represent a farm’s economic resources, and hence, they are used in the game to implement changes on the farm and are a representation of the monetary budget a farm could have to implement technologies or practices in the real world. This allows the player to purchase either an expansion to their farm, in the form of more cattle, land or other. Or they could use the points to invest in measures such as new technologies or practices that help create a more sustainable farm and farming practice.

The points are also used to unlock the different measures and expansions in the game. Because the player has a limited number of points, it is up to the player to decide how best to spend them. The points are based on the production of the farm and active measures from grants or other avenues. Hence, they consist of points that come from the economy of the farm and extra points that could be, e.g., a governmental grant or a bonus.

At the start of the game, the player is allocated some points. Each game has ten rounds, where each round represents a year. For each round, the player can take two types of actions which are to implement an enhancement measure to increase production, or take an action to reduce emissions, both of which are represented in the game by Action Cards. Each action card has a cost associated with it as in real life, and this means that the player will have to use one or more points. Hence, the player has to manage the points during the game. The aim for the player is to balance the farm’s production and emission over ten years. The player can also choose to view the status of the farm on the “My Farm” page.

At the beginning of the game, the player is provided an overview of the status of the farm and allocated points. The player is then presented the possibility to plan for the next year with the options to take an action, enhance or view the status of the farm. A part of the screen that shows some of the actions is shown in Figure 5. Depending on the choice, the player is then given an overview of the possible actions, or enhancements or the current status of the farm. The list of actions or enhancements are given as a set of cards where each card shows the name of the action or enhancement, a picture, results achieved during the year by taking this action and the value for many years and the number of points it costs. By clicking on the picture on the card, a detailed explanation of the action and consequences are available. Examples of the action cards are shown in Figure 5.

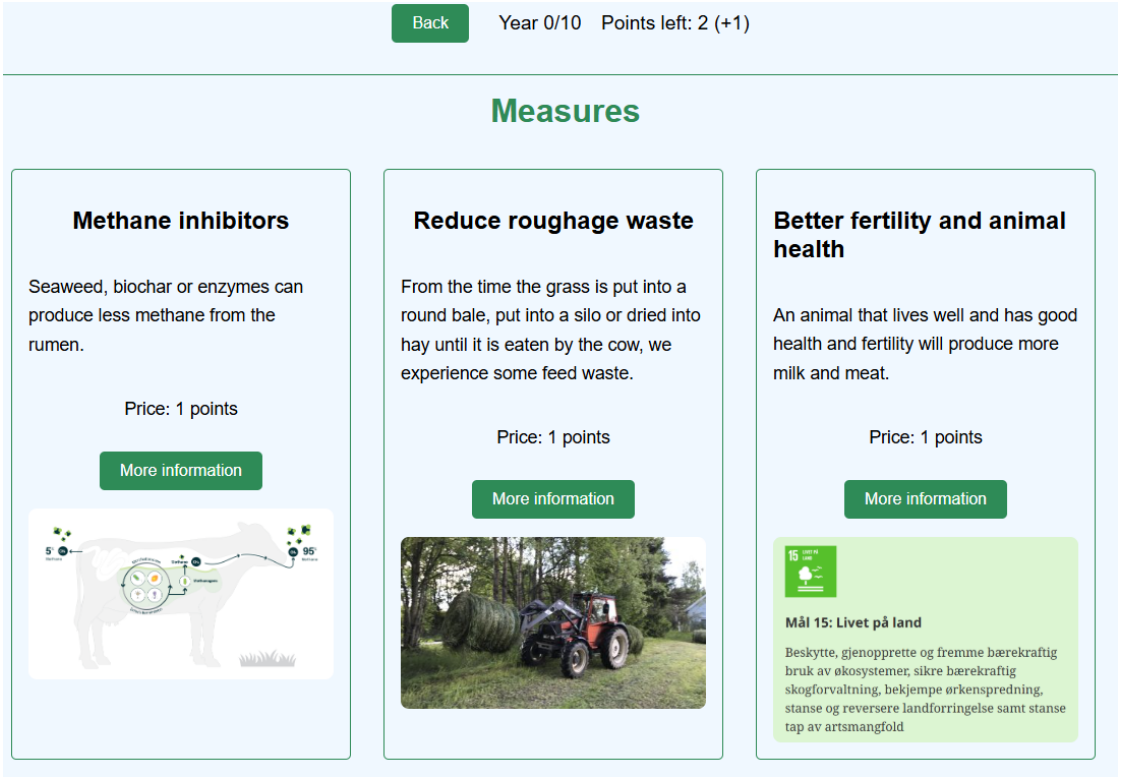

Figure 5: Main Page of Game 2

The consequences of the selected action or the enhancement are calculated using the climate calculator to determine the new state for each round, which is shown on the "My Farm" page; Figure 6. This page includes information about the area of the farm used and the quantity of products (e.g., no. of cows), total amount of emissions in tons of CO2e, production (e.g., kg of milk,) and emission per product (e.g., how much of the emissions come from milk). In addition, the breakdown of production and emissions are also shown as pie charts on the same screen. The no. of the round and the points that the player has remaining are shown on the top of the screen.

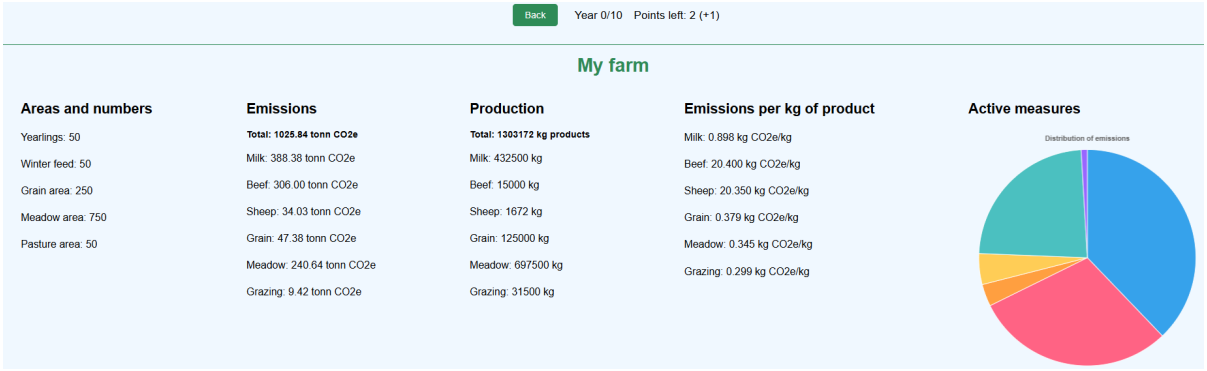

Figure 6: Consequence of an action or enhancement

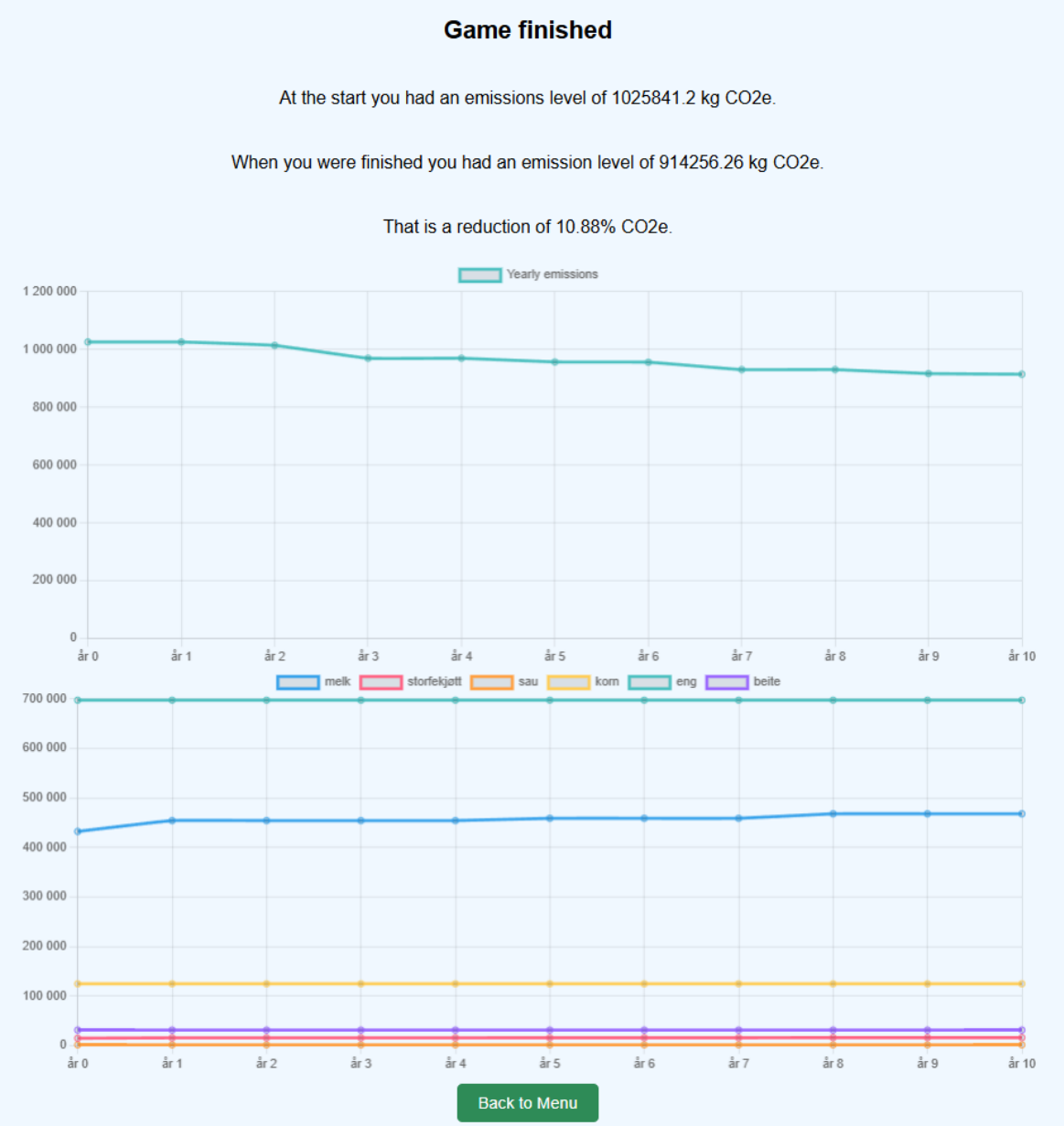

Figure 7: End state of the game after ten rounds showing CO2e emissions each year. Top graph shows the total amount of CO2e emissions; bottom graph shows a breakdown of emissions

After ten rounds, the player can view the actions and enhancements that have been applied and see their progression. This is shown in the two graphs in Figure 7 where the vertical axes show the emissions in tons of CO2e and the horizontal axes show the game rounds (or years). Information about the emissions at the beginning and the end of the game are shown; in this case 1,025,841.2 kg CO2e at the beginning, and 914,256.26 kg CO2e at the end of the 10 rounds, showing a 10.88% reduction of CO2e.

The quantitative values and the graphs are designed to give an indication of a score. In particular, if several individual players play the game, they could compare their quantitative values and the graphs at the end of the game, after ten rounds.

5. Expert Evaluation

Both the game concepts have been evaluated by the expert who had also been consulted during the design phase of the games. The expert evaluation was conducted to obtain feedback on the knowledge content and to improve the design, and to confirm that the game concepts have potential to support the learning goal. As a first step, the actions or measures and the consequences of the actions that were used in both game concepts

meet the learning goals for the students in the agriculture school. Beyond that, a challenge still remains on how to balance the different actions.

It was also clear that the motivation of the player is important for games such as these, and that making something engaging can be challenging. It was recommended to keep the idea of displaying both quantitative data and visual changes to the farm (e.g., see Figure 4), but also with the caveat that it can be difficult to convey certain concepts through that alone; e.g., what makes a cow more environmentally friendly, visually speaking? The feedback is summarised as a set of recommendations for improving the game:

- User Interface:
- *Provide clearer visual cues or warnings when the player has no more points to purchase a measure on their farm (in game 2). This would help the player understand that they have used their resources and prompt them to go to the next round.*
- *The game was easy to manage in the early stages. However, some areas were hard to identify, such as the limitations of undoing actions and where to proceed to the next turn.*
- Feedback mechanisms:
- *Feedback to the user and communicating the state of the farm through qualitative data such as progress in the game should be distinguished. (The current game versions do not include explicit feedback, hints or help to the player.)*
- *A graph could help players identify when they invested in a measure and how it impacted the farm, in such a way that a player could more intuitively understand what their choices mean.*
- *A representation of the state of the farm, e.g., a visual metaphor, could be helpful.*
- Game design and game mechanics:
- *Clearer distinction between farm expansions and other measures, and explanations of these are recommended. One suggestion was to increase the number of points per round so that there would be more to do during the first round and enable strategic decision making.*
- *Scoring design: points could be given separately for production and climate improvement. Bonus points could be given if player does/doesn't look up theory and hints.*
- Educational aspects and theoretical integration:
- *Connect domain knowledge and theory at possible places in the game, e.g., in game 2, the graph displaying emissions per round could have the specific action or enhancement, economy and relevant theory made available to the player on each value displayed on the graph.*
- *The player could be asked a random question or recommended to read theory after a set no. of actions and the player can only proceed after fulfilling this (e.g., for game 1).*
- *Including subsidies, carbon credit and economy was suggested.*
- *A leader board that shows different production and the reduction in emissions to create competition, to engage students.*
- *The division between information given and discovering solutions was commented on. One suggestion was to start with less information on the card, then present theory. Hints or help could be made available for the player as needed.*
- *Need careful consideration of actions that need to be done continuously, e.g., fodder, or sequence of actions that need to be carried out for effective results, and other similar domain related specific knowledge.*
- Motivation and user engagement:
- *Possibility for students to question and critique.*
- *Clear learning objectives that show how these things from the game work in the real world and what challenges there are in agriculture.*
- *Use of a reputation system which could affect how competitive the environment is and how much subsidies are given to a farm.*

6. Conclusion and Future Work

In this paper, we describe two game concepts based on a climate calculator that is used to teach students in an agriculture school. The aim of the games is to engage students and to enhance the understanding of the consequences of actions in farming and agriculture, and to manage the resources to achieve zero emission farms efficiently. The learning goal for the first game is to understand the greenhouse gas emissions and the consequences of taking an action or a combination of actions. The learning goal of the second game is to manage the greenhouse gas emissions in a farm over time through the use of available resources. Both game

concepts use cards to represent actions, and the consequences of actions are calculated as CO2e emissions using a climate calculator. Both games are designed as digital games, in collaboration with an expert and a teacher from an agriculture school. An expert evaluation of both games confirmed that the game concepts had potential and the knowledge contents in the game, presented as action cards and consequences of taking an action, were aligned with the learning goal for the target audience, who are the students in Agriculture schools. The expert evaluation also confirmed that the knowledge in the climate calculator was used correctly and the game had the potential to increase awareness about actions and their consequences to production and CO2e emissions. The feedback and recommendations from the evaluation are currently being reviewed.

Currently only emission reduction is considered for the games. Ideas for future developments include supporting multiple languages, stimulating multiple senses and using multiple media (e.g., movement, colour and text simultaneously) to increase the likelihood that a user retains information. For both games, the scoring needs to be designed and motivational aspects such as leaderboards will be considered. We also plan to evaluate the game with the target player group to see how the game could affect their learning capabilities and to identify how the game could be used both in and outside the classroom, and a design workshop is planned to identify potential improvements in the game designs and user interfaces.

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Ethics declaration: Ethical clearance was not required for this work.

AI declaration: No AI was used in this paper.

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Level-Up Tutor-Qualification: A Digital Escape Room for Game-Based Learning in Higher Education

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Abstract: This paper presents the development and formative evaluation of an early-stage prototype of a digital escape room designed for student tutor training at TUD Dresden University of Technology. The study focuses on usability and motivation rather than learning gains. The escape room simulates typical challenges encountered in the everyday life of student tutors, such as dealing with technical issues, structuring seminars, and responding to disruptions. The scenario places players in the role of a tutor who must prepare a seminar room within a limited timeframe while overcoming realistic obstacles. Each task must be solved logically and sequentially, guided by minimal interface elements and visual feedback. The challenge lies in identifying problems, making decisions under time pressure, and learning through trial and error, elements that mirror real tutoring situations. The design is anchored in the principles of flow theory (Csikszentmihalyi, 1990) and deindividuation theory (Zimbardo, 1969; Joinson, 2001) to enable engaging and supportive learning. The prototype was evaluated in a two-stage process: qualitatively using the thinking-aloud method, and quantitatively via an online survey on self-efficacy and usability. Initial feedback shows high acceptance of the format and a strong motivational effect, particularly due to the immersive setting, clear progress indicators, and gamified elements. Nevertheless, findings also revealed areas for improvement, most notably in onboarding, clarity of task instructions, and technical stability. Planned improvements directly address these points through redesigned task prompts, enhanced navigation aids, and an introductory onboarding module. The project demonstrates how such game-based formats can serve as scalable, accessible tools for tutor training in higher education.

Keywords: Digital escape room, Gamification, Problem-Based learning, Tutor training, Higher education didactics

1. Introduction

As an important interface between teachers and students, tutors are responsible for knowledge transfer, moderation and organisational support. However, they often lack formal didactic training or teaching qualifications. As preparation for tutorials often focuses solely on subject content or organisational aspects, many tutors feel overwhelmed when they start teaching and are unable to respond effectively to everyday situations. This uncertainty can negatively impact the quality of teaching. Furthermore, due to the dual demands of their own studies and teaching activities, they often lack the time for traditional, theory-focused training formats that are inflexible and often impractical. In light of these circumstances, the TUD developed a digital escape room to encourage tutors to learn in a motivating, playful and action-oriented environment. It prepares tutors for the typical challenges involved in preparing for and conducting tutorials through experience-based learning. In a virtual room, users engage with situations that also arise in everyday university life, such as faulty technology, unclear room organisation, time pressure and lack of accessibility. The aim is to promote confidence and problem-solving skills through exploratory learning and direct feedback when solving tasks.

Drawing on elements from game-based learning research, the project combines these with the didactic principles of university teaching and the technical capabilities of Unity[1], Blender[2] and Spatial.io[3]. The escape room is web-based, accessible and multilingual, and can be used on any device.

This article outlines the didactic concept and technical implementation of the prototype. It also describes the two-stage evaluation process, which incorporates qualitative and quantitative usability data. The aim is to evaluate the potential of a digital escape room for tutor training and to present initial empirical findings on its use, acceptance and effectiveness. The next section provides a more detailed description of the background and the current state of research. The theoretical frame of reference is then explained in more detail to establish a

[1] Unity (https://unity.com) is a powerful development environment for creating 2D, 3D and virtual reality applications, which is particularly frequently used in game development and interactive learning.

[2] Blender (https://www.blender.org/) is a free, open-source 3D graphics suite for modelling, animation, simulation, texturing and rendering 3D objects and scenes.

[3] Spatial.io (https://www.spatial.io) is a platform for creating and exploring interactive 3D spaces directly in the browser. It allows users to design immersive virtual environments and integrate interactive scripts.

didactic framework and clarify the psychological basis. This is followed by a presentation of the prototype's design and technical implementation (Chapter 4). Chapter 5 describes the qualitative and quantitative evaluation methods in more detail, before Chapter 6 presents the results of the two-stage evaluation method. The following chapter discusses the results in the context of current research, theoretical considerations and concepts. Chapter 7 concludes with a summary and an outlook on future developments and further applications in the field of education.

2. Background and State of Research

The qualification of student tutors is a central task of university didactics. As a link between teachers and students, they make a significant contribution to promoting learning, social integration in study contexts and ensuring teaching quality (Zitzelsberger, 2019). A survey conducted at TUD in June 2024 (Ludwig, Pippig, Thamm, 2025) revealed that 86% of the tutors surveyed expressed a need for further training, with 68% highlighting key competencies such as classroom moderation, coping with challenging situations, course organisation, didactic structuring and the development of soft skills. In view of these identified challenges, the implementation of practice-oriented training methods is necessary to prepare tutors for their work as teachers. Inspired by the room of horror from medical training (Zimmermann, Schwappach, 2019), a digital escape game format was developed at TUD to test typical challenges in teaching, such as structuring seminars or dealing with disruptions and technical problems.

Game-based learning and gamification are often used to promote motivation and collaborative problem solving. Educational escape rooms take advantage of these characteristics by appealing to the cognitive and emotional engagement of learners. Research shows that escape rooms can contribute to deeper and more sustainable learning outcomes, especially due to the realism of the tasks set under time pressure (Pais et al., 2023). In higher education, escape rooms have so far been used primarily to liven up existing courses or in specialised subject contexts such as medicine or STEM subjects. The focus there is usually on teaching subject-specific content or training individual skills such as teamwork or time management. However, initial studies demonstrate the potential of digital escape rooms to promote skills relevant to university teaching (Zimmermann, Schwappach, 2019). Until now, however, escape rooms have hardly been used in the context of tutor training. The web-based escape game developed here closes this gap by making typical practical situations tangible. Tutors can thus be prepared for their diverse and often demanding role, with a focus not only on subject-specific content, but also on soft skills, self-organisation and stress resilience. Tutors can go through the escape room flexibly, regardless of location and time, which is an essential requirement given their often tight schedules. Thanks to its integration into a digital 3D environment based on Unity and Spatial.io, the format is not only easy to use, but also technically compatible with multiplayer options and extensions. This project extends prior work by applying the escape room concept specifically to tutor training, a domain where it has rarely been tested.

3. Theoretical Framework

The design of the escape room is based on three central theoretical approaches: Csikszentmihalyi's flow theory (1990); the problem-based learning approach; and Zimbardo's deindividuation theory (1969), as interpreted by Joinson (2001).

Flow theory describes a state of complete immersion and concentration, whereby learners actively engage with a task without being distracted by external factors. Flow occurs when the demands of a task are balanced with the learner's abilities. The learning environment must offer clear goals, immediate feedback, and an appropriate level of difficulty. When designing the escape room, time pressure and problem-centred tasks were employed to create a challenging yet feasible experience. This is made possible by a clear task structure and embedded clues. However, care must be taken to ensure that the time limit is appropriate and that the controls are understandable, in order to avoid overwhelming players. This playful learning principle makes use of situational learning, whereby knowledge is acquired in the context of everyday situations typically encountered by tutors, such as disorganised rooms, malfunctioning equipment, and time-related stress factors. This principle is complemented by problem-based learning approaches, in which learners actively and independently solve challenges instead of passively receiving information. Another effective principle comes from research on visual anonymity in the digital space. Drawing on Zimbardo's (1969) deindividuation theory and Joinson's (2001) subsequent empirical research, it has been demonstrated that anonymised digital spaces can increase the willingness to explore and make mistakes. For new tutors who have not yet established their role, a gaming environment without social observation can encourage experimentation. It can also help tutors who feel uncertain in face-to-face training and frequently compare themselves with others to get started. For this reason,

there are no plans to personalise the avatars or clearly identify them by player names in the game. Finally, the escape room can be viewed as an example of a 'cognitive apprenticeship' as defined by Collins, Brown and Newman (1989). Players implicitly observe what 'good preparation' means, try it out, receive situational feedback, and can revise their strategies. Through this process of experiencing and repeating problems, specialist and practical knowledge is built up. Learning is therefore most likely to occur when it is challenging but not overwhelming, and when learners have a personal connection to the learning content.

4. Didactic Concept and Technical Implementation of the Prototype

The project aimed to develop a digital, interactive learning format to prepare tutors for the typical challenges they face when planning and conducting courses, in a realistic yet playful environment. Players take on the role of a tutor whose seminar is due to start in 20 minutes. However, they find that the assigned seminar room is chaotic, with technical defects, misaligned chairs and missing materials, and there is no time for extensive preparation (see Figure 1). Players must get the room ready for class in time.

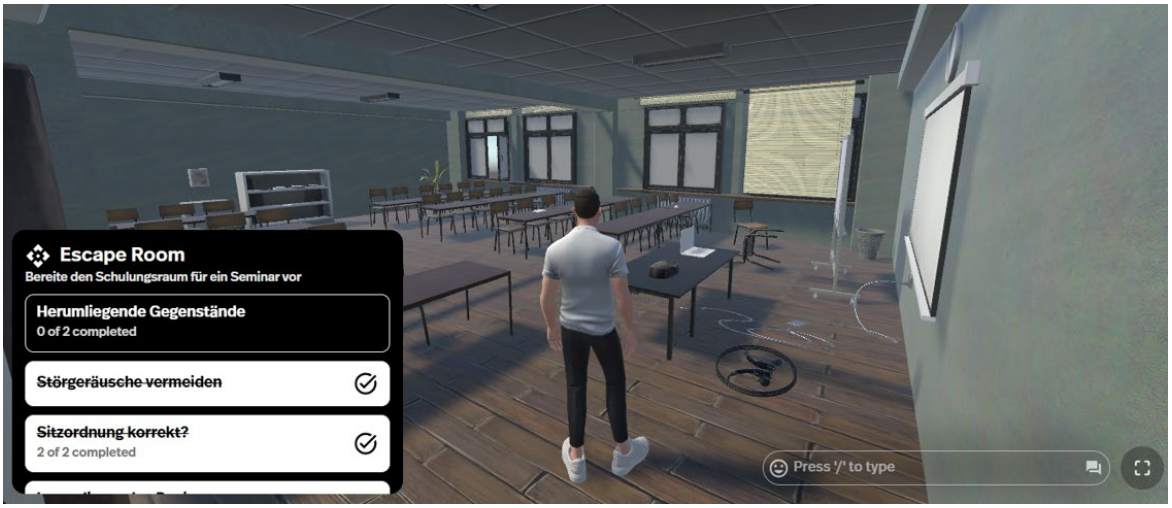

Figure 1: Game environment of the digital escape room (own illustration)

The tasks were selected based on didactic principles to address key areas of competence frequently required of tutors: organisation, technical proficiency, problem-solving, time management, and communication sensitivity. Situations that regularly occur in real teaching contexts, but which are often not systematically addressed in training courses, were deliberately chosen. The aim is to encourage learners to analyse and respond to authentic problem situations. The tasks are divided into so-called 'pitfalls' that must be worked through one after the other and assigned to typical problem areas. These include technical issues such as an unconnected laptop or a non-functioning projector, organisational issues such as a whiteboard with no pens or paper, and communication issues such as an open window with street noise or a muted microphone for online participants. These types of tasks represent common but often unforeseen hurdles in tutorials that require quick, goal-oriented action. To enable accessibility for all, the environment has been designed so that all tasks can be completed in a linear fashion and without prior knowledge. A progress bar shows the status of the remaining tasks, thus supporting self-directed learning. The linearity of the tasks was chosen deliberately to enable structured evaluation of usability, particularly during the initial testing phase. However, non-linear variants are also being considered for the future, to allow for situation-specific prioritisation. After successfully completing a task, players receive immediate feedback, such as visual confirmation, a progress bar or confetti, to promote intrinsic motivation and support orientation within the game.

The escape room was technically implemented using the Unity game engine and the Spatial.io Creator Toolkit, supplemented with our own 3D models from Blender. The seminar room was modelled to scale and imported into Unity in glTF format. Interactive objects were given triggers and specific action options using Unity's visual scripting system. A custom progress system comprising individual 'quests' was programmed to control the game flow and save progress. The minimalist user interface focuses attention on what is happening in the room and is derived from Cognitive Load Theory (Sweller et al., 2011). The environment can be used directly in the browser via Spatial.io, which is an important feature for enabling tutors to access it regardless of their location or the time. All interactions are performed via keyboard or mouse click. As soon as interactive objects enter the radius

of action, they are marked with the relevant action options. Playing time is limited to 20 minutes to simulate a realistic seminar situation.

5. Evaluation Methods

To further improve the first prototype and evaluate the motivational quality of the digital escape room, a combination of qualitative and quantitative methods was employed. Qualitative usability tests involved analysing individual game runs and conducting follow-up interviews, while quantitative data was collected during two workshops. The aim was to gain insight into the user experience and collect feedback on usability and implementation. This initial feedback is not intended primarily to measure effectiveness, but rather to inform the further development of the game from technical and didactic perspectives.

Combining both methods allowed us to gain individual insights into the perceptions and user experience of the test subjects, as well as collecting standardised feedback on the design, comprehensibility, and motivational effect of the format. The qualitative method, particularly the thinking-aloud technique, enables targeted collection of information about thought processes, interaction problems and intuitive reactions, especially at the beginning of development (Rubin, Chisnell, 2011). This enables usability issues and signs of frustration during task processing to be identified as early as possible.

In addition, quantitative surveys, such as standardised questionnaires (e.g. the System Usability Scale), provide comparable user assessments and enable an initial classification of the user-friendliness and motivation involved in the overall experience. Combining these two approaches is particularly meaningful as it allows qualitative impressions to be combined with quantitative evaluations. This enables the development process to be viewed from both the users' perspective and a broader analytical perspective. This approach has proven particularly useful in the prototypical development of digital learning formats.

5.1 Qualitative Results: Think-Aloud Method and Interviews

In the first phase, four usability tests were conducted using the think-aloud method. Four test subjects were asked to complete the first prototype of the escape room in a quiet environment, saying aloud what they saw, thought and did as they did so. These sessions were documented using a screen recording that included mouse pointer tracking and audio recording.

This method aims to identify problems in user guidance and gaps in understanding tasks. The method is intended to demonstrate the intuitiveness of the game and identify where usability problems occur. This enables initial conclusions to be drawn about user behaviour, particularly in the early stages of development, and allows technical weaknesses to be identified at an early stage. Four test subjects were selected for the sample, as four to five tests are sufficient to identify most error sources and usage problems, as suggested by Nielsen et al., 1993. As the prototype is at an early stage of development, the initial focus of the test was on a qualitative in-depth analysis of usability rather than on achieving the highest possible number of cases. After playing the game, the test subjects were asked about their overall impression, motivation, any disruptions, and the relevance of the content in a semi-structured interview. The qualitative data were transcribed, systematically coded, and evaluated using a category system comprising seven inductively formed categories. These categories are: graphic design and atmosphere; task comprehension; orientation and control; motivation and enjoyment of the game; technical problems; realism of the tasks; and suggestions for improvement. During the initial test games, it became clear that all test subjects found the start of the game too abrupt, as an explanation of the game principle and general gameplay was missing. In many cases, the test administrators also had to explain how to use the controls. Due to the lack of an introduction, participants often failed to recognise the tasks displayed at the beginning or overlooked them. The graphic design received positive ratings across the board, and the atmosphere was described as appropriate, albeit somewhat oppressive. This was acknowledged as being stylistically appropriate. Overall, the tasks were well understood, but some confusion arose from the choice of terms ('correct seating arrangement') or tasks that had not yet been fully implemented. The linear structure of the task sequence was also discussed. On the other hand, the realism and perceived relevance of the tasks were consistently rated positively. The high level of motivation and enjoyment triggered by the game was emphasised in particular. Elements such as the high level of interactivity and gamification were also perceived positively. Several participants expressed a desire to continue playing the game or working on further tasks: *'I wanted to continue.'* (Quote from Test Subject 2). While the majority described the controls in the room as successful, individual problems with the camera work were mentioned. The keyboard controls were considered intuitive, even by those with limited gaming experience. There were minor technical limitations, such as incomplete tasks or slight control issues. However, these were considered to be expected weaknesses of an early prototype and

did not affect the overall usability. Future improvements should focus on providing a more targeted introduction to the game, as well as adding additional tasks and gamification elements, such as Easter eggs, time limits and playful rewards.

Qualitative testing procedures carried out in the early development stage revealed comprehension difficulties and technical errors, while confirming the motivational potential of a digital escape room.

5.2 Quantitative Results: Standardised Questionnaires

In the second phase, a larger group (n = 24) tested the escape room as part of two workshop concepts. Afterwards, participants completed a standardised online questionnaire consisting of the System Usability Scale (SUS), a Likert scale on game motivation, sense of flow and perceived learning gains, and three open-ended questions. The quantitative data were analysed descriptively (mean, median and variance). Participants rated ten statements using a five-point Likert scale (*1 = strongly disagree, 5 = strongly agree*). The results are shown in Figure 2.

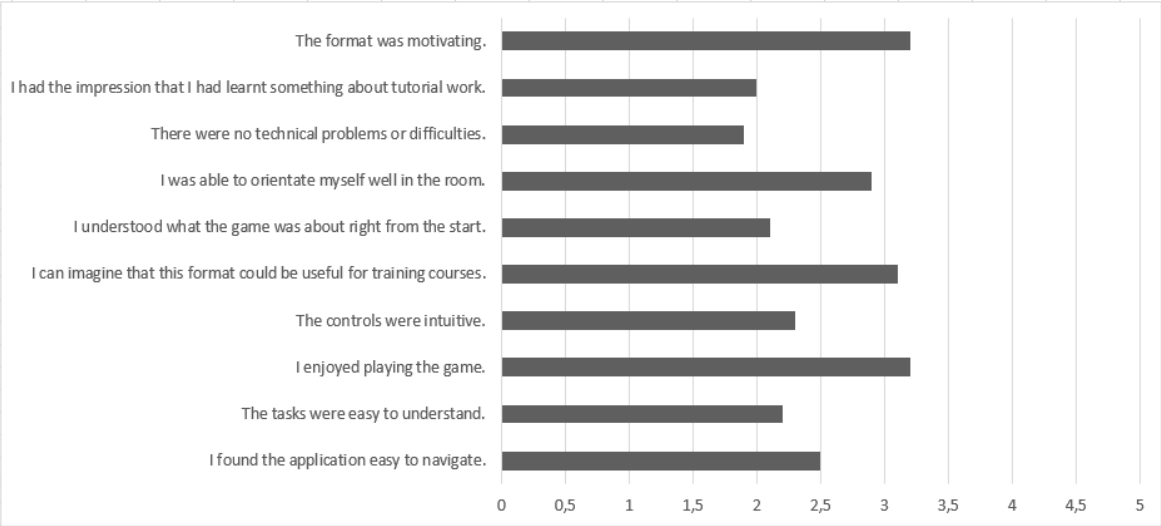

Figure 2: Quantitative Likert scale (from 1 = strongly disagree to 5 = strongly agree) for evaluating the prototype

In usability research, values above 3.0 indicate predominantly positive agreement, whereas values below 2.5 suggest room for improvement (Bangor et al., 2009). Participants particularly enjoyed the game (mean = 3.3), felt motivated (mean = 3.2) and found it easy to orient themselves in the room (mean = 3.2). The game's general suitability for training was also rated positively (mean = 3.0).

However, lower ratings were given for aspects of usability and clarity: 'The controls were intuitive' (mean = 2.5), 'The tasks were clearly understandable' (mean = 2.3), and 'I understood what the game was about right from the start' (mean = 2.3). The statement 'There were no technical problems' received a mean score of 2.2. Open-ended feedback was mixed. While terms such as *'great idea'* and *'modern'* reflected positive impressions, critical feedback included *'not self-explanatory'*, *'unclear controls'*, and *'technical errors'*. When asked what they would improve, respondents mostly said they wanted more structure and clarity.

The demographic analysis of the evaluation shows a higher proportion of female participants (Figure 3).

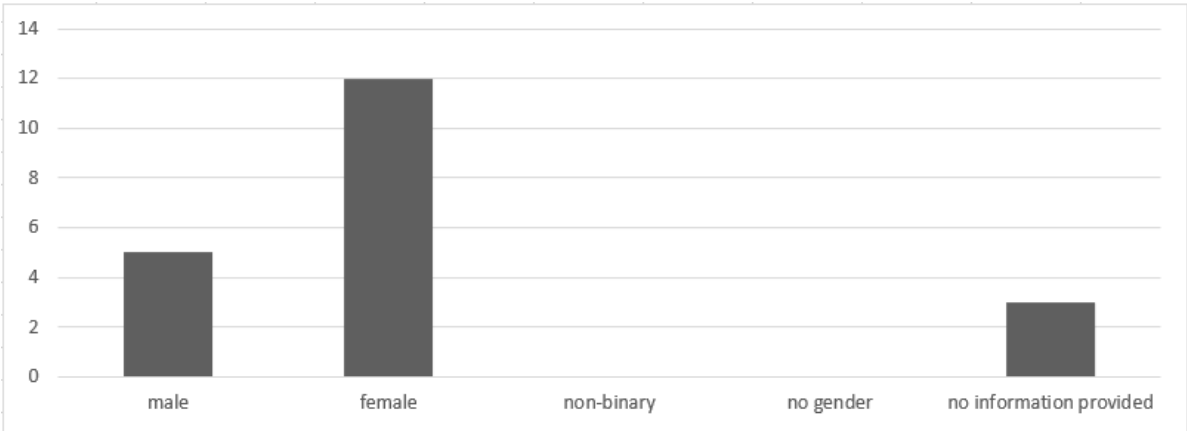

Figure 3: Distribution by gender

This distribution reflects the common tendency for more individuals who identify as female to be active in university teaching. The age distribution also shows a pronounced spread, focusing on young adults and individuals of working age (see Figure 4).

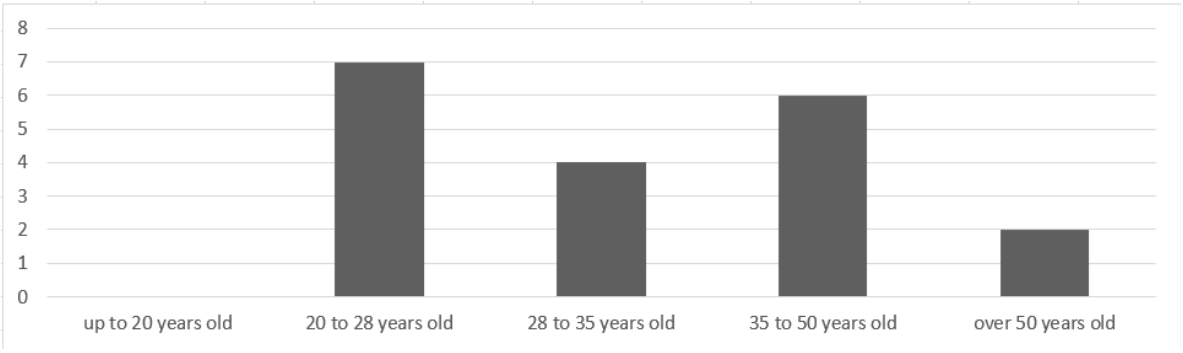

Figure 4: Distribution by age

Feedback came from a variety of disciplines. Although the concept of the game was perceived as innovative and motivating, the results clearly indicate that its implementation was considered insufficiently structured, technically unstable, and difficult to understand. Criticism was particularly levelled at the lack of instructions relating to the controls, the task logic and the game objective. Many of the aforementioned problems could be resolved through technical adjustments, particularly by providing a guided introduction to the game and simplifying the structure of the tasks.

It should be noted when analysing the results that only an initial prototype has been tested so far, and that no final conclusions can yet be drawn about the technical design and learning effectiveness. Nevertheless, the initial findings suggest that the escape room is motivating, but there is scope for improvement, particularly with regard to user guidance, task clarification and technical introduction.

6. Discussion

The evaluation results indicate that the digital escape room is perceived as a promising tool for preparing tutors for practical teaching challenges. The format's high level of acceptance as a learning medium is particularly positive. Both the quantitative evaluations ('I enjoyed the game,' 'The format motivated me') and the open feedback *('cool idea*', *'great concept'*) indicate that a game-based setting is considered a valuable part of tutor training.

The positive SUS ratings and feedback on the fun factor may indicate that the escape room can promote conditions that are consistent with Csikszentmihalyi's (1990) flow concept, particularly through the balance between challenge and ability. However, this needs to be verified through further evaluations. In particular, the balance between challenge and ability was perceived as motivating. The opportunity to make mistakes and learn from them was described as an educational added value. This could help to reduce uncertainties when dealing with technology or organisational requirements, for example. However, the evaluation also revealed significant potential for improvement, particularly with regard to user guidance and task comprehension. Participants often

expressed uncertainty about the game's objective, difficulty in navigating the environment, and confusion regarding the order and structure of the tasks. Statements such as *'I found the application easy to use', 'The tasks were clearly understandable'*, and *'I understood what the game was about from the start'* received the lowest ratings. Due to these low ratings and the qualitative feedback regarding the comprehensibility of the tasks, the task instructions are currently being revised to be more concise and better embedded in the game context. Frequent disorientation during the game has also led to the development of a structured introductory tutorial that explains the game's purpose, controls, and basic mechanisms. A progress bar will be added to structure the sequence of tasks and provide support in the form of hints during longer breaks. Further suggestions from open feedback, such as introducing additional gamification elements (e.g. bonus points, Easter eggs or simulated disruptions), will also be incorporated to increase motivation to play. Future versions will feature a more flexible task structure, with multiple task strands unlocked simultaneously to strengthen learners' autonomy and sense of control. A final reflection component will help players to consider their learning process and the decisions they made during the game. It is important to emphasise that the present results are formative in nature and reflect an early stage of development. The study takes a design-based research approach, focusing explicitly on usability and motivation rather than on measurable learning outcomes or long-term effectiveness. The results are therefore intended to inform the further development of the prototype and will be incorporated into future design iterations. A summative evaluation focusing on learning outcomes will be conducted in later phases of the project. The results also highlight the importance of adaptive and inclusive design. Not all users have the same technical, cognitive, or physical prerequisites from the outset. Therefore, aspects of accessibility, such as keyboard control, contrast mode and intuitive icon design, will be prioritised in future development phases. Beyond the qualifications of the tutors, the evaluation also demonstrates the broader potential of digital escape rooms as a learning format in higher education and vocational training. They could support new teachers in lesson preparation, mentors in practical school internships, and induction processes in educational institutions. They could also be used in training scenarios for crisis management, inclusion, or hybrid teaching. Realistic scenarios could also be designed as digital learning spaces in vocational schools or social settings, for example to prepare for internships, train workshop leaders, or teach crisis intervention strategies.

The evaluation provides a detailed and differentiated picture of user-friendliness and acceptance, offering clear, actionable guidelines for further developing the escape room.

7. Conclusion and Outlook

The digital escape room developed offers a practical addition to existing training formats and addresses typical challenges in tutor training in a playful way. The evaluation showed that participants found the concept very appealing, especially the motivating design, the realistic scenarios and the potential for use in higher education. At the same time, the results highlighted areas for improvement, such as onboarding, control and task logic. Many of the challenges identified are common problems in the early stages of developing digital environments and provide important pointers for targeted further development. The results reinforce the assumption that digital escape rooms can function as a learning medium if tailored to the needs of their target group and appropriately designed. In the long term, this format could also be adapted for other groups, such as new teachers, mentors, and student teams. Topics such as 'communication in hybrid settings', 'barrier-free teaching' and 'crisis management in tutorials' could be covered. The escape room can serve as both an introductory and a qualification tool.

The next development steps will focus on content, technical, and pedagogical refinement. Initially, an introductory tutorial will be integrated to provide players with clear guidance before they immerse themselves in the actual game situation. This tutorial will explain the controls and clarify the goal of the escape room and the basic game mechanics. This should lower the barriers to entry and improve the gaming experience. Furthermore, situation-specific task hints are planned. These will offer players targeted assistance based on their interactions without revealing the solution. The aim is to make the task structure more intuitive and reduce uncertainty when dealing with the game environment. Visual feedback can also indicate when a task has been completed successfully and suggest the next steps. Additionally, a final reflection after the game ends can encourage players to consider their decisions and insights, for example in the form of short self-reflection questions or optional group discussions. Future evaluation phases will combine qualitative usability tests (e.g., think-aloud method) with quantitative surveys to systematically assess improvements in task comprehensibility, navigation, and motivational impact. By triangulating individual user experiences with broader measurement, the project ensures an evidence-based, iterative development process. In this way, the escape room has the potential to become a scalable and transferable model for competence development in higher education and beyond.

Ethics Declaration: No ethical approval was required for the research presented in this paper, as all data were collected anonymously, voluntarily, and without any intervention posing risk to participants. Participants provided informed consent prior to taking part in the usability tests and survey.

AI Declaration: AI-assisted tools (e.g. ChatGPT and DeepL Write) were used to help structure and word individual sections, especially for linguistic optimisation, summarising qualitative results and translation. The author critically reviewed, edited and supplemented all generated content to ensure scientific accuracy, coherence and originality. The author takes final responsibility for the content.

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Investigating Pupils' Motivation with a Reward-Driven Feature in a Game-Based Learning Environment

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Abstract: This study examines how 31 Swiss primary pupils engaged with the *Compendium*—an optional, loot box–inspired feature embedded in the GamesHub platform for reading comprehension. We combined an adapted EGameFlow survey and trace data (total usage time) to identify distinct engagement profiles. Results show high Knowledge ratings and varied usage patterns: some pupils spent little time yet rated the *Compendium* highly, while others used it extensively with more moderate scores. These findings highlight that non-essential, reward-based tools can foster intrinsic motivation and early appropriation (instrumental genesis), suggesting design guidelines for inclusive, learner-driven game mechanics.

Keywords: Game-Based learning environment, Game mechanic design, Instrumental genesis, Motivation, Loot box

1. Introduction

While the educational potential of video games has been widely explored – particularly in relation to learner motivation, engagement, and performance (Gee 2003; Connolly, Boyle, MacArthur, Hainey and Boyle 2012; Irina 2023; Luo 2024; López-Fernández, Gordillo, Pérez and Tovar 2024) – less attention has been paid to how pupils interact with appropriate embedded non-essential tools within these environments. In that respect, most studies focus on core game mechanics that directly affect performance or progression (Wouters, van Nimwegen, van Oostendorp and van der Spek 2013), overlooking secondary features such as glossaries, encyclopedias, or collectible systems that may still influence knowledge construction and learner autonomy (Clarck, Tanner-Smith and Killingsworth 2016).

To better understand how pupils engage with such peripheral elements, this study draws on the concept of instrumental genesis (Vérillon and Rabardel 1995) which describes how users transform *artefacts*[1] into *instruments*[2]. Surprisingly, and despite its relevance for examining how learners make sense of optional digital tools they use, this framework has rarely been applied to learning environments or even to serious games or gamified learning platforms.

In parallel, recent developments in game design have shifted attention away from traditional gamification elements - like points, badges, and leaderboards that are some of the most common game mechanics used in gamified learning environments (Dehghanzadeh, Fardanesh, Hatami, Talaee and Noroozi 2023) - towards new combinations of mechanics centered around narrative, avatars, and characters. If gamification aims to have a positive and effective impact on learners' motivation and performance, the design of these mechanics should be responsive to the cognitive and behavioral profiles of the target learners (Dehghanzadeh, Fardanesh, Hatami, Talaee and Noroozi 2023).

One mechanism could be the *loot box*, used extensively in modern video games. Loot boxes are a reward mechanism that is used to motivate players to accomplish challenging activities, in the form of packages that give out random digital rewards when opened. In a gamification context, loot boxes may foster motivation in education and performance, particularly when rewards are intrinsic, by promoting collection curiosity and discovery (Lichtenber and Brendel 2020).

[1]We call *artefact* any tool or resource provided by a learning environment, external to the learner's own cognitive schemes, and endowed with specific functionalities (Vérillon and Rabardel 1995).

[2]We call *instrument* the dual entity resulting from instrumental genesis: the artefact as transformed by the learner's schemes of use and the cognitive structures that emerge from this interaction (Vérillon and Rabardel 1995).

This paper investigates the *compendium*, a feature embedded in the GamesHub platform, developed as part of the DocTALE-Fr[3] project. Designed for primary school children aged 8 to 10, one of the main learning objectives included in GamesHUB is the reading-comprehension of short texts, with French as the schooling language. GamesHUB includes the loot box as a gamification feature: the *compendium* is an inventory system that accumulates extrinsic rewards obtained by learners by succeeding in mini games. Although it is tied to performance for unlocking content, it does not influence progression, making it an ideal case to explore the educational value of non-performative, reward-based tools. This secondary feature has also been integrated as it may promote knowledge structuring the learner autonomy (Clarck, Tanner-Smith and Killingsworth 2016); this latter point being a purpose of the platform developed as an inclusive and universal tool (within the meaning of universal design for learning, UDL, CAST, 2024).

We aim to understand how learners engage with the *Compendium*, and whether such a feature – though not instrumental in gameplay – can turn into an instrument of personal learning through processes of appropriation. This raises the following research question:

How do pupils engage with and appropriate a feature that belongs to the gameplay but remains non-essential for task completion? And what does it reveal about their motivation and learner agency?

2. Theoretical Background

This study builds on three interrelated theoretical strands: (a) random rewards mechanics in gamification, (b) learner motivation and agency, and (c) *instrumental genesis*. Together, they form a coherent lens to explore how pupils engage with the *compendium* — a feature in the GamesHub platform designed to reward performance through collectible but non-performative content.

2.1 Gamification and Reward Mechanics

As previously stated, current design trends show a shift toward more immersive and narrative-based elements, such as avatars, characters, or randomised rewards inspired by mechanics like loot boxes that are packages revealing random digital contents, typically used to sustain motivation by generating excitement and surprise. While controversial in commercial gaming (Drummond and Sauer 2018), recent studies suggest that loot box-inspired systems can support engagement and performance in educational contexts — provided they are ethically designed and not linked to monetary transactions (Lichtenberg and Brendel 2020). Indeed, there are valid criticisms, though, of the linkage between loot boxes and gambling (Yokomitsu, Irie, Shinkawa and Tanaka 2021). Implementing mechanisms initially designed to encourage spending money in the form of microtransactions brings serious issues when applied in schools. Nevertheless, if the loot box is well used, a study showed that the top motivations among adolescents for buying loot boxes were: (a) gaining in-game rewards, (b) completing a collection, (c) the excitement of opening the box itself, and (d) cosmetic reasons (Zendle, Meyer and Over 2019).

In our platform, we added a feature called the *compendium* that integrates some of the loot boxes principles: after each mini-game, pupils receive a performance score (0 to 3 stars) which unlocks a random element of a themed collection. These entries span topics like mythology, geography, and biology (all linked to the current school study programme), and include a title, an image, and a short description. Although this feature is indirectly tied to performance, it is not essential to gameplay progression and thus aims at functioning as a pedagogical reward system rather than a competitive incentive. In this way, it may impact motivation and learner agency.

2.2 Motivation and Learner Agency

Our study is informed by Self-Determination Theory (Deci and Ryan 2000) which identifies autonomy, competence, and relatedness as key motivational needs. In game-based learning, pupils tend to be more engaged when they can act autonomously and explore content at their own pace (Gee 2003). This last point is in line with another pillar of the overall project: to develop an inclusive teaching and learning tool with the universal design for learning (UDL) (CAST 2024) as a perspective.

Because the *compendium* provides no in-game advantage, its use depends on the learner's intrinsic motivation and interest in the content. Students can browse the entries they unlock whenever they want, if they want to, they can expect to complete specific collections and share their discoveries with peers. This opens the

[3]Project *Documenter et Tester l'Apprentissage Adaptatif à L'École en Français*, **FNS** n°100019_215373

possibility that learners will develop personal engagement strategies that go beyond extrinsic incentives. This may lead to a personal appropriation of the feature, transforming it and its basic purpose, which is the central perspective of the instrumental genesis.

2.3 Instrumental Genesis

Instrumental genesis (Vérillon and Rabardel 1995) refers to the dual process by which a user transforms an artefact - something initially external and neutral - into an instrument that becomes part of his/her activity. This dual process includes: (a) Instrumentation, in which the tool, in turn, structures and influences the user's cognitive activity; (b) Instrumentalization, in which the user adapts the artefact to his/her needs. Though widely used in the study of digital tools in education (Artigue 2002; Trouche 2004; Drijvers 2019; Gueudet and Trouche 2022; Pittalis and Drijvers 2023), instrumental genesis has rarely been applied to game-based environments. Yet, these environments often include optional features that are not directly tied to task success or progression, and whose appropriation depends on learner agency. In this study, we investigate whether pupils appropriate the *compendium*- an artefact that provides no direct advantage in gameplay- as an instrument. The question is not whether the feature works, but how it is used, transformed and integrated into the learners' activity, becoming a tool.

Rather than prescribing how a feature should support learning, we observe how learners—regardless of their cognitive profiles or needs—engage with it in practice. From our point of view, instrumental genesis offers a useful lens for understanding inclusive learner-driven appropriation and provides design insight with UDL principles (Meyer, Rose and Gordon 2014; Al-Azaei, Serenelli and Lundqvist 2016). In sum, by combining these three perspectives -gamification, learner motivation, and instrumental genesis- this study examines how pupils engage with the *compendium*, and whether it can evolve from a simple collection feature into a real tool for using or even building knowledge to succeed in games.

3. Research Context and Methodology

To drive this study, we use the data collected during the second round of experimentation of the platform in primary classrooms.

The GamesHub platform is a digital didactic tool aiming to assist teaching and to promote learning reading-comprehension of short texts in French as the schooling language, at primary school, and for all pupils whatever their needs. In that scope, the platform uses Adaptive Learning to personalize learning pathways. A pathway is an articulation of games and game levels (Karoui, Alvarez, Geoffre, Guin, Lefèvre, Lachand-Pascal and Ramalho 2022) and that is where the *compendium* appears.The study was conducted in two French-speaking elementary school classrooms, in Switzerland. Participants (n = 31) were pupils (from 3rd and 4th grade of primary school) who used the GamesHub platform across 20 sessions over a period of 10 weeks, with or without adaptive learning activated, according to the single case design protocol the team used. The digital hardware was provided by schools, and attendance at such sessions was uncommon.

3.1 The Compendium in GamesHUB

The *compendium* is an encyclopedia with an embedded random reward system where students increasingly earn tokens to complete it. It consists of a list of entries organized in twelve theme sets, for example, "Gods and Goddesses of Greek Mythology" or "The Solar System". Each entry has a title, a picture, and a short description, and each set is an issue of a general knowledge topic — geography, history, or biology — mapped onto the Plan d'Études Romand (Swiss French curriculum framework)[4].

[4]Plan d'Études Romand (PER) (Swiss French Study Program): https://portail.ciip.ch/per

Figure 1: The *compendium* in GamesHUB shows the collection "The first 10 Swiss Cantons"

After completing a mini game, the pupil earns 0 to 3 stars. 5 stars are required to open an element of an entry (image, description, or title) randomly selected from the pool. Higher scores mean faster completion of entries.

The *compendium* is a feature designed to increase learners' motivation through random reward mechanisms in an in-game benefit-free manner. The *compendium* works as a pedagogical encyclopedia taking advantage of several motivational game mechanics: (a) randomness, (b) performance-based advancement, (c) accumulation of content, and (d) comparing collections with peers. Practice conforms to the most recent recommendations on the use of lootbox-like mechanisms within education regarding ethicality and efficiency (Lichtenberg and Brendel 2020). We could directly observe that the *compendium* contributed as expected to students' motivation, but this point isn't discussed here as we aim to go further and document if and how it has been moved from a feature to an instrument facilitating learning. We then used an adapted version of the eGame Flow survey.

3.2 Instrument: The eGameFlow Survey

The games will only be useful to increase reading-comprehension skills if they are correctly played, which means that the learner's interaction with the tool, via the player's interface, must be sustained. Flow experience is essential to keep players' engagement, and this engagement is itself a guarantee of motivation. Flow and engagement may therefore contribute to the process of instrumental genesis: experiencing flow while interacting with an optional resource like the *compendium* could facilitate its appropriation, transforming it from a peripheral artefact into a meaningful instrument.

The eGameFlow survey is a standardized instrument for measuring learners' satisfaction in game-based learning contexts (Fu, Su and Yu 2009). It was originally created out of the GameFlow model, primarily designed to quantify the flow experience in computer games (Sweetser and Wyeth 2005). In 2022, a child-appropriate version was developed (Alvarez, Llorens and Rodríguez 2022) and used in the context of the DocTALE-Fr project to assess pupils' flow experience using the platform, prior to integrating the *compendium* feature. For this phase, we created and used a revised version of the questionnaire[5]. The new version now contains five dimensions: Concentration, Challenge, Autonomy, Immersion, and Knowledge improvement. The 2022 version lacks the Knowledge improvement dimension that has been added following the inclusion of the *compendium*. This specific dimension refers to the information shared in the content of the collections based on the Swiss French Curriculum Framework. Instead of assessing pupils' perceived gains in knowledge —since the validity of self-assessment at this age is questionable— the new questions inquire about whether pupils

[5] https://zenodo.org/records/15308805

use the *compendium* and if they enjoy acquiring new entries. Like in the 2022 version, numerical values were replaced with smiley faces and some statements rearranged for improved readability and child-friendliness. Having researchers accompanying classes was familiar to pupils since they typically went through focus groups, particularly with how they used another additional feature, the visual lexicon tool (Plessis-Ouzariah and Geoffre 2025). For this research, the second researcher also joined the classrooms when the flow survey was proposed. Pupils filled out the questionnaire simultaneously as the researcher read each question aloud. Clarifications were always present if they were unable to get some questions, with pupils encouraged to ask in case they had difficulties. We consider social desirability bias risk (Krumpal 2013) to be low, as the pupils were instructed to respond based on their overall feelings and were accustomed to researchers' presence during learning sessions.

4. Results

The adapted EgameFlow used in this study consists of five dimensions: (1) C.Concentration (3 items): games must encourage concentration and minimize cognitive overload; (2) H.Challenge (5 items): feedback must help players assess progress; (3) A.Autonomy (3 items): players must feel in control of decisions; (4) I.Immersion (2 items): games must promote engagement; (5) K.Knowledge Improvement (3 items): game must be conductive to curriculum goal. The leftmost column of Table 1 identifies each eGameFlow dimension being measured. The second column (N) shows the number of participants who provided valid responses for each dimension. The third column (Mean) displays the arithmetic mean (average) of pupils' ratings for each dimension on the 5-point scale. The questionnaire used a 5-point scale where: 1 = strongly disagree/very poor experience, 2 = disagree/poor experience, 3 = neutral/adequate experience, 4 = agree/good experience, 5 = strongly agree/excellent experience.

Interpretation Benchmarks:

- Means above 4.0: Indicate strong positive experiences
- Means 3.5-4.0: Indicate moderately positive experiences
- Means 2.5-3.5: Indicate neutral to mixed experiences (not observed in this study)

The fourth column (SD) shows the standard deviation, which measures how much individual responses varied around the mean. The two last columns (Min, Max) show the lowest and highest rating given by any participant for each dimension.

Table 1: Descriptive statistics of the "flow" documented with the adapted eGameFlow

Variables	N	Mean	SD	Min	Max
C.Concentration	31	4.14	0.65	1	5
H.Challenge	31	4.26	0.77	3	5
A.Autonomy	31	4.32	0.53	2	5
I.Immersion	31	3.70	1.09	1	5
K.Knowledge Improvement	31	4.47	0.60	1	5

As can be seen in Table 1, the five dimensions of eGameFlow modified for children rated rather high. Average ratings were 4.14 (SD = 0.65) on concentration, 4.26 (SD = 0.77) on challenge, 4.32 (SD = 0.53) on autonomy, 3.70 (SD = 1.09) on immersion, and 4.47 (SD = 0.60) on knowledge. What is striking to observe here is that the knowledge category, linked to the items of the compendium, had the highest mean rating. The relatively low SD combined with high mean indicates reliable positive experience.

In the open-response section of the questionnaire, the pupils gave drawings that primarily depicted the compendium and rewards that accompanied it (n = 12), as well as their favorite games. In the answers related to the compendium, pupils expressed pleasure at gaining rewards and watching their collection grow, with a score of 4.87.

During the experiment, teachers had reported that the pupils enjoyed using GamesHub and were very engaged in the games. Pupils frequently discussed the compendium with one another and delighted in unlocking and learning about its content. One of the possible reasons that may have contributed to the high flow scores is the general enthusiasm for the games themselves. When asked to name their favorite aspects of GamesHub, the most prevalent mentioned features were the games (n = 17), then the compendium and

reward system (n = 12). Adaptive learning (n = 1) and the visual lexicon tool (n = 1) were further noted as favorites, though to a lesser degree.

Table 2: Pearson correlation matrix that shows the relationships between five eGameFlow dimensions

Variable		C.Concen.	H.Challe.	A.Autono.	I.Immers.	K.Knowle.
C.Concentration	r	-				
	p-value	-				
H.Challenge	r	- 0.271	-			
	p-value	0.140	-			
A.Autonomy	R	0.090	0.334	-		
	p-value	0.629	0.066	-		
I.Immersion	R	0.633	- 0.303	- 0.035	-	
	p-value	<0.001	0.098	0.853	-	
K.Knowledge Improvement	R	0.486	0.135	0.052	0.579	-
	p-value	<0.001	0.469	0.782	<0.001	-

Table 2 is organized as a correlation matrix, which is a standard statistical format for displaying relationships between multiple variables. The table has both rows and columns representing the same five eGameFlow dimensions. The leftmost column identifies which eGameFlow dimension is being correlated with all others. Each variable appears twice in this column: first as the variable name (e.g., "C.Concentration"), second as "p-value" (the statistical significance level for that row's correlations)

Table 2 shows strong and significant correlations between Knowledge improvement and Concentration ($p < .001$), Knowledge improvement and Immersion ($p < .001$), and Concentration and Immersion ($p < .001$). These results show that the *compendium* can keep learners engaged for extended periods—particularly since the experiment took weeks. The other eGameFlow dimensions were less strong or statistically insignificant, compared to Fu (2009) original results. These discrepancies may be a consequence of the shortened or altered version of the questionnaire used with younger children.

We also measured pupils' *compendium* browsing time and related it to their survey scores since instrumental genesis is a cumulative process that occurs over time. Measuring duration could therefore provide information on variations in learner engagement. The correlation between the two was weak ($r = 0.21$) and non-significant (p-value = 0.24), offering no clear evidence that the increased use of the *compendium* was related to increased enjoyment of GamesHub.

However, to better understand potential differences, we visualized each pupil's *compendium* usage alongside their self-reported score (Figure 2).

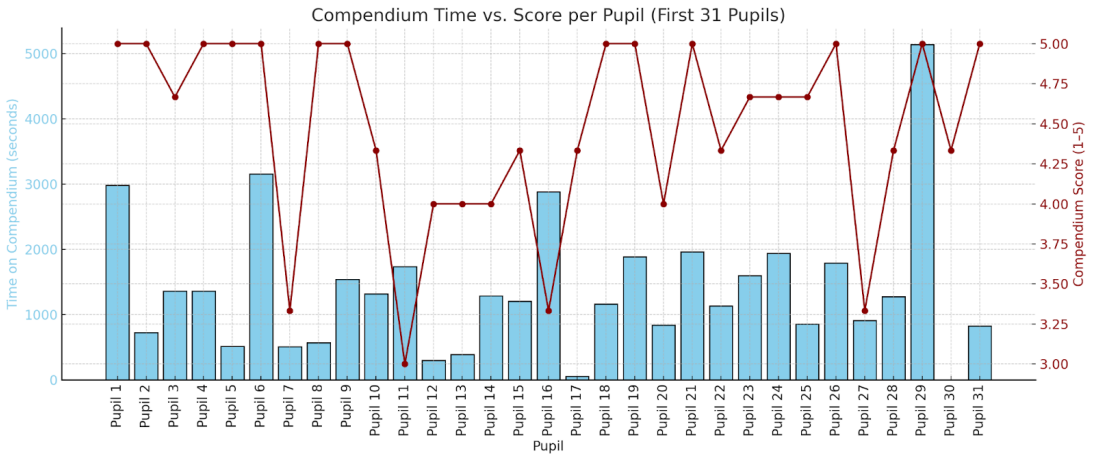

Figure 2: Pupils' time spent on the *compendium* and their appreciation scores (dimension K)

This dual-axis graph compares the total time each of the 31 pupils spent interacting with the *compendium* (blue bars, in seconds) and the appreciation score they assigned to it (red line, on a scale of 1 to 5). While

many pupils who used the *compendium* frequently also rated it positively, some showed high appreciation despite brief interaction. Conversely, a few pupils spent considerable time with the feature but gave more moderate scores. This representation helps to highlight diverse engagement behaviors across individuals and may give some clues to specify the different ways of use of the *compendium*.

5. Discussion

5.1 Overview of key Results

Overall, the results from the adapted EGameFlow survey suggest that pupils rated their experiences positively across all dimensions, with Knowledge emerging as the highest-rated dimension.

Qualitative responses indicated that pupils not only enjoyed collecting rewards but also actively represented the *compendium* in their drawings and peer discussions, which shows emotional investment and affective engagement. The significant correlations observed between knowledge, concentration, and Immersion further suggest that the *compendium* contributed to maintaining sustained attention and emotional involvement throughout the learning sessions.

5.2 Flow and the Early Stages of Instrumental Genesis

Beyond immediate engagement, these results may be interpreted through the instrumental genesis concept (Vérillon and Rabardel 1995). Experiencing flow—particularly high concentration and immersion—could facilitate the first stages of appropriation of a digital artefact. In this case, the *compendium*, initially designed as a secondary feature, appears to have started transforming into an instrument for some pupils. While full instrumental genesis would imply more deliberate cognitive strategies (such as thematic organization or knowledge restructuring), the observed affective investment - pleasure in collecting and discussing gains - is an essential prerequisite. It creates favorable conditions for instrumentalization, whereby pupils begin assigning personal meaning to the artefact. In this way, we may suggest flow experiences can indirectly support the genesis of learning tools such as GamesHub, even for non-performative functions such as the *compendium*, by making interaction more fluid, enjoyable and autonomous.

5.3 Types of Engagement and Learner Agency

The data also reveal some layers of engagement. Affective engagement was evident because pupils expressed enjoyment by showing pride in building complete collections. Even if the social aspect of engagement is less dominant, we have observed it when pupils discussed their progress with peers.

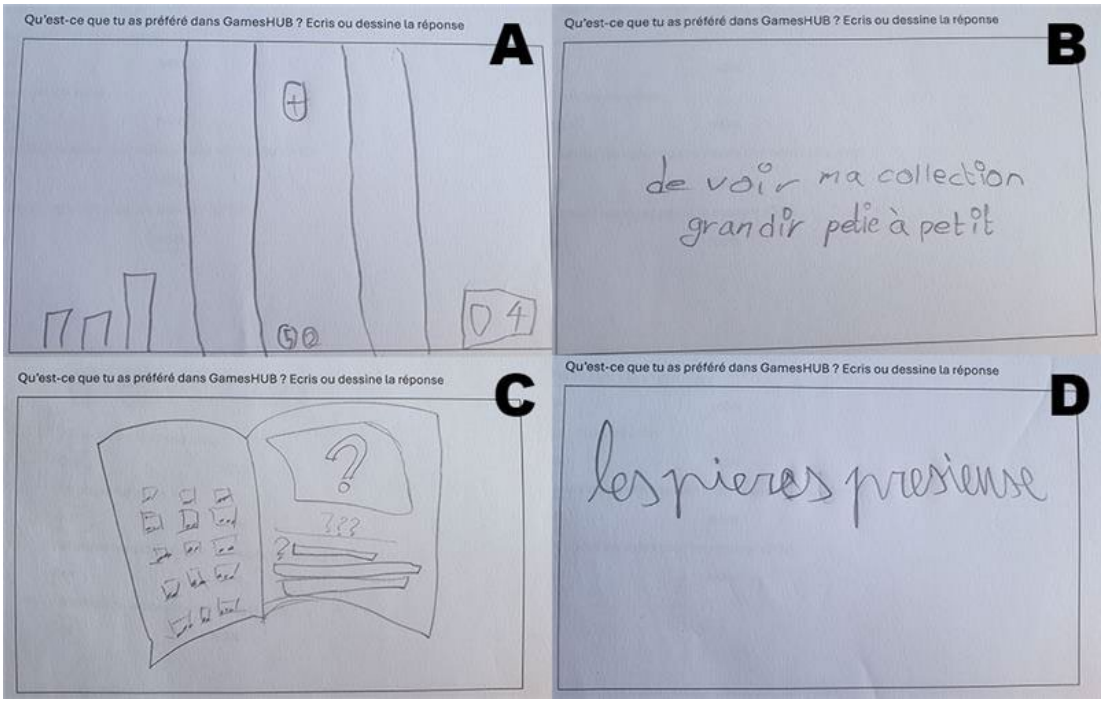

Figure 3: A-an illustration of a mini-game, B-a text saying "Watching my collection grow," C-an illustration of the compendium, D-a text saying "Precious stones," representing the items in the collection

What about the learner agency? By allowing pupils to unlock content without affecting their performance in the game, the *compendium* provided a space for autonomous exploration. Students could spend as much time as they wanted in the *compendium*. In fact, they could access it at any time during the game. We might then suggest that a reward-based system can encourage a sense of ownership and autonomous playing, allowing autonomous learning.

To further investigate this point, we compared pupils' actual use of the *compendium* (time spent) with the appreciation scores they assigned to it. Although the overall correlation between the two was weak and non-significant, a closer examination of individual profiles revealed contrasting behaviors. Some pupils reported high enjoyment despite limited usage, suggesting a strong but punctual interest, while others spent considerable time in the *compendium* with varying levels of appreciation. These discrepancies point toward differentiated forms of appropriation that are not visible in aggregate data. They could also support types of learner engagement and autonomy depending on the pupils' intentions and references.

Moreover, some pupils were even willing to look up the meaning of certain words in the *compendium* description texts using the visual lexicon, which supports this openness to learner autonomy in the activity. However, it should be noted that further analyses would be necessary to evaluate the role of the *compendium* in the construction of knowledge or in the strategic use of cognitive abilities for a more complete process of instrumental genesis.

6. Conclusion

This study investigated how pupils engage with and appropriate the *compendium*, examining whether a non-essential, reward-based game mechanics could transform from a peripheral artefact into an instrument of personal learning. The *compendium*'s design, which incorporated randomness, performance-based advancement, content accumulation, and peer comparison opportunities, successfully generated what pupils described as excitement about "watching my collection grow." However, the highest mean rating across all eGameFlow dimensions was for Knowledge Improvement ($M = 4.47$, $SD = 0.60$), suggesting that pupils valued the educational content itself rather than merely the reward mechanism.

These finding challenges simplistic interpretations of gamification that focus solely on extrinsic motivation, indicating instead that well-designed reward systems can create pathways to intrinsic engagement with learning content. The qualitative evidence further supports this interpretation. Pupils' drawings predominantly featured the compendium and its rewards, and their spontaneous discussions about unlocked content demonstrated genuine interest in the educational material. This suggests that the loot box-inspired mechanism served as an effective bridge between extrinsic motivation and intrinsic curiosity about curriculum-aligned content spanning mythology, geography, and biology.

The fact that some pupils voluntarily used the visual lexicon tool to understand compendium descriptions provides evidence of self-directed learning behaviors. This cross-feature usage demonstrates how autonomous engagement with one tool can catalyze broader learning strategies, supporting the development of learner agency that extends beyond the immediate context of the *compendium* itself. While the *compendium* was initially designed as a secondary feature to enhance motivation, our results suggest that, for many pupils, it began transforming into a genuine learning instrument through processes of appropriation and personal meaning-making.

The strong correlations between Knowledge Improvement and both Concentration ($r = 0.486$, $p < .001$) and Immersion ($r = 0.579$, $p < .001$) indicate that pupils' engagement with the compendium supported sustained attention and deep involvement with learning content. These correlations suggest that the feature facilitated what Vérillon and Rabardel describe as the dual process of instrumental genesis (1995): pupils adapted the compendium to their personal learning needs (instrumentalization) while simultaneously allowing the tool to structure their cognitive engagement with curriculum content (instrumentation).

While our findings provide valuable insights into pupils' engagement with reward-driven educational features, several limitations should be acknowledged. The study was conducted over a 10-week period with 31 participants from two classrooms, which limits the generalizability of findings to broader populations and longer-term usage patterns. Additionally, the adapted eGameFlow survey, while appropriate for the target age group, may not have captured all dimensions of flow experience with the same precision as the original instrument. Future research should investigate the long-term development of instrumental genesis with educational game features, examining how pupils' uses of tools like the *compendium* evolve over extended periods. Longitudinal studies could reveal whether the early appropriation behaviors observed in this study

develop into more sophisticated learning strategies and whether these strategies transfer to other educational contexts. Additionally, research examining the relationship between different types of reward content and learning outcomes could inform more targeted designs. Our study focused on general knowledge content aligned with curriculum standards, but investigation of how different content types (procedural knowledge, conceptual understanding, metacognitive strategies) interact with reward mechanisms could yield valuable design insights.

Future research should explore individual trajectories of appropriation. Case studies could help identify how specific learner profiles emerge over time, and how variables such as in-game performance, initial motivation or curiosity influence the appropriation and perceived value of optional features like the *compendium*. Longitudinal approaches would also clarify whether sustained us reinforce learners' interest in optional content or encourage more deliberate and strategic forms engagement over time.

Ethics declaration: All procedures performed in this study involving human participants were conducted in accordance with the ethical standards. Informed consent was obtained from the legal guardians of all individual participants included in the study. Participation was voluntary, and the data collected were anonymized to ensure confidentiality. The research was conducted in collaboration with the schools involved, with the full support of teachers and school administrators.

AI declaration: DeepL translator, an Artificial intelligence tool developed by DeepL SE a Cologne-based company, used to support translations from French to English. All results were reviewed and validated by the authors.

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Phygital Game-Based Learning in Early Childhood Education: An Exploratory Review

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Abstract: This paper examines the role of phygital game-based learning (PGBL) in early childhood education, with a specific focus on its potential to foster critical thinking and problem-solving skills in children aged 3 to 8 years. PGBL refers to hybrid educational tools that combine physical manipulatives with interactive digital interfaces, offering multisensory and responsive learning experiences that aim to enhance cognitive engagement and symbolic reasoning. Through a literature-based qualitative review, the study analyzes five representative tools—Osmo Tangram, KIBO Robot, LEGO DUPLO Stories, Marbotic Smart Letters, and PlayShifu Orboot Earth—selected for their pedagogical relevance, documented educational use, and theoretical grounding. Drawing from constructivist and socio-cultural learning theories, particularly those of Piaget, Papert, and Vygotsky, the paper explores how these tools embody principles such as hands-on learning, scaffolding, iterative exploration, and meaningful play. Each tool is evaluated in terms of its support for higher-order cognitive functions, including sequencing, spatial reasoning, emergent literacy, and collaborative learning. The findings reveal that while PGBL tools show promise in promoting engagement and foundational executive functions, their effectiveness depends on factors such as design flexibility, ease of integration into pedagogical practice, and inclusivity. Implementation challenges such as limited open-ended play, cognitive overload, unequal access to digital infrastructure, and the need for educator training are critically examined using Universal Design for Learning (UDL) and Technological Pedagogical Content Knowledge (TPACK) frameworks. Rather than presenting definitive causal claims, this review provides a structured synthesis of current academic literature, highlighting both the affordances and limitations of phygital tools in early education. The analysis also underscores the importance of aligning PGBL tools with developmentally appropriate practices and culturally responsive pedagogy. By offering insights across tool design, implementation, and impact, the paper aims to inform educators, researchers, and policymakers seeking to enhance early learning environments through evidence-based, interactive technologies.

Keywords: Phygital game-based learning, Early childhood education, Critical thinking, Learning theories, Constructivism, Problem-Solving

1. Introduction

Play is central to early childhood learning, supporting the development of cognitive, social, and emotional skills through exploration, experimentation, and symbolic reasoning (Hirsh-Pasek et al., 2009). As digital technologies increasingly permeate educational spaces, phygital game-based learning (PGBL)—which merges physical manipulatives with digital feedback—has emerged as a promising modality in early childhood education (ECE). By leveraging the strengths of both physical play and digital interactivity, PGBL tools offer multisensory, adaptive experiences that align with how young children naturally learn.

This paper adopts a qualitative literature-based case study methodology to analyze five representative PGBL tools: Osmo, KIBO, LEGO DUPLO, Marbotic, and PlayShifu. These tools were selected for their relevance to ages 3–8, presence in formal ECE settings, and claims of supporting cognitive development. Each is examined in relation to learning theories, design features, and empirical findings to understand how such tools engage children in structured, playful problem-solving tasks.

Two guiding research questions frame this inquiry:

RQ1: How do selected phygital game-based learning tools engage children in critical thinking and problem-solving processes?

RQ2: How can these tools be integrated into early childhood curricula to support holistic and inclusive learning?

The study is grounded in developmental learning theories that emphasize active, scaffolded engagement. Piaget's (1952) constructivist theory posits that children construct knowledge through direct interaction with their environment, with play acting as a key driver of cognitive development. Extending this, Papert's (1980) constructionism emphasizes learning through making—where children build tangible artifacts, often supported by technology, to reflect and deepen understanding. Complementing these perspectives, Vygotsky's (1978) socio-cultural theory highlights the role of social interaction and guided support in learning. His concept of the Zone of Proximal Development (ZPD) describes how children achieve more complex tasks with appropriate scaffolding—provided by adults, peers, or well-designed tools. PGBL platforms such as LEGO DUPLO Stories or

PlayShifu Orboot align with this model by offering structured prompts, feedback, and opportunities for collaboration that extend children's capabilities.

Despite growing market presence, many PGBL tools lack rigorous empirical validation, particularly concerning their impact on higher-order thinking skills such as critical thinking and problem-solving (Neumann & Neumann, 2017). Some designs are overly structured, limiting open-ended exploration (Resnick, 2006), while others raise concerns about cognitive overload, accessibility, and inconsistent pedagogical integration (Christakis et al., 2018; Mishra & Koehler, 2006). These gaps underscore the need for research that critically evaluates not only the engagement potential of PGBL but also its developmental relevance. By analyzing the pedagogical affordances and limitations of these tools, the study contributes to the discourse on the developmentally grounded integration of edtech, with implications for educators, designers, and policymakers working in early childhood education.

2. Literature Review

2.1 Theoretical Foundations

The integration of physical and digital play in early childhood education is grounded in classical developmental theories. Jean Piaget (1952) emphasized that children construct knowledge through active exploration and self-initiated interaction with their environment. His theory underscores that play is central to cognitive development, enabling children to experiment, assimilate new ideas, and solve problems through concrete manipulation. These activities are particularly evident in preoperational stages, where symbolic play and trial-and-error reasoning help refine mental schemas.

Seymour Papert's (1980) constructionism further elaborates this notion by advocating for "learning by making," where learners deepen understanding by creating tangible artifacts. Papert highlighted the value of tools like programmable robots that promote iterative problem-solving and creative thinking. Constructionist learning environments not only encourage autonomy but also provide scaffolds that allow learners to reflect on and refine their creations—concepts central to modern educational technologies.

Lev Vygotsky (1978) introduced the socio-cultural dimension through his Zone of Proximal Development (ZPD), wherein learners achieve higher-order thinking when supported by peers or adults. Guided play and collaborative problem-solving position learning within this zone. In phygital environments, interactive feedback and peer co-regulation serve as effective scaffolding mechanisms, externalizing cognitive processes and guiding learners toward mastery.

Contemporary neuroscience aligns with these perspectives. Diamond (2013) emphasizes that executive functions—planning, working memory, and cognitive flexibility—develop through goal-directed activities that demand self-regulation. Engaging with complex, playful challenges helps strengthen neural pathways critical for academic success. Moreover, social-emotional competencies are cultivated through cooperative play, where children negotiate roles, express empathy, and regulate emotions (Lillard, 2013). Collectively, these theoretical perspectives provide a foundation for designing learning environments that merge tactile exploration with digital interactivity to support holistic cognitive growth.

2.2 Phygital Game-Based Learning (PGBL) in Early Childhood

Phygital Game-Based Learning (PGBL) represents a pedagogical shift that blends physical manipulatives with digital interfaces, creating immersive, multisensory educational experiences tailored to early learners. Traditionally, physical and digital learning tools have existed in silos—blocks and puzzles fostering fine motor skills, while apps target numeracy or literacy through screen-based interactions. PGBL bridges this divide by offering hybrid platforms where physical inputs (e.g., letter tiles, robots) are recognized by digital systems and enhanced with interactive feedback.

This blended format leverages children's natural learning tendencies—particularly kinesthetic and visual learning styles—while maintaining the intrinsic motivation of play. Crucially, PGBL aligns with a "playful pedagogy" where educational goals are embedded within exploratory, game-like challenges that emphasize curiosity, experimentation, and collaboration (Torres et al., 2021). These platforms are particularly suited for young learners, whose cognitive engagement increases when activities are framed as games with evolving challenges and narratives.

In an empirical study by Maldonado and Zekelman (2019), children using tangible app-linked games demonstrated high persistence, self-correction, and exploratory behavior. The physical components served to

anchor attention, while digital feedback sustained engagement and encouraged reflection. These environments foster active construction of knowledge, aligning with constructivist theories and advancing early executive function development.

Moreover, PGBL tools support inclusive learning by catering to multiple modalities—tactile, visual, auditory—thus accommodating neurodiverse learners. This multisensory input reduces cognitive load, enabling deeper processing of abstract concepts. The adaptive nature of digital elements allows for real-time scaffolding, with cues or corrections that help children remain within their ZPD. When combined with physical trial and error, these feedback loops become powerful mechanisms for building foundational skills.

2.3 Critical Thinking and Problem-Solving in Early Years

Fostering critical thinking and problem-solving skills in early childhood is crucial for developing adaptive learners who can navigate complex tasks effectively. These higher-order cognitive skills enable young children to evaluate options, generate solutions, and reflect on their reasoning processes. Bakken et al. (2017) identify these competencies as core pillars of early cognitive development and predictors of long-term academic success.

Play is a natural conduit for developing these skills. Activities such as constructing models, resolving peer conflicts, or completing puzzles inherently involve strategy formulation, hypothesis testing, and reflection. Educators can deepen these learning moments by using structured prompts, open-ended questions, or iterative tasks that challenge learners to revise and refine their approaches.

Digital components within PGBL environments enhance this process by providing immediate feedback, error correction, and varied pathways to success. For instance, coding toys like KIBO or puzzle-based apps like Osmo allow learners to debug errors, visualize alternatives, and build metacognitive awareness. These tasks mirror scientific inquiry: children form predictions, test their solutions, and adjust their strategies based on the outcomes.

Kazakoff et al. (2013) demonstrated the efficacy of such tools in a study involving 34 children (ages 4–6). After a one-week intervention using KIBO robotics kits, participants exhibited significantly improved sequencing skills—a foundational element of computational and logical reasoning. These gains occurred in a playful, learner-led context, underscoring the value of PGBL over traditional didactic instruction.

Importantly, many phygital tools encourage collaborative engagement, further enriching problem-solving. When learners negotiate building plans, divide coding tasks, or co-create narratives, they engage in distributed cognition—sharing mental models and refining ideas through peer interaction. These social learning experiences not only build cognitive flexibility but also foster empathy, communication, and resilience.

To illustrate how these principles are applied in practice, we examine five phygital learning tools that have gained traction in early childhood settings: Osmo, KIBO, LEGO DUPLO, PlayShifu Orboot, and Marbotic. Each tool combines physical manipulatives with digital content, targeting different age groups and learning domains, and aligning with slightly different theoretical emphases.

Table 1: It provides a comparative overview of these tools, including their intended age range, connections to learning theory, and key findings from studies on their use

Tool	Osmo	KIBO	LEGO DUPLO	PlayShifu Orboot	Marbotic
Intended Age Range	5–8 years	4–7 years	3–6 years	4–10 years	3–6 years
Learning Theory Alignment	Constructivist (Piaget), Social Constructivist (Vygotsky)	Constructionist (Papert), Cognitive Constructivist (Piaget)	Constructivist (Piaget), Socio-cultural (Vygotsky), Montessori	Constructivist, Multisensory Learning, Situated Cognition	Montessori, Embodied Cognition, Constructivist
Engagement in Critical Thinking & Problem-Solving	Promotes spatial reasoning and collaborative problem-solving via digital puzzles	Encourages sequencing, debugging, and planning through	Supports open-ended problem-solving, storytelling, and	Fosters exploratory learning and fact recall through	Enhances early literacy and logical reasoning via tactile letter

Tool	Osmo	KIBO	LEGO DUPLO	PlayShifu Orboot	Marbotic
	and real-time feedback	hands-on robotics and code blocks	planning through block play	interactive AR globe	manipulation and app feedback
Design Features Facilitating Higher-Order Thinking	Immediate feedback, tangible-digital integration, visual cues within ZPD	Screen-free coding, iterative design, tangible programming blocks	Open-ended, symbolic play, collaborative construction	AR-based self-guided exploration, sensory-rich prompts	Tactile engagement, self-correcting inputs, phonics integration
Challenges / Limitations	Requires iPad; may restrict open-ended exploration if over-structured	Limited screen-based feedback; needs adult facilitation for deeper learning	Limited digital enhancement; relies on teacher scaffolding	Structured content may limit creativity; tech setup needed	Limited large-scale studies; tech dependency may hinder tactile-only play
Curricular Integration Potential	High potential for spatial reasoning, logic, and group tasks in STEM curriculum	Strong fit for coding, robotics, and computational thinking modules in early tech programs	Effective in integrated storytelling, motor skills, and SEL curriculum	Valuable for geography, vocabulary, and world knowledge learning centers	Well-suited for phonics, early reading, and inclusive multisensory literacy programs
Tool	Osmo	KIBO	LEGO DUPLO	PlayShifu Orboot	Marbotic
Key Empirical Findings	Improved spatial reasoning and peer collaboration in tangram tasks (Schroth et al., 2019)	Enhanced sequencing and executive function in preschoolers (Kazakoff et al., 2013)	Boosted planning and creativity through play (O'Byrne et al., 2018)	Increased engagement and vocabulary via AR (Kelpšienė, 2020)	Early evidence of literacy gains and task persistence (Maldonado & Zekelman, 2019)

These tools all integrate physical and digital elements but in diverse ways: Osmo and Marbotic use tangible manipulatives to teach concepts (spatial puzzles, literacy/numeracy) with real-time feedback; KIBO uses a programmable robot to teach sequencing and engineering design through hands-on construction; LEGO DUPLO leverages open-ended building and storytelling to develop cognitive and social skills; and Orboot employs augmented reality to inspire exploration of world knowledge. Their theoretical alignments reflect the design choices: for instance, KIBO explicitly draws on Papert's constructionism, encouraging children to learn programming by physically assembling code; Osmo and Orboot invoke Vygotskian ideas by scaffolding tasks with hints and allowing shared participation; Marbotic echoes Montessori by emphasizing self-paced, tactile learning. The evidence so far (though still emerging in some cases) suggests that phygital tools can indeed realize the promise of PGBL: increasing engagement, supporting diverse learners (through multiple modalities), and improving specific skills from executive functions to early literacy. However, the literature also notes the importance of balance – structured digital tasks should be balanced with open-ended play to avoid over-scaffolding, and educators must thoughtfully integrate these tools into curricula to harness their benefits truly. The following section will outline how the present study approached its analysis of PGBL tools and literature.

3. Methodology

This study adopts a literature-based qualitative synthesis methodology, drawing on principles of comparative case analysis as outlined by Creswell (2014) and Merriam (2009). Rather than conducting field-based empirical case studies, the paper constructs analytical case exemplars based on documented evidence from secondary sources. The goal is to synthesize educational affordances, theoretical alignments, and cognitive outcomes associated with selected phygital game-based learning (PGBL) tools in early childhood education (ECE).

The research is guided by a deductive conceptual framework grounded in constructivist, constructionist, and socio-cultural learning theories (Piaget, 1952; Papert, 1980; Vygotsky, 1978). A purposive sampling strategy was used to select five representative tools—Osmo Tangram, KIBO Robot, LEGO DUPLO Stories, Marbotic Smart Letters, and PlayShifu Orboot Earth—based on the following inclusion criteria: (1) designed for learners aged 3–

8 years; (2) blending physical manipulatives with digital interactivity; (3) documented use in formal or non-formal ECE settings; and (4) presence of at least one empirical or conceptual peer-reviewed source evaluating educational impact.

Data sources included peer-reviewed journal articles, white papers, implementation studies, and design reports. Each tool was examined through five deductive categories derived from the research questions: (a) critical thinking and problem-solving affordances; (b) alignment with developmental learning theories; (c) support for inclusive pedagogy (e.g., Universal Design for Learning); (d) curriculum integration feasibility (e.g., via TPACK framework); and (e) scalability and contextual viability.

This structured qualitative synthesis facilitates a cross-case understanding of how different PGBL tools support higher-order cognition in early learners. Although the study does not claim empirical generalizability, it contributes to theory-building and practical insight by consolidating and analyzing documented patterns across the existing literature.

4. Limitations

As a literature-based qualitative synthesis, the methodology is limited by its reliance on secondary data, which constrains the depth and granularity of analysis. The absence of primary fieldwork—such as direct observation, interviews, or classroom trials—restricts the ability to contextualize tool usage within diverse pedagogical environments. Additionally, the quality and scope of available empirical studies vary significantly across the selected tools, with some lacking robust or longitudinal evidence. As a result, the findings primarily reflect documented potential rather than confirmed outcomes. Despite these constraints, the methodology provides a structured, theory-informed lens for evaluating the educational affordances of PGBL tools.

5. Key Implementation Challenges in Phygital Game-Based Learning (PGBL)

The effective integration of Phygital Game-Based Learning (PGBL) tools in early childhood education (ECE) is shaped by several implementation challenges. These were identified through a conceptual synthesis of constructivist and constructionist learning theories (Piaget, 1952; Papert, 1980), the Universal Design for Learning (UDL) framework (Meyer et al., 2014), and principles of implementation science (Fixsen et al., 2005). This section outlines four recurrent and theoretically grounded challenges: (1) constraints on open-ended play and cognitive overload, (2) inequities in access and inclusion, (3) educator preparedness and pedagogical alignment, and (4) cost and scalability.

5.1 Constraints on Open-Ended Play and Cognitive Overload

PGBL tools often embed structured content and fixed gameplay, which can limit improvisation and agency—key tenets of constructionist learning. Papert (1980) emphasized learning through design and self-directed exploration, advocating for environments with “low floors” (easy entry), “high ceilings” (complexity), and “wide walls” (diversity of approaches) (Resnick, 2006). Tools that over-rely on prescriptive digital sequences may diminish children’s capacity for divergent thinking and reduce opportunities for iterative learning (Neumann & Neumann, 2017). Additionally, rapid feedback loops and multimodal stimuli, while engaging, can lead to cognitive overload in young learners. Christakis et al. (2018) caution that overstimulation from fast-paced media may hinder the development of attention span and executive function.

5.2 Inequities in Access and Inclusion

Disparities in infrastructure and inclusive design constrain the potential of PGBL to support diverse learners. Vygotsky’s (1978) sociocultural theory emphasizes the mediating role of tools within the Zone of Proximal Development (ZPD); however, this mediation is dependent on equitable access to these tools. Children in under-resourced environments may lack access to tablets, internet connectivity, or adaptive interfaces, thereby exacerbating educational inequalities (Pynnönen et al., 2022). The UDL framework stresses the importance of offering multiple means of engagement and expression; yet, many PGBL tools lack affordances for learners with sensory, motor, or linguistic diversity (Gargiulo & Metcalf, 2022).

5.3 Educator Preparedness and Pedagogical Alignment

Effective PGBL use requires educators to shift from didactic instruction to constructivist facilitation (Bers, 2020). However, many early childhood educators lack the Technological Pedagogical Content Knowledge (TPACK) necessary to integrate PGBL into developmentally appropriate practices (Mishra & Koehler, 2006). Without sufficient training and curriculum alignment, tools risk being used superficially or as entertainment rather than

as vehicles for critical thinking and reflection (Donohue & Schomburg, 2017). This disconnect undermines the cognitive affordances of PGBL and may reinforce traditional hierarchies rather than promote learner autonomy.

5.4 Cost and Scalability

PGBL tools often combine physical kits with digital subscriptions, presenting financial barriers to widespread adoption. Fixsen et al. (2005) emphasize the need for scalable and sustainable implementation strategies in educational innovation. Public institutions with limited budgets face challenges related to device procurement, maintenance, and teacher training. Without open-source alternatives or modular pricing, the scalability of PGBL remains restricted.

In sum, these implementation challenges are not merely logistical but reflect deeper tensions between pedagogical ideals and practical realities. Anchoring these categories in theory ensures a rigorous evaluative framework and highlights pathways for addressing systemic constraints.

6. Tools Overview

This section presents an analytical overview of the five representative phygital game-based learning (PGBL) tools that integrate physical manipulatives with digital feedback mechanisms in early childhood education (ECE). Drawing on key implementation challenges outlined earlier, each tool is evaluated in terms of its design features, educational affordances, and empirical evidence of impact.

6.1 Osmo Tangram

Osmo Tangram utilizes physical puzzle pieces and a tablet-mounted reflector to enable spatial problem-solving through real-time digital feedback. Research demonstrates that Osmo enhances children's engagement and collaborative reasoning by aligning physical manipulation with visual cues that scaffold learning within the Zone of Proximal Development (ZPD) (Schroth et al., 2019). However, limitations include potential overstimulation and restricted exploratory space, which may hinder open-ended play.

6.2 KIBO Robot

Developed by the DevTech Research Group, KIBO is a screen-free robotics platform that fosters computational thinking through tangible programming blocks. Grounded in Papert's constructionist theory, KIBO enables iterative, hands-on learning by encouraging children to build, test, and revise sequences (Bers, 2018). Empirical studies indicate significant improvements in sequencing and planning skills (Kazakoff et al., 2013). However, high costs and the need for intensive teacher training present barriers to scalability.

6.3 LEGO DUPLO Stories

LEGO DUPLO Stories combines physical block construction with digital storytelling via smart assistants, such as Alexa (Poulter, 2020). It supports open-ended creativity, spatial reasoning, and collaborative play—key attributes for early STEM readiness (Diezmann & Watters, 2000). The platform aligns with constructivist pedagogy by encouraging symbolic representation and hypothesis testing. Nevertheless, usability challenges and the dependency on external devices can affect autonomous exploration.

6.4 Marbotic Smart Letters

Marbotic Smart Letters integrate wooden alphabet pieces with phonics-based apps, delivering multisensory feedback that supports emergent literacy. The tool reflects Montessori principles and promotes cognitive flexibility through tactile experimentation (Maldonado & Zekelman, 2019). Although promising, the limited scope of peer-reviewed evidence and high dependency on tablets may reduce its inclusivity and limit its alignment with universal design.

6.5 PlayShifu Orboot Earth

PlayShifu's Orboot Earth utilizes augmented reality (AR) to provide interactive geography learning through a physical globe and companion app. It promotes curiosity, vocabulary enrichment, and contextual learning by situating information in real-world settings (Kelpšienė, 2020). However, its structured content design may constrain imaginative play, and access to AR-compatible devices can pose equity challenges.

Table 2: It presents a comparative synthesis of the five analyzed PGBL tools, evaluated across five key dimensions derived from the implementation challenges: open-ended play and cognitive flexibility, accessibility and equity, educator integration, cost and sustainability, and empirical evidence. This synthesis links theoretical constructs to practical considerations in early childhood education

Tool	Osmo Tangram	KIBO Robot	LEGO DUPLO Stories	Marbotic Letters	Orboot Earth (AR)
Open-Ended Play & Cognitive Flexibility	Moderate: Scaffolded problem-solving with limited free play	High: Constructionist iterative play	High: Promotes symbolic, creative construction	Moderate-High: Tactile literacy engagement	Moderate: Curiosity-driven, but pre-set narratives
Accessibility & Equity	Requires tablet & base (moderate access)	High cost; low accessibility in low-income settings	Relies on smart assistant devices	Tablet-dependent; limited UDL adaptation	High tech requirement; AR device needed
Educator Integration	Minimal setup; moderate pedagogical alignment	Requires intensive training (TPACK)	Moderate teacher facilitation	Low training threshold	Moderate integration
Cost & Sustainability	Moderate cost; app-based	Expensive hardware; non-scalable	Moderate cost; branded ecosystem	Mid-cost; limited classroom trials	Moderate-High cost
Empirical Evidence	Engagement, spatial reasoning (Schroth et al., 2019)	Sequencing, planning (Kazakoff et al., 2013)	Spatial & social skills (Diezmann & Watters, 2000)	Engagement, phonics (Maldonado & Zekelman, 2019)	Vocabulary, geography interest (Kelpšienė, 2020)

7. Discussion

Phygital learning tools hold transformative potential when aligned with core principles of cognitive development. However, their educational value is contingent on how well they uphold the tenets of play, learner agency, and scaffolding.

Osmo's visual-spatial games promote symbolic thinking and collaboration, aligning with Piaget's constructivist learning theory. KIBO's screen-free robotics supports early coding skills while reinforcing executive functions—especially when children engage in debugging and iterative design (Diamond, 2013; Bers, 2018). LEGO DUPLO Stories, through guided storytelling and brick-building, facilitate SEL and spatial reasoning, though reliance on Alexa narrows the scope for child-led inquiry. PlayShifu's Orboot globe and Marbotic's tactile phonics apps exemplify multisensory learning (Torres et al., 2021).

Yet, while these tools claim to foster critical thinking, the empirical validation varies widely—some, like KIBO, offer rigorous classroom-based results (Kazakoff et al., 2013), while others rely on qualitative or design-based observations (Maldonado & Zekelman, 2019). When assessed against implementation challenges, gaps become evident. For instance, while KIBO aligns with constructionist "low floor, high ceiling" principles, it demands high educator involvement. Similarly, Orboot encourages cultural learning but is limited in unstructured play. These gaps necessitate design enhancements grounded in universal design for learning (Meyer et al., 2014) and iterative evaluation models.

Thus, a critical takeaway is that the success of PGBL hinges not merely on tool design, but on the contextual integration of educator training, equitable access, developmental alignment, and curriculum synergy. Bridging these gaps can not only catalyze stronger learning outcomes but also foster innovation in inclusive digital pedagogy.

8. Conclusion

Phygital game-based learning tools offer promising avenues for fostering higher-order thinking in early childhood. However, their long-term educational value requires further investigation. Future research should

adopt longitudinal, cross-cultural, and multi-method approaches to assess sustained cognitive and socio-emotional outcomes. Emphasis must also be placed on inclusive design aligned with Universal Design for Learning (UDL) to support diverse learners. By integrating cognitive assessments, classroom observations, and teacher insights, future studies can deepen understanding of how PGBL tools contribute meaningfully to differentiated instruction and holistic development across varied educational contexts.

Ethics Declaration: This research study draws exclusively on publicly accessible academic literature, institutional reports, and secondary data sources. No primary data involving human participants was collected, and no confidential or proprietary information was accessed through non-disclosure agreements. Consequently, ethical approval was not required for this study. All case analyses—Osmo, KIBO, Marbotic, PlayShifu, and LEGO DUPLO Stories—are based on open-source materials and existing research. Appropriate scholarly conventions and citation practices have been followed throughout to ensure academic integrity.

AI Declaration: Artificial intelligence tools, specifically ChatGPT and Perplexity AI, were utilized to aid in identifying recent academic references and publicly available literature relevant to the study. As the author, I conducted the conceptual framing, thematic development, structure, and writing of this paper independently without generative language support from AI tools. All AI-assisted outputs were critically evaluated and verified against original academic sources before inclusion.

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The Role of Gamification in Learning Transfer: Does Early Skill Learning Predict Performance in Complex Tasks?

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Abstract: Gamification is widely employed in digital education to enhance engagement and motivation, yet its effectiveness in promoting cognitive skill transfer remains debated. This study investigated whether early learning efficiency in foundational levels (L1–L4) predicts performance in more complex tasks (L5–L8) within a physics-based educational game, and whether gamification moderates this transfer process. Ninety-four secondary school students were randomly assigned to either a gamified (n = 49) or standard (n = 45) training condition. Performance outcomes included overall efficiency, average points per attempt, and conceptual learning gains. Independent Welch's t-tests revealed no significant group differences across these metrics (all $p > .05$, $ds < 0.12$), suggesting a high degree of performance equivalence between the gamified and standard conditions. Regression analyses indicated that early learning efficiency significantly predicted later performance in Level 5 ($\beta = 0.611$, $p < .001$) and Level 7 ($\beta = 0.427$, $p = .017$), but not in Levels 6 and 8. A composite model across Levels 5–8 confirmed a generalized transfer effect ($\beta = 0.405$, $p = .002$, $R^2 = .10$), emphasizing the critical role of foundational skill acquisition in complex problem-solving. Gamification did not significantly moderate this overall transfer relationship. However, a notable exception emerged at Level 7: a significant interaction ($\beta = 0.762$, $p = .031$) suggested that gamification enhanced transfer under conditions of heightened conceptual complexity, likely by supporting adaptive learning processes. No significant trajectory effects were observed across successive levels, with participants maintaining relatively stable performance. Further analysis of foundational levels revealed that strategic variation and cognitive challenge in Levels 2, 3, and 4 contributed most strongly to later success, whereas simple introductory practice in Level 1 was insufficient. These findings indicate that while gamification alone does not universally improve learning transfer, it may selectively facilitate skill adaptation when learners face novel or disruptive challenges. The results highlight the importance of scaffolded instructional design, emphasizing task complexity and strategic engagement during early learning stages, and suggest that gamification should be deployed adaptively rather than uniformly to optimize educational outcomes.

Keywords: Gamification, Learning transfer, Skill acquisition, Cognitive flexibility, Educational psychology, Instructional design

1. Theoretical Framework

Foundations of Learning Transfer. The ability to transfer acquired skills and knowledge to novel contexts is regarded as a central challenge in education and cognitive science. In an increasingly complex and dynamic world, fostering learning transfer is critical for preparing learners not merely to perform routine tasks, but to adapt and innovate in unfamiliar situations.

Learning transfer, the process of applying knowledge or skills acquired in one context to new, often more complex situations, is widely recognized as a core objective of education. The foundational work of Perkins and Salomon (1987, 1988, 1989, 2012) distinguishes between near transfer and far transfer, based on the degree of similarity between learning and application contexts. Near transfer involves the effortless application of well-practiced skills in similar environments through "low-road transfer," relying on extensive practice and automaticity. Far transfer, by contrast, requires conscious abstraction and recontextualization, termed "high-road transfer," and demands metacognitive reflection, cognitive flexibility, and the active construction of connections between prior learning and novel situations (Salomon & Perkins, 1987; Perkins & Salomon, 1989).

Perkins and Salomon's detect–elect–connect model (2012) further refines the understanding of high-road transfer as a deliberate cognitive process, emphasizing the learner's active role in detecting potential applicability, electing to engage prior knowledge, and connecting it meaningfully to new tasks. Critically, transfer is not a guaranteed consequence of learning but a complex phenomenon requiring intentional educational design. To foster transfer, Perkins and Salomon (1988) propose two complementary strategies: hugging, designing learning experiences closely aligned with real-world applications to support low-road transfer; and bridging, encouraging learners to reflect on the generalizability of their knowledge, thus supporting high-road transfer.

Game-Based Learning and Cognitive Development. Building on these theoretical foundations, recent research has increasingly highlighted game-based learning (GBL) as a powerful medium for promoting cognitive development and transfer. Games offer dynamic environments for feedback, exploration, and simulation, each serving critical roles in facilitating deeper learning. Feedback loops, as identified by Garris et al. (2002), provide

immediate and informative responses to learner actions, sustaining engagement and promoting refinement of understanding. Hamari et al. (2016) further confirmed that the perceived challenge inherent in GBL environments significantly predicts learning outcomes, mediated through heightened cognitive engagement.

The exploratory nature of games supports active meaning-making. Gee (2007) emphasized that well-designed games encourage players to navigate complex systems, fostering systems thinking and conceptual understanding. Simulation-based learning extends these benefits by offering risk-free environments in which theoretical knowledge can be applied to realistic problems (Kumar & Sherwood, 2007). Recent findings by Sounthornwiboon et al. (2025) demonstrated that simulation games not only improved conceptual learning but also enhanced cognitive processing skills, including problem-solving and decision-making.

Empirical evidence from Ke et al. (2016) and Pratama and Setyaningrum (2018) illustrates that game-based learning can scaffold the progression from affective engagement (curiosity and challenge) to deep cognitive engagement (strategic thinking and conceptual understanding), ultimately supporting critical thinking and reflective learning processes. GBL environments thus provide fertile grounds for promoting the kind of metacognitive activity necessary for high-road transfer.

Gamification, Motivation, and Cognitive Load. While game-based learning and gamification share common elements, gamification specifically refers to the integration of game mechanics in non-game contexts to enhance engagement (Deterding et al., 2011). Underpinned by Self-Determination Theory (SDT) (Ryan & Deci, 2000), effective gamification aims to fulfill basic psychological needs for autonomy, competence, and relatedness. Empirical studies demonstrate that choice-driven mechanics (Luarn et al., 2023), adaptive feedback systems (Sailer et al., 2017), and social interaction features (Kam & Umar, 2018) align gamified environments with these motivational needs, thereby fostering intrinsic motivation and deeper engagement.

A comprehensive review by Ortiz-Rojas, Chiluiza, and Valcke (2017) supports these findings, identifying consistent short-term engagement effects across diverse gamified learning environments, though with mixed results for long-term performance improvements.

Nevertheless, empirical findings underscore that the impact of gamification is highly context-dependent. Domínguez et al. (2013) and Hanus and Fox (2015) reported that while gamification initially enhanced engagement, overemphasis on external rewards, such as points and badges, eventually led to frustration, distraction, and diminished intrinsic motivation. Similarly, Fung et al. (2024) highlighted that gamification tends to be more effective in structured STEM contexts but can be counterproductive in informal learning environments.

Further complicating the picture, Deci et al. (1999) found that extrinsic rewards tied to performance can undermine intrinsic motivation, reinforcing the need for carefully balanced gamification designs that prioritize psychological meaningfulness over superficial incentives. Kam and Umar (2018) additionally warned that excessive gamification elements could increase extraneous cognitive load, particularly in cognitively demanding domains like STEM, thereby hindering rather than helping learning.

Conditions Supporting Gamified Learning Transfer. Recent research identifies specific conditions under which gamification can successfully support learning transfer. Chen et al. (2022) demonstrated that gamified flipped learning environments, when carefully aligned with meaningful learning tasks, can optimize cognitive load management by reducing extraneous distractions and enhancing intrinsic engagement. Similarly, Baah et al. (2024) confirmed that gamified courses designed with clear instructions and immediate feedback effectively minimized cognitive distractions, fostering greater cognitive investment and engagement.

Meta-analyses further support these findings. Wouters, van Oostendorp, and van der Spek (2013) found that serious games promote both near and far transfer when design features such as feedback, scaffolding, and reflective activities are embedded. They emphasize the importance of contextual alignment, where game environments closely mirror real-world application settings, to facilitate "hugging" transfer. Mayer (2019) complements this perspective, applying the Cognitive Theory of Multimedia Learning (CTML) to highlight the role of coherence, signaling, and spatial contiguity in minimizing cognitive overload and enhancing generative processing, both critical for successful transfer.

Both Wouters et al. and Mayer converge on the principle that feedback loops, cognitive load management, and contextual or conceptual alignment are central mechanisms mediating the relationship between gamification and learning transfer. Poorly designed systems that violate these principles risk cognitive overload and

motivational decline, ultimately hindering the very learning outcomes gamification seeks to promote (Mayer, 2019).

Summary. In sum, the literature demonstrates that gamification and game-based learning can substantially support learning transfer when grounded in cognitive, motivational, and instructional principles. Alignment with SDT needs, careful cognitive load management, provision of feedback and reflection opportunities, and contextual relevance emerge as critical design imperatives. Conversely, gamification that relies excessively on extrinsic incentives or adds cognitive complexity without pedagogical justification can impair both motivation and transfer. Building on the frameworks articulated by Perkins and Salomon, and drawing on empirical insights from Wouters, Mayer, Chen, Baah, Ortiz, and others, the present study investigates the extent to which early learning efficiency in gamified foundational tasks predicts successful performance in more complex transfer tasks, and explores the moderating role of gamification design quality.

2. Methods

Participants. The research data presented in this study was collected through direct recruitment of school classes, despite the app being publicly available. This approach allowed for (a) greater control over session conditions and (b) increased commitment to completing the pre- and post-tests. Each participating class received an incentive of 300 CHF for the class fund to encourage full participation. In total, 170 secondary school students from nine classes initially took part in the study. The sample included 71 male and 73 female students, with 26 not specifying gender. Grade levels ranged from 6th to 9th grade: 10 students from 6th grade, 25 from 7th grade, 76 from 8th grade, and 34 from 9th grade, with 25 not indicating grade level. The average age was 13.66 years (SD = 0.79; range = 11–16).For the present analyses, only students who completed both the pre- and post-test assessments and full gameplay data were included. This resulted in a final sample of 94 students (mean age = 13.48 years, SD = 1.01), with 55.2% identifying as female (n = 48), 41.4% as male (n = 36), and 3.4% as diverse (n = 3). Group assignment was randomized, resulting in 49 participants in the gamified condition and 45 in the standard condition. No group assignment data was missing.

Study Design. The study employed a between-subjects design to investigate whether early learning efficiency in a digital physics-based game predicts later performance on complex tasks, and whether gamification moderates this transfer. Participants were randomly assigned to either the gamified or standard condition, ensuring equivalence in group characteristics.

Physics comprehension was measured using quizzes administered before and after the learning sessions. In contrast to earlier iterations of the learning environment, no motivation questionnaire was employed in this study, focusing the analyses exclusively on cognitive learning outcomes.

Digital Learning Environment: Basketball Physics Challenge. The learning environment was a web-based educational game called *Basketball Physics Challenge*, developed using HTML5, CSS, and JavaScript, with backend logging via PHP and mySQL. To ensure privacy compliance, no cookies were used. The game ran on desktop and mobile devices, ensuring usability for school learners.

The game simulated a basketball shooting task in which players used a virtual cannon to adjust physical parameters (e.g., angle, initial velocity) in order to shoot a ball through a basket. Across successive levels, players encountered increasingly complex environmental manipulations requiring deeper engagement with physical principles such as force, motion, and trajectory.

Two versions of the game were developed:

- The **gamified version** featured points systems, timers, visual progress indicators, and playful graphical elements designed to foster motivation and engagement.
- The **standard version** presented identical physics tasks but without additional gamification elements, emphasizing clarity and cognitive focus without external incentives.

Both versions shared the same core physics content and task structure, allowing direct comparison of the effects of gamification on learning outcomes.

Figure 1: Level 7 (magnetism). Left: gamified version. Right: standard version. Level with strongest gamification effect

Level Structure and Cognitive Progression. The game included eight sequential levels that scaffolded learning from basic procedural skills to complex adaptive tasks:

- **Foundational levels (L1–L4):** These initial levels emphasized isolated control of motor-physics parameters. Level 1 served as a basic motor warm-up focusing on simple shooting mechanics. Levels 2 to 4 introduced systematic variation: Level 2 altered launch heights, Level 3 constrained launch angles (fixed 30°), and Level 4 required adaptation to steeper angles (fixed 60°). These foundational levels aimed to build procedural fluency and strategic flexibility.
- **Complex levels (L5–L8):** The later levels integrated previously isolated skills under novel or conceptually demanding conditions. Level 5 required the simultaneous adjustment of angle and speed. Level 6 introduced reduced gravity conditions simulating lunar environments. Level 7 incorporated magnetic field interference selectively affecting iron projectiles. Level 8 presented underwater physics, altering ball dynamics through fluid resistance.

The level design was grounded in a competency model derived from international curricula, particularly referencing the Swiss *Lehrplan 21* (NT.5.1.3.b). This ensured that the cognitive progression aligned with educational standards on force and motion, focusing on the development of transferable problem-solving skills.

Learning Task and Quiz Structure. Learning outcomes were assessed using an 8-item multiple-choice physics quiz administered both before and after the gameplay sessions. The quiz was specifically developed for this study to evaluate not only factual knowledge but also deeper conceptual understanding and the prevalence of persistent misconceptions in fundamental physics domains.

Each item addressed a key concept that is frequently misunderstood by learners, including initial velocity, motion and trajectory, throwing angles, gravitational effects, friction and air resistance, as well as material-dependent forces in magnetic and fluid environments. Correct answers contributed one point each toward a composite physics comprehension score, with no penalties for incorrect responses. The total score thus ranged from 0 to 8 points.

The quiz design was informed by cognitive science research on common misconceptions in physics learning, drawing upon frameworks such as those developed by McDermott and Redish (1999) and the PISA science literacy standards. Special emphasis was placed on constructing distractors that represented scientifically plausible but incorrect reasoning, allowing for a more precise identification of conceptual errors related to force dynamics, motion, environmental resistance, and material interactions.

By integrating both straightforward factual recall and diagnostic misconception targeting, the quiz provided a robust measure of participants' conceptual grasp and the extent to which gameplay interventions facilitated the correction of misunderstandings.

Data Collection and Performance Metrics. In-game performance metrics—including successful hits, total attempts, time to completion, and accumulated points (where applicable)— were automatically logged by the backend system. These behavioral data allowed for detailed analyses of learning efficiency and task mastery. Statistical analyses focused on four main aspects: First, Welch's t-tests were used to compare learning outcomes between the gamified and standard conditions. Second, linear regression models examined the predictive relationship between foundational learning efficiency and later performance in complex tasks. Third, interaction terms were included to test whether gamification moderated this transfer effect. Finally, linear mixed-effects models were employed to assess performance trajectories across levels. All tests were two-tailed with an alpha level of 0.05.

3. Results

Learning Outcomes Across Groups. To examine differences between the gamified and standard training conditions, independent Welch's t-tests were conducted on three primary outcome measures: overall gameplay efficiency (Levels 1–8), average points per attempt, and quiz learning gains. Across all measures, no statistically significant group differences were observed. Participants in the gamified group (M = 0.439, SD = 0.123) and the standard group (M = 0.440, SD = 0.149) achieved nearly identical efficiency scores, t(85.68) = –0.05, p = .962, with a negligible effect size (d = –0.01, 95% CI [–0.42, 0.40]). Similarly, no significant differences were found for average points per attempt, t(85.47) = –0.58, p = .565, d = –0.12, or for quiz learning gains, t(87.89) = 0.52, p = .606, d = 0.11. These results suggest a high degree of performance equivalence between the two instructional conditions.

Generalized Transfer from Foundational to Complex Tasks. To assess generalized skill transfer, a composite score representing complex task performance (Levels 5–8) was regressed on early foundational efficiency (Basis_Effizienz, averaged across Levels 1–4). The analysis revealed a statistically significant positive relationship, $F(1, 92) = 10.52$, $p = .0016$, $R^2 = .10$, $\beta = 0.405$, indicating that higher early efficiency was associated with better subsequent complex task performance. When instructional condition (gamified vs. standard) and its interaction with foundational efficiency were added to the model, the overall model remained significant, $F(3, 90) = 4.39$, $p = .0062$. However, neither the interaction effect ($\beta = 0.391$, $p = .121$) nor the main effect of foundational efficiency ($\beta = 0.202$, $p = .266$) remained individually significant, suggesting that the transfer effect occurred similarly across both groups.

Level-Specific Transfer Patterns. Further regression analyses were conducted separately for each complex task level. Foundational efficiency significantly predicted performance in Level 5, $F(1, 92) = 16.85$, $p < .001$, $R^2 \approx 0.155$, $\beta = 0.611$, and in Level 7, $F(1, 92) = 5.86$, $p = .017$, $R^2 \approx 0.06$, $\beta = 0.427$. No significant predictive relationships were found for Level 6 ($F(1, 92) = 1.20$, $p = .276$) or Level 8 ($F(1, 92) = 1.44$, $p = .234$). Moderation analyses revealed that gamification significantly enhanced the transfer relationship at Level 7 ($\beta = 0.762$, $p = .031$), while no significant moderation effects were observed for Levels 5, 6, or 8. This suggests that gamification may support skill adaptation particularly under conditions of increased conceptual complexity.

Efficiency Trajectories Across Levels. To explore the progression of learning efficiency across the eight game levels, a linear mixed-effects model was fitted with Level (1–8), Group (Gamified vs. Standard), and their interaction as fixed effects. No significant main effect of Level ($\beta = –0.0036$, SE = 0.0057, t = –0.64) or Group ($\beta = 0.0373$, SE = 0.0463, t = 0.81) was found, nor a significant Level × Group interaction ($\beta = –0.0080$, SE = 0.0082, t = –0.98).

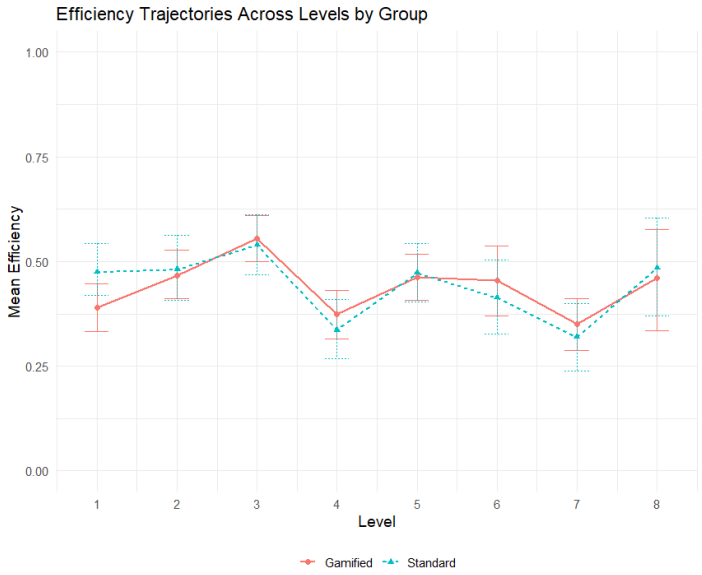

Figure 1: Efficiency trajectories across game levels for both groups

As shown in Figure 1, both groups demonstrated relatively stable levels of efficiency across the sequence of game levels. No significant upward or downward trend was identified. This finding indicates that neither instructional condition engendered differential learning curves across the progression of complexity.

Contributions of Individual Foundational Levels. Finally, a multiple linear regression model assessed the differentiated contributions of efficiencies in foundational Levels 1–4 to overall complex task performance (Levels 5–8). The model revealed an excellent fit, $F(4, 90) = 10{,}340$, $p < .001$, Adjusted $R^2 = 0.998$. Levels 2, 3, and 4 contributed significantly to later success (L2_effizienz: $\beta = 0.233$, $p = .010$; L3_effizienz: $\beta = 0.282$, $p < .001$; L4_effizienz: $\beta = 0.281$, $p = .003$), while Level 1 efficiency did not ($\beta = 0.145$, $p = .161$). These findings suggest that strategic complexity and task variation during foundational training were crucial in promoting transfer to more complex challenges.

4. Discussion

This study investigated whether early learning efficiency in foundational game levels (L1–L4) predicts performance in subsequent complex challenges (L5–L8), and whether gamification moderates this transfer process. The results offer differentiated insights into mechanisms of skill acquisition, transfer, and the conditional role of gamified instructional design.

First, analyses revealed no significant differences between the gamified and standard groups across overall gameplay efficiency, average points per attempt, or quiz learning gains. These findings confirm that, despite its motivational appeal, gamification did not inherently enhance learning outcomes relative to a standard training condition. This aligns with previous critiques suggesting that gamification, when implemented superficially, may increase engagement without necessarily improving cognitive outcomes (Domínguez et al., 2013; Hanus & Fox, 2015).

However, closer examination of transfer processes revealed that early learning efficiency robustly predicted later complex task performance, particularly for Levels 5 and 7. In Level 5, which required the integration of angle and speed control, early proficiency in foundational tasks significantly supported learners' ability to generalize isolated physics principles under increased task demands. Similarly, Level 7, introducing a magnetic field that altered material behavior, exhibited a significant predictive relationship, but with an important addition: the relationship between early learning efficiency and later performance was significantly stronger for gamified learners. This suggests that gamification may contribute positively when learners face novel, disruptive conditions that demand cognitive flexibility. Gamified environments might have supported exploratory learning strategies or sustained attention.

However, the absence of a consistent gamification effect across all complex tasks suggests that gamification alone may not sufficiently scaffold the cognitive processes required for more routine or procedurally similar tasks. Where task demands do not fundamentally disrupt established strategies, intrinsic motivation and existing skill schemas may suffice, rendering additional motivational scaffolds less impactful.

In contrast, no significant predictive relationships were found for Levels 6 and 8, which introduced substantial environmental deviations such as reduced gravity and underwater physics. The absence of transfer in these tasks suggests that procedural skills acquired in the foundational stages were insufficient when the environmental context diverged substantially from initial learning conditions. This observation is consistent with theories of far transfer (Perkins & Salomon, 1992), which posit that applying knowledge to dissimilar contexts demands deliberate abstraction and reasoning, processes that were not explicitly scaffolded within the present training design.

The linear mixed-effects analysis of efficiency trajectories further corroborated the stability of performance across the eight levels. Neither a main effect of level nor group was detected, nor an interaction between the two. This suggests that participants, after an initial phase of skill acquisition, reached a performance plateau that persisted. Such stability may reflect early mastery of core mechanics without substantial cognitive elaboration.

Further analysis of the contributions of individual foundational levels revealed important nuances. Efficiencies in Levels 2, 3, and 4 emerged as significant predictors of later complex performance, whereas Level 1, a basic introductory exercise, did not. This pattern underscores the critical importance of practice quality. Foundational tasks that introduced strategic variations and constraints—such as adjustments in launch height and constrained angle modulation—fostered stronger skill transfer than simple repetition. The observed effects support the theoretical distinction between low-road and high-road transfer mechanisms proposed by Perkins and Salomon (1992), highlighting that task variability, complexity, and cognitive engagement are necessary conditions for promoting the abstraction and flexible application of learned skills.

The differentiated contributions of foundational levels emphasize that effective transfer is not merely a function of exposure but depends on strategically designed early experiences. Levels 2–4, through structured variation

and cognitive challenge, scaffolded strategic thinking processes necessary for both near transfer, as evidenced in Level 5, and more flexible adaptation under novel conditions, as evidenced in Level 7.

Taken together, these findings illustrate that gamification, while not universally beneficial, may enhance transfer when learners encounter tasks that require adaptation rather than routine application. Gamification's potential thus appears to be context-dependent, emerging particularly in situations where learners face conceptual disruptions that challenge their existing skillsets.

From an instructional design perspective, these findings suggest that gamification should be used selectively in learning environments where adaptive reasoning and transfer are explicitly targeted. Educators and developers should combine gamified elements with scaffolded challenges and reflective prompts to optimize engagement and skill generalization.

This study contributes to growing evidence that early-stage learning quality—not mere exposure—is key to complex task performance. It highlights the need for instructional designs that go beyond shallow engagement and promote cognitively rich experiences. While gamification can support learners under specific cognitive demands, its blanket use is unlikely to yield consistent benefits. These results call for rethinking gamification strategies: rather than relying on universal engagement mechanics, future implementations should respond to task complexity and learner needs. The study thus offers empirical insights and practical guidance for the targeted, evidence-based integration of gamification into digital learning environments.

Implications for Instructional Design. The present findings carry important implications for the instructional design of game-based learning environments. First, the results suggest that not all forms of practice are equally effective in promoting transfer. Foundational experiences must be designed to incrementally build complexity and foster cognitive engagement rather than merely facilitating rote repetition. Strategic task variation, involving constraints and decision-making demands, appears essential for developing flexible, transferable competencies.

Moreover, while gamification did not consistently enhance performance across all tasks, it demonstrated a supportive effect under conditions of heightened cognitive load and task novelty. Thus, gamification elements should not be uniformly applied but rather targeted selectively to scaffold learner motivation and adaptation when instructional challenges intensify. This suggests that adaptive gamification strategies—responsive to learner needs and task characteristics—may be more effective than static designs.

Limitations and Future Research. Several limitations of this study should be acknowledged. The sample size, while sufficient for detecting medium-sized effects, limits the generalizability of the findings. Additionally, transfer was assessed in a near-immediate timeframe, precluding conclusions about the durability of learning over longer periods. The study also focused exclusively on a physics-based game environment, which may limit applicability to other knowledge domains.

Future research should address these limitations by investigating longitudinal transfer trajectories in gamified and non-gamified contexts, exploring adaptive gamification designs that adjust challenge dynamically based on learner performance, and systematically examining mechanisms for fostering high-road transfer through explicit abstraction, reflection, and metacognitive scaffolding.

Ethics declaration*:* This study was conducted in accordance with institutional and national ethical guidelines. Formal ethical approval was not required, as the research involved non-invasive educational interventions within school settings. Informed consent was obtained from all participants and their legal guardians. Participation was voluntary, and all data were anonymised prior to analysis.

AI declaration*:* AI tools (ChatGPT, OpenAI) were used to support academic editing, linguistic refinement, and formatting assistance during the preparation of this manuscript. The authors reviewed and verified all content to ensure scientific accuracy and originality. No AI-generated content was accepted without human oversight or critical assessment.

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The Spectrum of Abstraction and Realism in Serious Games for Learning

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Abstract: The design of serious games for learning is shaped by a fundamental tension between realism and abstraction. Realism in serious games can manifest in multiple dimensions, such as graphical fidelity, sound design, game mechanics, narrative structure etc. Some serious games aim for high-fidelity simulation, replicating real-world scenarios as closely as possible (e.g., flight simulators or medical training applications). Others may incorporate abstract elements while still being grounded in real-world principles, such as strategy games that simplify complex decision-making processes. Abstraction, by removing unnecessary complexity, may reduce extraneous cognitive load and enhance generalisation of learning. In contrast, realism may support situated learning and contextual skill transfer, particularly when training requires familiarity with real-world environments. To better understand the implications of abstraction and realism in serious game design, this paper comparatively explores two case studies: FLIGBY, a corporate leadership development game Cipher, a language-learning game designed for children. Findings identify six key dimensions that differentiate abstraction and realism in serious games: visual style, audio style, mechanics and interface, rule systems and feedback. Engagement, motivation and cultural perception are also considered, noting that realism may appeal more in professional settings, while abstraction may be particularly effective in child-centred learning environments. This research contributes to the broader field of serious games by providing a conceptual framework to guide educators, game designers and researchers in making informed design decisions, also offering a foundation for future empirical research.

Keywords: Serious games, Abstraction vs. realism, Learning transfer, Game design

1. Introduction and Problem Statement

Serious games operate within a complex design space where developers must balance abstraction and realism to effectively achieve the desired cognitive, behavioural and affective outcomes. As Adams, (2014) notes, all game design involves a degree of abstraction, whether through simplification of mechanics, stylisation of visuals or metaphorical representations of complex systems. When designing for learning however, the implications of such abstractions must be carefully considered in terms of what they emphasise, obscure or distort and how they serve the pedagogical goals. Realism is commonly associated with high-fidelity simulations, aiming to mirror real-world environments and procedures for situated cognition and skill transfer (Risley & Wanick, 2025). In contrast, abstraction often distils core elements of experiences, intentionally stripping away other surface-level complexity to focus attention, reduce cognitive load and potentially improve generalisation across learning contexts (Bai et al., 2023; Ravyse et al., 2017; Xu et al., 2024). This has also been found in some cases to lead to higher levels of enjoyment and engagement, therefore motivation when compared to a more realistic counterpart (Lee et al., 2020).

The pedagogical benefits and trade-offs of these approaches have been explored in prior work, but definitions of abstraction and realism often remain imprecise, particularly across different game elements. Existing research has typically addressed isolated dimensions of fidelity such as visual realism (Bai et al., 2023; Hameed et al., 2021), narrative structure (Naul & Liu, 2020), or interaction mechanics (Ye et al., 2020), but few studies have synthesised these into a cohesive framework to support holistic design decisions. Moreover, studies often focus on one end of the spectrum or conflate realism with quality, ignoring how abstraction can be equally deliberate and pedagogically effective. For example, fantasy-based learning games have been shown to enhance motivation and conceptual understanding when abstraction is closely aligned with learning goals (Naul & Liu, 2020; Papastergiou, 2009; Xu et al., 2024). However, realistic representations, particularly in the form of high-fidelity visuals, believable soundscapes or authentic scenarios can enhance credibility and the perceived 'seriousness' of a game (Risley & Wanick, 2025). This is especially relevant in domains such as business, medicine and aviation where simulation-style fidelity is typically expected to mirror real-world training needs and underpins assurances of professional competence (Abdulhussain et al., 2022; Fox & Uzuegbunam, 2018; Noble, 2002).

This presents a gap in literature and space for a structured framework that allows game designers to consider, analyse and balance these concepts in a systematic and pedagogically informed way. Realistic and abstracted approaches are each grounded in sound pedagogical reasoning, yet the literature reveals limited clarity in how the various elements of realism and abstraction are defined, assessed and ultimately operationalised across elements of game design. This work seeks to address that gap by proposing a conceptual framework comprising six key dimensions: visual style, audio, mechanics, rule systems, narrative and feedback - each considered along a spectrum of abstraction and realism.

2. Related Work: Theoretical Foundations

Play is increasingly recognised as a powerful mechanism beyond simple recreation through which individuals can learn, experiment and engage with structured systems of meaning. Huizinga's (1955) notion of the "magic circle" conceptualises play as a bounded, voluntary activity, distinct from ordinary life yet deeply meaningful within its own internally consistent logic. This separation can afford learners a protected space for exploration where risk is minimised, failure is instructive and boundaries are negotiable to a greater or lesser extent. Games further formalise this space through rule-bound structures (Salen and Zimmerman, 2004), creating what Adams (2014) terms "pretend realities" - representations that always involve some degree of simplification, stylisation or metaphor. These abstractions are therefore seen not as flaws but foundational design features; even games that appear realistic are inherently selective in terms of fidelity, choosing which elements of the real world to simulate and which to adjust. This selectivity appears to be central to the pedagogical strength of serious games. Realism, whether sensory, procedural or narrative can enhance immersion, credibility and learning transfer by anchoring learning in familiar contexts. Abstraction however enables playability, supports generalisation across scenarios and focuses attention on conceptual relationships, unhindered by additional cognitive demands (Westera et al., 2008). In the context of playful learning as a phenomenon mediated by some degree of abstraction it therefore stands to reason that realism and abstraction sit at either ends of a broad spectrum rather than being categorically binary concepts.

Realism and abstraction often function as overlapping design strategies that shape how serious games communicate meaning, structure interaction and guide learning. These qualities operate across multiple components such as visuals, narrative, mechanics etc and are rarely applied uniformly. Fernández-Vara (2011) proposes that realism is shaped by the alignment between a game's rules, the fictional world and the relevant simulation systems; where this alignment is strong, experiences tend to feel more coherent and believable. In serious games, this coherence is often regarded as supporting skill transfer or professional relevance, yet it may also limit the design space or reduce accessibility for novice learners. Conversely, abstraction can heighten clarity and reduce distraction, but may require players to exert more interpretive effort to understand how in-game actions relate to real-world contexts. Rather than resolving this through universal rules, designers must work across several dimensions. Furthermore, Ye et al. (2020) distinguish between objective fidelity: the extent to which in-game systems mirror real-world counterparts and subjective fidelity: how authentic and meaningful the game feels to its audience. Both can influence engagement and learning outcomes, but their value depends on the learner's prior knowledge, the purpose of the game and the complexity of the content. Further attempts to formalise these patterns are emerging in the work of authors such as Rogers et al. (2022), who present a taxonomy breaking realism into several discrete types across visuals, mechanics, sound, narrative and systems logic. While its granularity poses challenges for practical use, this work does illustrate how realism is constructed, rather than inherent, reinforcing the need for frameworks to assist designers making informed decisions across each design dimension.

The design of serious games must also take account of learners' cognitive capacities. Cognitive Load Theory (Sweller, 1988) highlights how unnecessary complexity can impose extraneous processing demands, which may hinder comprehension, particularly for learners with limited prior knowledge. Serious games that prioritise high-fidelity realism across visual or interactional elements may inadvertently burden learners with unnecessary additional information, reducing the cognitive resources available for the target task. Ravyse et al. (2017) extend this concern to game environments, noting that excessive detail or realism, especially when not directly aligned with the learning objective, can actually obscure rather than enhance instructional clarity. Abstraction, in contrast, can function as a pedagogical tool by focusing learners' attention toward core concepts. However, where learners are expected to navigate professional or domain-specific scenarios, greater realism may be necessary to situate decisions in context and support transfer to authentic settings (Risley & Wanick, 2025). The effectiveness of realism therefore appears to lie in how deliberately it is aligned with learners' existing knowledge and the complexity of the task. At opposite ends of a spectrum, abstraction and

realism function as strategic design choices, shaping how information is processed and supporting learner-centred progression.

The design of serious games inevitably raises the question of what kind of learning is intended to transfer beyond the game environment and under what conditions such transfer is most likely to occur. This aligns with research by Ye et al. (2020) who distinguish between physical fidelity (how environments are visually and spatially represented) and functional fidelity (how tasks and systems behave). Both contribute to the perceived authenticity of a simulation and may reinforce domain-specific routines - in many learning scenarios the objective is not replication but adaptation. Perkins and Salomon's (1992) distinction between near and far transfer draws attention to the value of abstraction in fostering generalisable understanding. Abstract representations, by stripping away surface features, can help learners focus on the deeper structure of a task or principle, making them more likely to apply this knowledge across novel or variable contexts. This is particularly relevant in domains such as ethics, communication or early-stage skill development, where fixed procedural knowledge may be less useful than conceptual flexibility. Naul and Liu (2019) further argue that narrative abstraction, including the use of metaphor or fantastical framing, can make complex or sensitive topics more accessible. In this sense, abstraction is not a compromise in fidelity but a deliberate strategy to support transfer across cognitive, emotional and cultural boundaries. For game designers, the goal is therefore to calibrate fidelity in line with the kind of learning transfer the game intends to support, rather than maximising fidelity. This requires a nuanced understanding of how different forms of abstraction and realism function within and across learning contexts.

Motivation and engagement are foundational to effective learning through games, with intrinsic motivation often linked to enjoyment, autonomy and mastery - shaped by how realism and abstraction are implemented in a game's design (Ryan & Deci, 2020). Lee et al. (2020) found in some contexts, abstracted designs led to greater enjoyment and engagement than their more realistic counterparts, particularly when stylisation enhanced playability or reduced cognitive friction. For younger learners, abstracted environments can be especially powerful in sustaining engagement with stylised visuals, simplified mechanics and imaginative metaphors supporting playful exploration and psychological safety, while enabling learners to focus on core concepts without distraction (Naul & Liu, 2020; Papastergiou, 2009). In contrast, learners in professional settings may be motivated by high-fidelity scenarios mirroring lived experiences. For instance, realistic feedback, authentic narrative and decision-making enhances the perceived seriousness and relevance of the learning task (Risley and Buzady, 2022). In these contexts, realism can be motivational as well as representational, reinforcing domain expectations and validating the learner's professional identity.

Finally, realism also raises ethical and cultural considerations, particularly in games addressing real-world events, identities or sensitive subject matter (Hormozi, 2025). McGonigal (2011) and Frasca (2003) argue that games are culturally situated artefacts which shape and are shaped by the narratives and values of the societies in which they circulate. In which case, abstraction offers somewhat of a pedagogical safeguard: a means of creating emotional distance, avoiding stereotyping and engaging players in critical reflection.

3. Framework Overview: Design Dimensions of Abstraction and Realism

Drawing on interdisciplinary sources from game studies, educational psychology and serious game design, a framework emerges composed of the following elements:

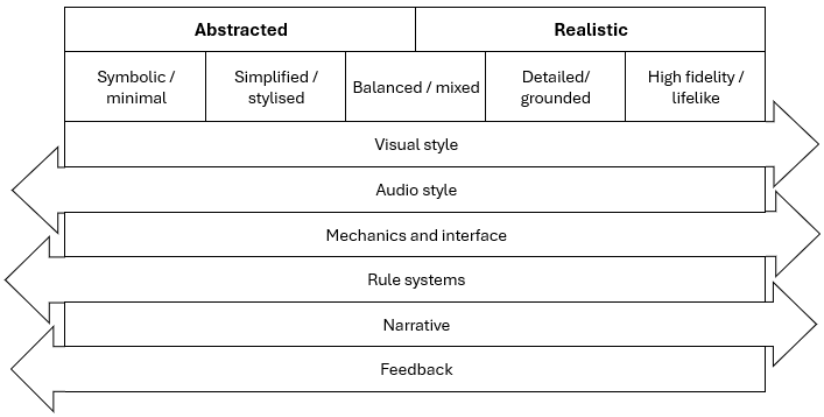

Figure 1: Design Dimensions Framework

3.1 Visual Style

Visual style is a key dimension through which abstraction and realism manifest in serious games. Realistic visual designs often incorporate photorealistic textures, anatomically correct models and adaptive lighting systems to replicate real-world environments. These are typically seen in simulation-based training tools such as medical procedure trainers or flight simulators, where visual accuracy supports domain-specific recognition and context-sensitive learning (Chalmers & Debattista, 2009). At the abstract end of the spectrum, games may rely on simple geometric shapes, colour-coded systems, or schematic representations to convey meaning. Language-learning games for children, for instance, often use cartoon-style avatars and simplified spatial layouts to reduce visual clutter and make core interactions more accessible (Bai et al., 2023). In these cases, abstraction supports cognitive economy, especially for novice users or when focusing on conceptual rather than spatial or procedural knowledge. Designers may also opt for stylised realism, which involves selectively enhancing or downplaying visual detail to support learning while maintaining user engagement (Ravyse et al., 2017).

3.2 Audio Style

Audio style contributes to immersion and instructional effectiveness, offering spatial, emotional and procedural cues that shape the player's interpretation of the game world. In realistic games, sound design might include ambient environmental noise, adaptive audio, or professional voice acting - all calibrated to mirror real-life acoustics and enhance situational awareness (Vontzalidis et al., 2024). This is particularly relevant in domains such as emergency response or clinical simulation, where auditory input is integral to task performance (Du et al., 2025; IEEE, 2025). High-fidelity audio can also support affective learning and well-integrated soundscapes have been found to enhance the emotional plausibility of scenarios, contributing to player engagement and memory consolidation (Ravyse et al., 2017). Marucci (2021) further argues that consistency between visual and auditory design supports internal coherence, reinforcing the learner's sense of presence within the simulated environment. At the abstract end of the spectrum, audio may consist of simplified cues such as chimes, buzzers and synthesised tones, or stylised music and effects. These can function effectively within symbolic or metaphorical game worlds, particularly when aligned with visual style and feedback systems. However, Bai et al. (2023) caution that even abstract sound design must remain consistent within the game's internal logic to avoid cognitive dissonance. For example, fantasy-based learning games may use non-representational soundscapes that, while lacking fidelity, remain perceptually congruent and maintain narrative engagement.

3.3 Mechanics and Interface

Game mechanics and interface design determine how learners interact with the game world. Realistic mechanics typically replicate real-world tasks or procedures, which might involve simulating the physical controls of a forklift, the steps of a surgical procedure, or the decision-making processes in a corporate setting, for example. In such contexts, learners engage with systems that mirror the complexity and sequencing of professional practice and high interaction fidelity, where user inputs closely match real-world actions can support skill transfer, particularly in procedural training domains (Ye et al., 2020). In contrast, abstracted mechanics typically simplify these interactions: a complex process may reduce to a click or visual choice. For example, rather than manipulating detailed instruments in a surgical simulation, a game might use a drag-and-drop system or a multiple-choice format to represent clinical reasoning. Similarly, interfaces in abstracted games tend to use symbolic icons, menu-based navigation or colour-coded feedback, supporting usability and lowering cognitive demand (Ravyse et al., 2017). Balance is important: while realistic mechanics can support experiential learning, particularly for advanced learners or high-stakes environments (Chalmers & Debattista, 2009), overly complex mechanics may hinder accessibility and immersion, particularly for novice learners.

3.4 Rule Systems

Rule systems define the underlying logic of a game: how player actions trigger outcomes, how time and resources behave and how the environment responds in turn. More realistic rule systems replicate domain-specific logic with high fidelity, for example flight simulators often model aerodynamics, engine systems and procedural checklists to ensure that training outcomes transfer to real-world performance (Ye et al., 2020). These systems typically prioritise procedural and functional fidelity, reinforcing cause-effect relationships in line with the real-world phenomena they aim to simulate. At the other end of the spectrum, abstracted rule systems may strip back complexity to foreground educational themes or streamline play. For instance a time-intensive process may be represented as a turn-based sequence or compressed into a single decision point,

such as a game on sustainability modelling resource management through simplified algorithms or metaphorical tokens rather than detailed environmental systems. These abstractions are often useful when the goal is conceptual understanding or values exploration, rather than procedural training (Ravyse et al., 2017). The credibility of the rule system ultimately depends on internal consistency and alignment with learner expectations and instructional goals. If rules appear arbitrary or inconsistent, they can undermine both immersion and learning outcomes, which has particular relevance in the behaviour of non-player characters (NPCs), whose responses must feel plausible even when simplified. Behavioural fidelity, as Ravyse et al. (2017) note, can anchor players' decision-making in realistic social dynamics even when underlying systems are partially abstracted.

3.5 Narrative Structure

Narrative is a powerful tool for anchoring meaning and whether presented through linear storylines or branching dialogue, narrative structures provide emotional context, scaffold decision-making and shape how learners interpret game events. At the realistic end of the spectrum, narratives draw directly from real-world settings, which may involve authentic professional dilemmas such as resolving conflict in a workplace, managing patient care, or making ethical business decisions. Realistic narrative design can enhance the relevance of educational content by embedding it in plausible social and institutional contexts (Xenos & Velli, 2020). When characters, settings and challenges reflect learners' lived or aspirational experiences, narrative is a powerful vehicle for situated learning, supporting the transfer of behaviours and attitudes into real-world practice. Abstract or metaphorical narratives instead prioritise more symbolic representations over strict realism, which might include allegorical journeys, cryptic quests or stylised metaphors for internal processes, such as battling diseases represented as defeating monsters. In educational games targeting conceptual understanding or personal growth, such abstractions can be highly effective; metaphorical framing can enhance emotional engagement and make abstract ideas more approachable - particularly in language learning or identity-based scenarios (Naul & Liu, 2020; Xu et al., 2024).

3.6 Feedback Systems

Feedback in serious games plays a central role in shaping learner behaviour, supporting reflection and sustaining engagement, informing players whether their actions are effective and helping them understand the consequences of their decisions. The degree of realism embedded in these feedback mechanisms can influence how learning is experienced and internalised (Mozdzer, 2021). More realistic feedback is largely embedded within the game world as a direct, contextually meaningful response. For example, in a medical simulation like Body Interact (Take the Wind, 2025), failing to administer treatment may result in a virtual patient's condition deteriorating. This form of diegetic feedback mirrors real-world cause and effect, reinforcing understanding through experiential learning (Marshall, & Honey, 2023). When aligned with authentic scenarios, realistic feedback supports situated cognition, helping learners understand not just what went wrong, but why. In comparison, abstract feedback systems often use external or symbolic cues to guide performance such as points, stars, badges or progress bars. These indicators can enhance transparency and motivation by making goals and achievements explicit, particularly in fast-paced or conceptual learning environments. Ravyse et al. (2017) argue that abstracted feedback can be effective when used to highlight core behaviours or scaffold understanding, provided it does not distort the underlying learning logic. In reality, effective serious games often adopt a hybrid approach. In-game consequences provide immediate, immersive feedback, while post-level summaries or visual dashboards allow for debrief and reflection.

4. Case Studies

4.1 Case Study One: FLIGBY

FLIGBY (Risley and Buzady, 2022) is a leadership training simulation designed for adult learners in corporate or professional education settings. FLIGBY's visual appearance blends stylised cartoon animation with interwoven use of realistic video elements filmed with live actors to produce a fluid, semi-realistic aesthetic (Figure 2). The hybrid visual style supports narrative congruence and distinguishes reflective moments from interactive sequences. Audio design is minimal and realistic, featuring ambient office sounds and selective voice acting that ground the experience in a plausible work environment. Dialogue is primarily text-based, with voiceovers used to signal key moments or reinforce tone.

Mechanically, FLIGBY employs simplified point-and-click interactions focused on managerial decision-making. Players select from response options during dialogue, shaping how virtual team members respond across the

simulation. Rule systems track multiple internal variables based on these decisions such as profit, sustainability and employee wellbeing - linking player choices to cumulative scenario outcomes.

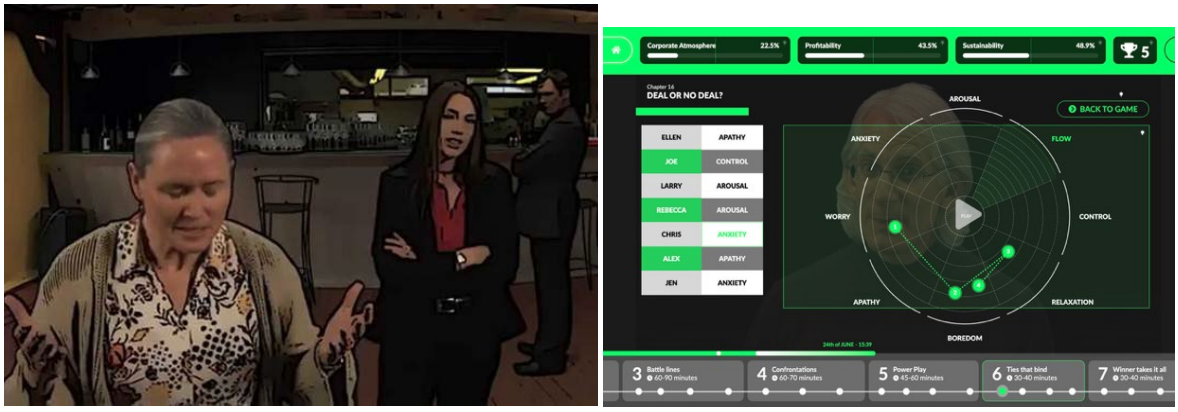

Figure 2: FLIGBY Stylised Narrative Scene and Gameplay Dashboard Screenshots

Narratively, the game unfolds through a linear scenario in which the player acts as general manager of a winery. Events are grounded in realistic workplace challenges, including conflict resolution, performance coaching and ethical decision-making. Feedback is delivered primarily through in-game consequences and post-scenario debriefs with an in-game mentor. Overall, FLIGBY's design reflects a realism-oriented approach, intended to simulate professional judgement in a contextualised, low-risk environment.

4.2 Case Study Two: Cipher

Cipher (Xu et al., 2024) is a serious game designed for learning Irish, through a relatively abstracted style. Visually, Cipher employs minimalist, cartoon-like, low-poly graphics, intentionally distancing itself from realism to reduce cognitive load and foster engagement without overwhelming learners (in this case, school children). AI-generated images are stylised further to maintain narrative consistency and avoid the uncanny valley effect (Figure 3). Its audio design mirrors this abstraction, featuring synthetic, dramatic voiceovers and sound effects that enhance the fantastical theme rather than aiming for naturalistic representation.

Figure 3: Cipher Gameplay Screenshots

Mechanically, interaction is simplified, relying on basic, intuitive controls that prioritise ease of access over realistic simulation. The interface is deliberately rudimentary, ensuring that learners focus on core language tasks (vocabulary, reading, writing, etc.) rather than complex navigational skills. Rule systems are metaphorical, involving gamified features such as 'spirit power' (points) and 'magical eyes' (power-ups), streamlining cause-effect relationships while maintaining motivational structures.

Narratively, Cipher draws on Irish folklore fused with imaginative elements, creating a symbolic storyline where players must lift spells corrupting ancient tales. Feedback is gamified and abstract, supporting flow and sustained engagement. Overall, Cipher leans toward the abstract end of the spectrum, exemplifying a design strategy that supports conceptual learning, engagement, and cultural immersion for young language learners.

5. Discussion

This work proposes a structured framework for examining how realism and abstraction are operationalised across six design dimensions in serious games. Drawing on established learning theory and design research, it

is argued that these concepts are best understood as design strategies, calibrated in relation to audience needs, learning goals and contextual expectations. The case studies of Cipher and FLIGBY show how different choices along this spectrum can serve distinct pedagogical functions. In Cipher, abstraction supports clarity, imaginative engagement and accessibility for younger learners. Stylised visuals, metaphorical mechanics and simplified feedback structures help maintain focus on core language tasks. These choices reflect an emphasis on generalisation over specificity and are consistent with evidence that abstraction can reduce cognitive load while supporting motivation and learning flexibility (Ravyse et al., 2017; Naul & Liu, 2020; Lee et al., 2020). In contrast, FLIGBY uses a more typically realistic design to reflect professional leadership challenges. Decision-making mechanics mirror workplace dilemmas and performance consequences are integrated across a longer timeline. This form of functional fidelity is designed to enhance authenticity and support transfer to real-world contexts (Ye et al., 2020; Squire, 2011). The game's hybrid visual style maintains accessibility while reinforcing the credibility of the scenario. In both cases, abstraction and realism are selectively applied across dimensions, rather than applied universally to the game. This reflects the core principle that fidelity should be matched to the pedagogical function of each design component.

A detailed matrix is included in Appendix 1, intended to provide a prototype tool for assessing serious games against the six design elements presented in the framework. Each dimension contains 5 contextual points describing the degree of abstraction or realism for designers to assess how these present in their games.

6. Conclusion, Limitations and Future Work

The proposed matrix serves as an initial framework but requires further refinement; its currently broad descriptors would benefit from greater specificity to better support design decisions. As research studying abstraction and realism across multiple game elements remains limited, future work will focus on empirical validation, including testing with game players, serious game designers and researchers. Iterative revisions based on structured feedback will help improve its clarity and applicability. Expanding the matrix to accommodate diverse educational contexts and cultural perceptions of realism and abstraction is also further a direction for future research.

Ethics declaration: This research did not involve human participants, personal data or any procedures requiring formal ethical approval.

AI declaration: The authors made very limited use of generative AI to explore alternative phrasings and check consistency in terminology. All intellectual contributions and analytical decisions were made by the authors.

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Appendix A: Matrix of Design Dimensions in Abstraction and Realism

Abstract <----------> Realistic					
Dimension	**Symbolic / minimal**	**Simplified / stylised**	**Balanced / mixed**	**Detailed/ grounded**	**High fidelity / lifelike**
Visual style	Icons / symbols / flat shapes with minimal detail / text only	2D or cartoon style, blurry / simplified anatomy or environment	Recognisable forms with selective realism in environments, characters etc	3D environments with natural scale and features , with selective stylisation	Photorealistic textures or environmental detail, anatomical accuracy
Audio style	No sound or basic tones (e.g. beeps, chimes), unrelated to game context	Stylised effects, limited audio cues, repetitive loops	Mix of sound effects and selective speech or ambient cues	Layered soundscapes with ambient details, some voice acting	Rich, dynamic spatial audio, nuanced effects, full voice acting
Mechanics and interface	Simple and not directly representational (e.g. click through menus / choices)	Basic controls (e.g. taps / clicks), functionally suggestive, low procedural detail	Reflective of real-world workflows, largely reduced complexity	Actions and interfaces mimic real-world procedures, tools or workflows	Realistic two-way input methods, precisely emulated actions / controls
Rule systems	Arbitrary rules, simplified logic (e.g. collecting coins), unrelated cause-effect	Simplified systems with basic logic & cause-effect, metaphors progress	Logic partly reflects real world cause-effect, without full complexity	Cause-effect reflects domain-relevant logic, modelled on real trade-offs	Closely models real-world dynamics, complex / linked outcomes
Narrative	Minimal context, no cohesive storyline (e.g. play framed by instructions only)	Simplified or fantastical story elements (e.g. fantasy quests / vague missions)	Loosely mirrors real-world themes, with metaphorical or fictional narrative	Authentic domain-relevant scenarios, plausible choices / characters	Facts, dialogue, choices based on real events, / dilemmas, authentic roles
Feedback	No in-game responses or minimal cues (e.g. score totalled at end)	Simple points or icons (e.g. stars, badges, timers) indicate success without context	Blended feedback combining scores with contextual reactions / system prompts	Gameplay consequences / system outcomes reflect player actions	Specific, real time feedback, fully embedded in gameplay / scenario itself

Note: To use this matrix, designers should review each of the six design dimensions then select the boxes that best describe how each element is implemented in the game.

All games are likely to include a mix of different levels across dimensions - for example using stylised visuals but realistic feedback. The goal is not to aim for one end of the spectrum, but to deflect deliberately on how each design choice aligns with the audience's context and learning objectives.

Embedding Reflective Game Design (RGD) into Digital Game Based Learning: Design Recommendations and Empirical Insights

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Abstract: Reflective learning enhances critical thinking, metacognition, and knowledge retention by encouraging learners to analyse their experiences. Digital games provide a rich environment for reflection through interactivity, feedback, and iterative exploration. While many games incorporate elements that support reflective learning, such as prompts, feedback displays, and decision-making mechanics, there has been limited systematic integration of reflective principles into digital Game-Based Learning (GBL) design. This study provides a structured Reflective Game Design (RGD) approach to embed reflective learning into digital GBL environments. Conducted in three phases, the research: (1) reviewed literature to identify core reflective strategies and game mechanics; (2) co-designed and developed two game prototypes, one with RGD features and one without; and (3) used a mixed-methods evaluation to compare usability, engagement, and learning outcomes across the two versions. Findings indicate that games designed with RGD features significantly enhance learners' critical engagement, emotional awareness, and knowledge retention. Features such as journaling, prompts, feedback systems, and emotional tracking, were particularly effective in deepening player connection and learning. This research offers actionable design recommendations and a flexible RGD framework to support the integration of reflective practices into educational games. It will be of particular value to GBL researchers, instructional designers, serious game developers, and educators seeking to create more meaningful, learner-centred digital experiences.

Keywords: Game-Based learning, Digital educational games, Reflective game design, Metacognition, Participatory design, Serious games

1. Introduction

Game-Based Learning (GBL) uses the motivational power and interactivity of digital games to support knowledge acquisition and skill development (Gee, 2004; Kapp, 2013). As educational technologies evolve, GBL environments increasingly incorporate learning theories to deepen engagement and understanding (Klopfer et al., 2009; Prensky, 2001; Takeuchi & Vaala, 2014). Reflective learning, in particular, promotes metacognition, critical thinking, and long-term behavioural change (Mezirow, 1994). Digital games are well suited to support reflection through their decision-driven, feedback-rich structure (Khaled, 2018). Features such as branching narratives and consequence-based choices naturally prompt introspection. Yet few games systematically apply reflective principles in their design (Shaheen & Fotaris, 2023).

This paper introduces the Reflective Game Design (RGD) framework, developed through a three-phase study combining theoretical analysis, participatory design, and evaluation. The aim is to offer actionable recommendations for educators, researchers, and game designers seeking to enhance the reflective capacity of GBL environments.

1.1 Reflective Learning in Education

Reflective learning involves critically examining one's experiences to gain insights that inform future actions (Dewey, 1933). It enhances metacognition, supports problem-solving, and fosters self-awareness by prompting learners to question assumptions, identify patterns, and explore alternatives (Mezirow, 1994; Schön, 1983).

Dewey describes reflection as active, persistent inquiry that moves beyond memorisation to interpretation and application. Schön (Schön, 1983) distinguishes between two modes essential for self-regulated learning: 1) Reflection-in-action, occurring in the moment to help learners adjust behaviours in real-time; and 2) Reflection-on-action, which occurs retrospectively to evaluate past decisions. Effective reflection also includes emotional and behavioural engagement, requiring learners to reassess motivations and emotional responses to drive change (Fleck and Fitzpatrick, 2010). Structured methods (such as journals, scenario analysis, and feedback) are widely used in education, from teacher training (Loughran, 2002) to healthcare (Mann et al., 2009) and workplace learning (Eraut, 2004).

In digital environments, these tools can be reimagined through dynamic feedback, in-game prompts, and visual progress indicators. However, integrating reflection without disrupting gameplay remains a key design challenge. As this paper argues, serious games offer an untapped opportunity to address that challenge.

1.2 Reflective Learning in GBL Design

Digital GBL environments provide immersive, interactive spaces that support experiential learning through feedback, simulation, and trial and error (Gee, 2004; Kapp, 2013) (Fotaris & Mastoras, 2019). These conditions align well with reflective learning. Yet in most educational games, reflection is incidental, not purposefully designed. To address this, Lin et al. (1999) outlined four adaptable strategies: process displays that visualise learning pathways; prompts that pause gameplay to ask players to justify choices; process models offering idealised comparisons; and social discourse through peer feedback. Sengers et al. (2005) expanded these into a Reflective Design framework that disrupts assumptions and fosters introspection. Khaled (2018) applied these principles to games, advocating for intentional disruption and self-reflection, even at the cost of immersion.

Reflective features can take many forms: emotion-tracking heads-up displays (HUDs), in-game journals, moral dilemmas, or post-level debriefs. Role-play and narrative immersion further support reflection by encouraging players to explore unfamiliar perspectives (Klopfer et al., 2009). Building on this, Khaled et al. (2024) presented "Reflective Surfaces" as an interactive game-as-research format where designers' reflective practices are explored through navigable desktops. They argued that tacit, practice-based knowledge can be better expressed through playful, digital forms rather than traditional academic style. The paper call for rethinking, how design research is articulated, reviewed, and shared to make knowledge forms suitable for their function. In GBL, Shaheen et al. (2023) investigated the efficacy of RGD by integrating features such as process displays, prompts, HUDs, UI elements, and reflective comparisons. The RGD approach and game prototype received positive feedback for engagement, content clarity, incorporation of reflective elements, and player immersion. Despite, these opportunities though, few games systematically integrate reflection into core design. The Reflective Game Design (RGD) framework introduced in this paper offers a research-based methodology to address this gap through iterative, learner-centred design.

2. Literature Review

While the theoretical case for embedding reflection in digital games is well established, its practical implementation remains inconsistent. Frameworks by Lin et al. (1999) and Khaled (2018) provide guidance, yet few educational games scaffold multiple levels of reflection, especially the deeper forms identified by Fleck and Fitzpatrick (2010), such as dialogic, transformative, and critical reflection. Even basic features like prompts, process displays, and structured feedback can enhance learner engagement and critical thinking. However, these are often deployed in isolation and lack integration into broader design systems. This section reviews key efforts to embed reflection in GBL and highlights recurring design tensions and gaps.

Kiili (2005) Experiential Gaming Model was an early attempt to integrate reflective feedback, but its emphasis on maintaining player flow often constrained deeper metacognitive engagement illustrating the persistent trade-off between immersion and reflection. The MIRROR Project (Pannese et al., 2012) used post-task feedback to promote on-action reflection in workplace learning. Though not designed for formal education, its use of game-informed strategies to trigger emotional insight shows the cross-domain potential of reflective design.

In education, Maram et al. (2024) developed Open Learner Models (OLMs) to support in-action reflection in classrooms through a visualisation system that helps students identify conceptual errors and explore alternative board states to enhance learning. They created the game "Ah! I See", which used OLMs to facilitate both in-action and on-action reflection. This work later evolved into a game-based version that integrated real-time and retrospective reflection using analytics and visualisation.

Reflective design has also been explored in immersive and IoT-enhanced settings. Huang and Ng (2020) applied Fleck and Fitzpatrick's framework in a museum-based game using sensor-driven interactions to promote critical reflection. Urwin and Flick (2019) used Augmented Reality (AR) to support mental health reflection, while Fiala et al. (2020) employed Virtual Reality (VR) simulations and interviews to support post-experience analysis in workplace safety.

Despite these advances, the field lacks a generalisable methodology for reflective GBL. Most implementations remain tied to specific tools, genres, or contexts. A unified set of heuristics is needed to help developers embed reflection more systematically. This study responds by proposing research-informed design principles to guide reflective GBL development.

3. Research Methodology

This study explored how RGD can enhance the educational impact of digital GBL and aimed to generate actionable design recommendations. It adopted Thinking (Dunne et al., 2006) and Human-Centred Design (ISO 9241-210:2019), both of which emphasise iterative development and sustained user involvement. A mixed-methods approach integrated the generalisability of quantitative data with the depth of qualitative insights. The research unfolded in three interconnected phases:

- Phase 1 - Foundation: Adapt reflective learning practices to inform digital GBL design.
- Phase 2 - Design and Iteration: Co-design and refine a digital GBL prototype with RGD features.
- Phase 3 - Evaluation: Assess the impact of RGD on usability, engagement, and learning outcomes, leading to design heuristics.

Participants were young adults aged 18-24, selected for their familiarity with digital games and interactive systems as these traits align with GBL's target users. Ethical approval was obtained via the Brighton Research Ethics Application Manager, with informed consent from all participants.

3.1 Phase 1: Foundation

This phase established the theoretical foundation for the RGD framework by mapping reflective practices onto game mechanics that support metacognitive engagement. Based on prior work (Shaheen et al., 2021) and frameworks by (Lin et al., 1999), (Kolb, 1984), and (Khaled, 2018), the RGD model was developed as an iterative, feedback-driven system. As shown in in Figure 1, reflective elements such as prompts, emotion tracking, and dynamic feedback are embedded throughout the player experience, making reflection a core gameplay component rather than a supplementary feature.

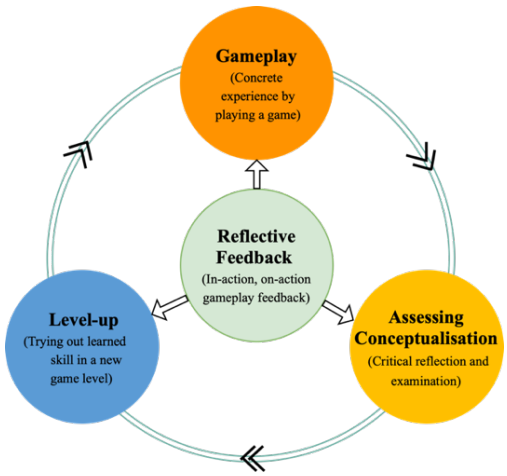


Figure 1: The RGD Framework, illustrating how reflective feedback is embedded across all stages of player interaction (Shaheen et al., 2022)

To ensure real-world relevance, the research team conducted surveys (N = 101) and interviews (N = 15), followed by thematic analysis (Shaheen & Fotaris, 2023). While participants showed limited awareness of serious games as educational tools, they linked digital games to problem-solving, critical thinking, and emotional awareness. These findings, along with user preferences for logic-based gameplay and minimalist UI, directly informed the mechanics and design strategies used in the next phase.

3.2 Phase 2: Design and Iteration

This phase translated theoretical insights into a practical game prototype using a Design Thinking approach. The aim was to create a user-centred experience addressing the reflective needs of young adults (18–24), with Phase 1 findings guiding the integration of narrative, mechanics, and learning objectives. Subject matter experts reviewed the prototype to ensure alignment with emotional and cognitive goals.

Co-design sessions (N = 6), based on participatory design principles (Agbo et al., 2021), informed an initial low-fidelity paper prototype (Walker et al., 2002), refined through two rounds of feedback (N = 25; N = 15) (**Figure 2**). Participants provided input via surveys, questionnaires, and interviews, shaping both content and interface elements for usability and relevance.

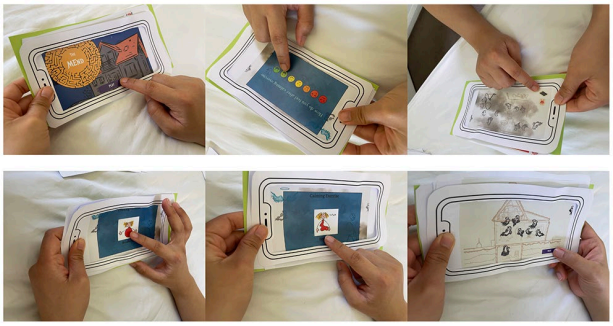
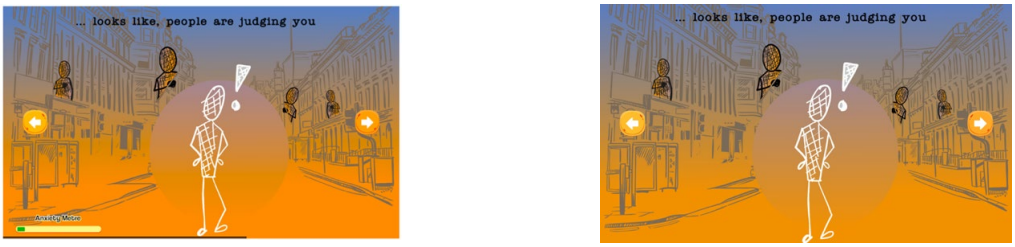
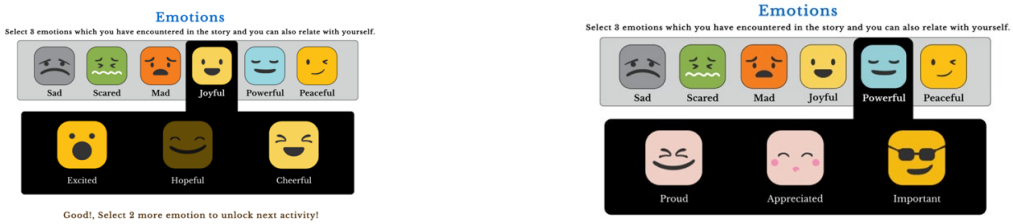


Figure 2: Paper prototype testing (N=25)

This process led to two digital prototypes for comparative testing in Phase 3: one with RGD features and one without. The game, The Mend, uses a home renovation metaphor to explore emotional resilience. Players face social and familial pressures personified as anxiety-inducing "daemons" in a deteriorating house, while a guardian angel (symbolising inner consciousness) guides them through puzzles and narrative choices. **Figure 3** illustrates how RGD features enhance the experience compared to the non-RGD version.



(a) Narrative scenes with and without reflective indicators (e.g., anxiety meter).



(b) Emotional choice activities with and without visual feedback.

(c) Breathing exercises using HUD elements for pacing and emotional state tracking.

Figure 1: Comparison of RGD and non-RGD gameplay elements in The Mend

The RGD prototype also included additional tools to promote deeper reflection and emotional awareness. These features are shown in **Figure 4** and include: (a) A diary system for tracking emotional states over time; (b) Reflective HUDs embedded at key decision points; (c) Process prompts providing feedback to support metacognitive engagement.

(a) Diary showing the reflective comparison (process model) of the player feelings.

(b) Reflective HUDs

(c) Reflective feedback in the form of process prompts

Figure 2: Reflective elements in the RGD prototype supporting player reflection and emotional tracking

3.3 Phase 3: Evaluation and Recommendations

In the final phase, two high-fidelity web-based prototypes, one with RGD elements and one without, were evaluated to assess the impact of reflective game design on learning outcomes in digital GBL. The evaluation had two key aims: i) to compare engagement, usability, and perceived learning between the RGD and non-RGD versions (Shaheen et al., 2023); ii) to measure the effect of RGD features on actual learning outcomes and knowledge retention (Shaheen & Fotaris, 2024)

A comparative mixed-methods study (N = 69) was conducted using pre- and post-test questionnaires. Results showed that participants using the RGD version demonstrated significantly higher learning gains and retention than those using the non-RGD version, supporting the hypothesis that structured reflective features can enhance educational impact. Participants highlighted the RGD prototype's ability to promote critical thinking, emotional awareness, and personal reflection. Some areas for improvement were also noted, including visual aesthetics and narrative pacing. Insights from this phase informed further refinement of the RGD framework, resulting in a set of practical heuristics and design recommendations for integrating reflection into future digital learning games.

4. RGD Recommendations

The following recommendations were derived from iterative design research, user testing, and co-design sessions, offering a structured framework for integrating reflective learning into digital gaThe heuristic statements for recommendations are defined by Van den Akker (1999) as if you want to design intervention X [for the purpose/function Y in context Z], then you are best advised to give that intervention the characteristics A, B, and C [substantive emphasis], and to do that via procedures K, L, and M [procedural emphasis], because of arguments P, Q, and R.

4.1 Utilise the RGD Framework for Iterative Reflective Design

Recommendation: If a game designer aims to integrate reflective design effectively for the purpose of enhancing reflective learning in the context of digital games, then they are best advised to utilise the Reflective Game Design (RGD) framework and iterate on the design of game activities, and to do this through continuous feedback, user testing, and iterative improvements, because doing so ensures that the reflective elements are effectively integrated and refined based on player experiences and feedback.

The presented RGD framework offers a structured and an iterative process model that helps incorporating reflective features into digital GBL.

The following are the key strategies to implement RGD framework effectively:

- Structured Approach: it helps to adopt a systematic process to incorporate reflective feedback into game mechanics, narratives, and activities.
- Flexible Adaptation: The iterative nature of this framework enables designers to integrate reflective feedback cycles to improve the reflective elements based on player experiences.

- Educational Value: As this framework offers to add concrete experience, critical reflection and using newly acquired skills in a new level. Therefore, designing a GBL through this framework encourages and enhance reflective thinking and educational value.

4.2 Foster Empathy, Respect, and User Involvement

Recommendation: If a game designer, whether focused on digital GBL or entertainment games, intends to create a reflective design intervention, they are advised to prioritise fostering respect and empathy towards its users. Furthermore, involving users in the design process to establish trust and foster confidence in players' reflective abilities is crucial. Additionally, the design should emphasise promoting self-respect within the game by valuing players' beliefs, actions, feelings, and identities. To achieve this, integrating mechanisms that consistently reinforce these values throughout gameplay is essential. This comprehensive approach creates a supportive and inclusive environment favourable to effective reflective learning.

This recommendation suggests that empathy-driven design enhances both player immersion and reflective learning, as supported by feedback from co-design sessions. Engaging users actively throughout development builds trust and fosters a supportive environment conducive to reflection.

The following are the key Strategies:

- Co-Design: Involve players early and continuously via focus groups, surveys, and playtesting to incorporate their perspectives and enhance user-centred design.
- Empathetic Narratives: Create diverse characters and storylines that model respect and understanding, encouraging players to relate and reflect on different viewpoints.
- Self-Respect Mechanics: Integrate gameplay elements that reinforce positive player choices and promote self-respect through meaningful feedback, such as consequences linked to decisions.

4.3 Balance Reflective Elements and Game Design Components

Recommendation: If a game designer, whether focused on digital GBL or entertainment games, intends to incorporate a reflective design for the purpose of fostering reflective learning, then they are best advised to ensure that it gives reflective feedback using process prompts/displays, process models, in-action, on-action, and social discourse, and to achieve a balance in terms of game complexity, game activities, HUDs, UI, and learning assessments, and to do this through structured feedback mechanisms, iterative design adjustments, and user-centred evaluation, because doing so promotes a supportive and immersive environment favourable to reflective learning.

A balanced game design prevents cognitive overload and maintains player engagement while supporting meaningful reflection. By thoughtfully integrating reflective feedback and managing game complexity, designers can create immersive experiences conducive to deeper learning. The following are the key Strategies:

- Structured Feedback: Implement reflective journals, prompts at the end of levels, and real-time feedback mechanisms to guide player reflection throughout gameplay.
- Balanced Complexity: Design gameplay that alternates between challenging tasks and reflective pauses, allowing players to consolidate learning without feeling overwhelmed.
- Diverse Assessments: Use a variety of evaluation methods such as quizzes, narrative-driven choices, and puzzles to comprehensively assess reflective understanding and learning outcomes.

4.4 Support Emotional Engagement and Mindful Reflection

Recommendation: Foster emotional engagement and mindfulness through compelling stories, reflective pauses, and intuitive design. These elements deepen metacognitive insight and personal resonance. Games that evoke tension, vulnerability, or moral ambiguity can prompt players to examine values and emotions. When paired with clarity, mindfulness techniques allow players to process these experiences with intention. Key strategies include:

- Reflective Prompts: Introduce deliberate pauses in gameplay, such as journal entries, self-evaluation tools, breathing exercises, or reflective dialogues, to encourage introspection on decisions, emotions, and evolving perspectives.
- Emotionally Charged Narratives: Craft arcs involving growth, challenge, and complex choices. These narratives invite players to emotionally invest and reflect on personal parallels.

- Emotional Intelligence Systems: Create mechanics that simulate social interactions, requiring players to navigate empathy, resolve interpersonal conflicts, or interpret emotional cues. Use feedback tools to prompt players to reflect on their relational choices and internal responses.
- Clarity in Design: Ensure interfaces and objectives are intuitive to minimise cognitive friction and enhance focus.
- Offer Immediate, Reflective Feedback: Use consistent visual or auditory cues, such as animations, sound effects, or HUD indicators, to reinforce reflection and support behavioural awareness during gameplay.

4.5 Encourage Authentic Growth and Real-World Transfer

Recommendation: Promote reflection that leads to personal and professional development by simulating realistic dilemmas and enabling players to track their emotional or ethical growth over time. Reflective games gain relevance when players can apply insights beyond the screen. Simulating professional, social, or emotional challenges strengthens the transfer of learning. Key strategies include:

- Progress Tracking: Use visual dashboards, experience logs, or reflective journals that help players monitor their development over time, reinforcing a sense of growth and self-efficacy.
- Authentic Role-Play: Design narrative challenges based on real-world decisions, professional dilemmas, or social situations. These prompt introspection and cultivate transferable insights into behaviour, judgment, and identity.
- Social Reflection: Support peer engagement through discussion forums, cooperative gameplay, or structured feedback loops. Community-based reflection promotes dialogue, broadens perspectives, and strengthens the reflective process.

4.6 Use Disruption to Spark Insight

Recommendation: Incorporate design elements that disrupt player expectations to stimulate critical thinking and reflection. This includes surprising narrative turns, ambiguous moral choices, or sudden shifts in gameplay. Disruption challenges assumptions and provokes deeper engagement. When paired with follow-up reflection, it helps players reassess their actions and emotional responses. Key strategies include:

- Dynamic Challenges: Introduce unexpected narrative developments, shifts in perspective, or changes in mechanics to surprise players and provoke deeper engagement.
- Structured Reflection After Disruption: Pair disruptive events with follow-up reflection opportunities, such as journaling, dialogue choices, or adaptive feedback, to guide post-event introspection.
- Varied Game Structures and Environments: Avoid repetition by regularly introducing new mechanics, locations, or character interactions. Novelty sustains curiosity and cognitive stimulation.
- Ethical Ambiguity: Present decisions with no clear right answer to encourage introspection and discussion about values and consequences.

5. Discussion

This study reinforces the value of embedding reflective learning into digital GBL through the RGD framework. Findings suggest that digital games can support metacognitive development by translating established reflective practices into interactive, system-mediated experiences. The three-phase methodology (comprising theoretical grounding, co-design, and comparative evaluation) produced a set of actionable design principles for integrating reflection into both educational and entertainment-focused games.

Rather than treating reflection as a separate or post-hoc activity, the RGD approach embeds it directly into core gameplay. This addresses a common shortcoming in earlier models, where opportunities for reflection were disconnected from player actions. Participant feedback highlighted how features such as reflective HUDs, process prompts, and emotion-tracking interfaces encouraged greater awareness of emotional and cognitive states during play.

Despite these promising outcomes, the study has limitations. While four reflective mechanisms were initially proposed (process prompts, process displays, process models, and social discourse) only the first three were implemented in the prototype. The role of social discourse in fostering collaborative reflection, peer learning, and emotional resonance remains an important area for future exploration. Incorporating structured in-game discussions or multiplayer decision-making scenarios could address this gap.

Additionally, while the comparative design demonstrated improved reflection and learning outcomes, it did not isolate the specific effects of individual reflective features. Future research should examine the standalone and combined impacts of these elements to better understand their respective contributions. Longitudinal studies with more diverse participant samples would also strengthen generalisability, particularly regarding the long-term effects of RGD on critical thinking, retention, and personal development.

This study focused on digital formats, but the underlying heuristics may also apply to non-digital experiences such as board games or tabletop role-playing. These formats offer strong narrative and social components that could support reflection in different but complementary ways. Similarly, future work could explore how RGD principles operate in entertainment games not explicitly designed for learning, where player engagement with emotionally charged or ethically complex content may provide a natural entry point for reflection.

In conclusion, this research contributes to a growing field focused on the intersection of reflective learning and GBL. The RGD recommendations offer a flexible, actionable framework that can inform the design of more meaningful, interactive gameplay to have a positive impact on GBL. Continued research, refinement, and cross-context application will be essential for advancing both the theoretical understanding and practical integration of reflection into digital learning environments.

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Gamification in Volunteer Feedback: Do Digital Rewards Really Work?

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Abstract: This study examines the impact of achievement badges on volunteer engagement and response quality in online surveys conducted by non-profit organizations. While gamification is often proposed to increase participation, its effectiveness in intrinsically motivated populations remains unclear. Using a custom-built survey platform, 57 Swedish volunteers were randomly assigned to either a gamified survey featuring badges or a non-gamified control version. Behavioral data, including time spent, word counts, badge interactions, and completion rates were recorded, alongside open-ended reflections. Results showed no statistically significant difference between conditions. Participants in the gamified group completed surveys faster but provided shorter written responses and showed minimal interaction with the badge system. PCA analysis and qualitative feedback reinforced the finding that badges did not meaningfully alter behavior or improve user experience. These outcomes suggest that in settings where intrinsic motivation is already high, such as non-profit volunteering, superficial gamification elements like badges may offer limited benefit. Instead, aligning survey design with volunteers' intrinsic values, such as purpose, autonomy, and impact, may be more effective. This research contributes to gamification literature by emphasizing the limitations of single-element strategies and calling for more nuanced, context-sensitive approaches in digital feedback systems.

Keywords: Gamification; Online surveys; Digital badges; Motivation; Non-Profit volunteers; Game-Based learning

1. Introduction

Gamification, the use of game design elements in non-game contexts, has gained popularity in education, business, and research for enhancing motivation and engagement (Deterding et al., 2011; Landers et al., 2015). Among these elements, digital badges stand out for their simplicity and visibility in signaling progress or achievement (Fanfarelli & McDaniel, 2015). However, while badges have been shown to improve enjoyment and participation in extrinsically motivated settings such as brand engagement (Hamari & Eranti, 2011; Hsu & Chen, 2018), their effects are less predictable in intrinsically motivated contexts. In environments where individuals are already internally driven, such as volunteerism, badges may appear unnecessary or even counterproductive, potentially undermining autonomy or perceived task value (Ryan & Deci, 2020; Harms et al., 2015). Though some studies note that badges add "fun," this does not always lead to deeper engagement or improved response quality (Guin et al., 2012).

Online surveys, while widely used for their efficiency and scalability (Ball, 2019), often suffer from low completion rates and superficial responses (Galesic, 2006). Gamification has been proposed to mitigate these challenges (Bailey et al., 2015; Warnock & Gantz, 2017), yet the isolated effects of badges in surveys, particularly among intrinsically motivated groups, remain underexplored. Sweden's non-profit sector offers a compelling test case. Volunteers here contribute significantly to society, driven by altruism rather than external incentives (Statistics Sweden, 2020; Volontärbyrån, 2022). In such settings, introducing badges into surveys may not align with participants' motivations and could even diminish engagement. This study investigates whether digital achievement badges improve engagement and response quality in online surveys completed by non-profit volunteers. Specifically, it asks how does the introduction of digital achievement badges impact non-profit volunteers' response behavior and survey experience? By examining a gamified survey in a high-intrinsic-motivation context, the study contributes to the literature on game-based learning and survey design, offering insights into the boundaries of badge effectiveness and design recommendations for volunteer-driven settings.

2. Literature Review

Gamification, defined as the application of game elements in non-game contexts, has been widely examined for its potential to enhance motivation, engagement, and user satisfaction across diverse domains such as education, employee training, and digital feedback collection (Deterding et al., 2011). Among its many components, digital achievement badges have emerged as a popular and accessible tool due to their visual simplicity, low implementation cost, and ability to signify behavioral milestones (Fanfarelli & McDaniel, 2015).

However, the motivational impact of badges varies substantially by context. In domains where extrinsic motivation dominates such as corporate training or brand loyalty programs badges can serve as effective stimuli by increasing perceived task value and offering symbolic rewards for effort (Hamari & Eranti, 2011; Hsu & Chen, 2018). In these settings, badges are often integrated with broader reward systems or competitive frameworks, reinforcing user engagement through mechanisms like social comparison or progress visualization.

Conversely, in intrinsically motivated environments such as volunteer work or civic participation, badges often yield more ambiguous results. Participants motivated by internal drivers such as altruism, identity, or personal fulfillment may find external incentives less compelling or even off-putting. Harms et al. (2015) demonstrated that while badges increased perceived enjoyment in surveys, they did not significantly affect completion rates or data quality. These findings suggest that badges, when introduced without sensitivity to participant motivation, may function more as decorative than transformative elements.

To understand this phenomenon, motivational psychology offers valuable frameworks. Self-Determination Theory (SDT) posits that intrinsic motivation flourishes when individuals experience autonomy, competence, and relatedness (Ryan & Deci, 2020). External rewards such as badges can undermine intrinsic motivation if they are perceived as controlling or misaligned with personal values. For non-profit volunteers, who often act out of civic responsibility or belief in a cause, badges may feel inauthentic or irrelevant, especially when not clearly tied to meaningful outcomes. Flow Theory (Csikszentmihalyi, 1975) adds another perspective by emphasizing that deep engagement arises when a task strikes a balance between challenge and skill. However, online surveys are typically brief and structured, offering little room for creativity or challenge. In such settings, the addition of static badges is unlikely to foster immersion or sustained attention. Expectancy-Value Theory (Eccles & Wigfield, 2002) further enriches this understanding by suggesting that individuals assess tasks based on the value they assign to outcomes and the effort required. In the case of open-ended survey questions, badges may not offer sufficient perceived reward to justify cognitive effort, especially when the task already feels purposeful. Participants may thus opt for shorter or more superficial answers, seeing no added benefit from expending additional effort.

Despite these challenges, online surveys remain indispensable tools for organizations due to their scalability and cost-effectiveness (Ball, 2019). However, they are often plagued by low completion rates, partial engagement, and shallow responses (Galesic, 2006). Gamification has been proposed to mitigate these shortcomings, with various elements such as progress bars, avatars, or storytelling prompts demonstrating potential to improve user experience (Bailey et al., 2015; Warnock & Gantz, 2017). Yet, as (Guin et al., 2012) found, the inclusion of gamified elements does not consistently translate into improved outcomes, especially when not holistically integrated.

One limitation may be the overreliance on single-element gamification. Studies increasingly emphasize that layered or narrative-driven gamification combining badges with social sharing, dynamic feedback, or collaborative challenges tends to be more impactful than isolated elements (Oliveira & Paula, 2021). This approach not only diversifies the motivational triggers but also fosters a more immersive and adaptive experience.

The case of Swedish non-profit volunteers provides a unique lens through which to analyze these dynamics. These individuals typically exhibit strong intrinsic motivation, engaging in activities not for external rewards but out of a sense of identity, social responsibility, or community affiliation (Volontärbyrån, 2022). In such contexts, gamification strategies must be carefully tailored. Instead of emphasizing individual performance or arbitrary milestones, more effective designs might focus on celebrating collective contributions, highlighting real-world impact, or providing reflective prompts that resonate with volunteers' values and experiences. In sum, while badges can contribute to survey engagement in some settings, their standalone use in intrinsically motivated populations is unlikely to produce substantial effects. A more effective approach may lie in integrating badges into richer, context-sensitive frameworks that support and affirm participants' core motivations.

3. Methodology

This study employed a controlled experiment to assess the effect of digital achievement badges on volunteer engagement and response quality in online surveys. A custom-built survey platform was developed to allow fine-tuned control over interface design and badge logic, while also capturing detailed behavioral data in real time.

Two survey versions were created: a gamified version featuring achievement badges and a non-gamified control version. Both versions contained identical content and layout, with the only difference being the presence or absence of badges. In the gamified version, badges were displayed prominently at the top of the screen and

were triggered when participants met specific behavioral milestones. Each badge activation was accompanied by a brief confetti animation, providing light celebratory feedback. Participants were randomly assigned to each version using a dynamic URL parameter system, minimizing selection bias and avoiding predictable assignment patterns (Keusch & Zhang, 2017).

The survey was distributed through four Swedish non-profit organizations. Of the 363 volunteers who received the link, 57 began the survey and 41 completed it. The sample reflected common demographic characteristics of Sweden's volunteer population (Volontärbyrån, 2022), with 81% identifying as women, and the remainder as men or other/prefer not to say. Over half of the participants (56%) accessed the survey using a mobile device, and respondents varied in age and length of volunteering experience, from under one year to over five years.

To meet the specific design requirements of the experiment, we developed a fully responsive survey platform using NextJS for the frontend and Firestore for backend data management. This allowed for precise logging of user interactions such as button clicks, text entries, page transitions, and badge unlock events, all timestamped in real time. The survey layout automatically adjusted to the user's device, with badge icons aligned horizontally across the top on mobile and across the header on desktop screens. Apart from the gamification elements, the visual and functional structure remained identical across conditions.

The badge system was inspired by gamification principles that emphasize simplicity and recognizability (Fanfarelli & McDaniel, 2015). Five core badges and three optional "bonus" badges were integrated. Badges were not overtly explained unless clicked, encouraging participants to explore them organically. Table 1 summarizes the criteria for badge activation:

Table 1: Badge Names and Activation Criteria.

Badge Name	**Criterion**
Wordspitter	Write at least 20 words in any open-ended question.
Shakespeare	Write at least 50 words in any open-ended question.
Advisor	Fill in a custom "3-answers" input for organizational suggestions.
Hero of the Day	Complete all mandatory questions in the survey.
Completionist	Submit the entire survey (all pages).

In addition to the five core badges, three optional "bonus" badges were included to encourage further exploration and reflection.

- **Voice of an Angel** : awarded for giving especially detailed feedback in any open-ended question;
- **Above and Beyond** : earned by completing additional optional questions; and
- **Explorer** : unlocked by clicking and reading all badge descriptions. While these badges were rarely unlocked, their inclusion aimed to capture deeper or more exploratory engagement behaviors.

The badge system was visually integrated into the survey platform, where participants could view locked and unlocked badges during their progress and receive real-time feedback when achievements were earned. An example of the badge display and the corresponding feedback notification is shown in figure 1.

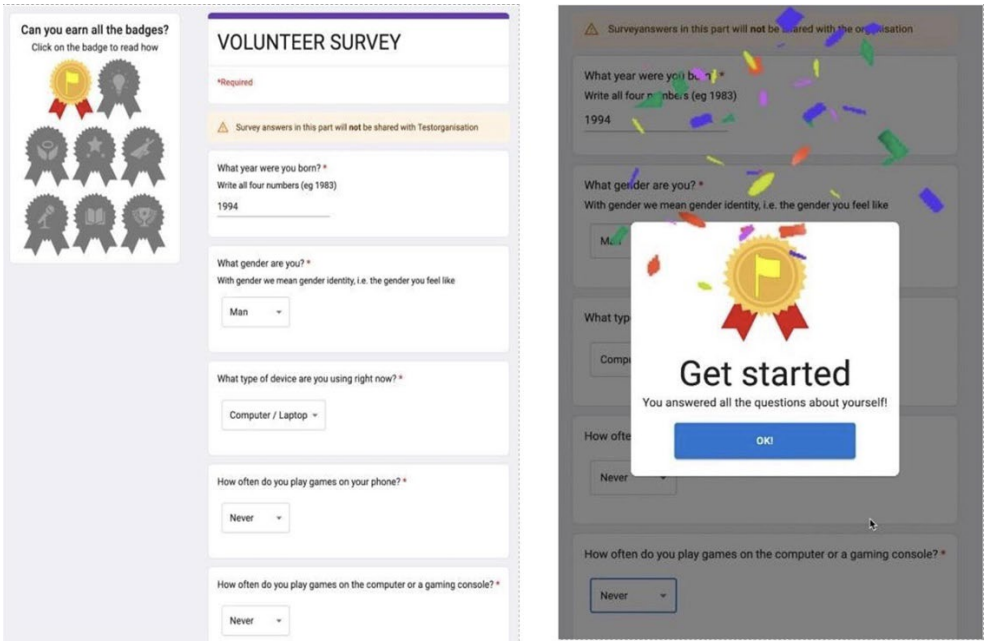

Figure 1: Digital badges in the gamified survey condition. (a) Survey interface displaying eight badge slots, including five core badges and three optional "bonus" badges. (b) Example of a badge achievement notification ("Get Started") with confetti feedback

To ensure ecological validity and data integrity, participants' interactions were recorded without collecting any personally identifiable information. Each respondent was assigned a unique anonymous ID. Those who dropped out before completing the survey were excluded from the final dataset. A mixed-methods approach was used for data collection and analysis. Quantitative metrics included time spent in the survey, number of questions answered, dropout status, word count across open-ended responses, and the number and type of badges earned. Qualitative feedback was collected through open-ended reflections on survey clarity, length, and overall experience. Analysis began with descriptive statistics to compare the average time spent, question completion, and word counts across the gamified and non-gamified groups. To account for non-normal distributions, Spearman's rank correlation was used to explore associations between experimental conditions (e.g., gamified vs. control, mobile vs. desktop) and behavioral outcomes such as response length. Additionally, Principal Component Analysis (PCA) was applied to interaction logs, including variables like total time, word count, page transitions, badge activity, and completion status, to identify clustering patterns in participant behavior. This helped illuminate whether badge exposure corresponded with distinct interaction styles. Together, these methods provided a comprehensive view of how achievement badges influenced volunteers' engagement with the survey and the quality of their responses, particularly in a context where intrinsic motivation was already expected to be high.

4. Results

4.1 Completion Rates and Time

Of the 57 volunteers who started the survey, 29 were randomly assigned to the gamified condition and 28 to the control group. The completion rate was 76% in the gamified group (22/29) and 68% in the control group (19/28). To assess whether this difference was statistically significant, we conducted a Fisher's Exact Test. Results showed no significant difference between groups (odds ratio = 1.49, $p = 0.565$), indicating that the presence of badges did not meaningfully affect survey completion. Interestingly, participants in the gamified group tended to finish the survey more quickly. As shown in Figure 1, the median time spent in the gamified condition was approximately 7 minutes, compared to 9.5 minutes in the control group. This may suggest that achievement badges encouraged more efficient task completion. However, as discussed below, this apparent efficiency did not necessarily translate into deeper engagement or higher-quality responses.

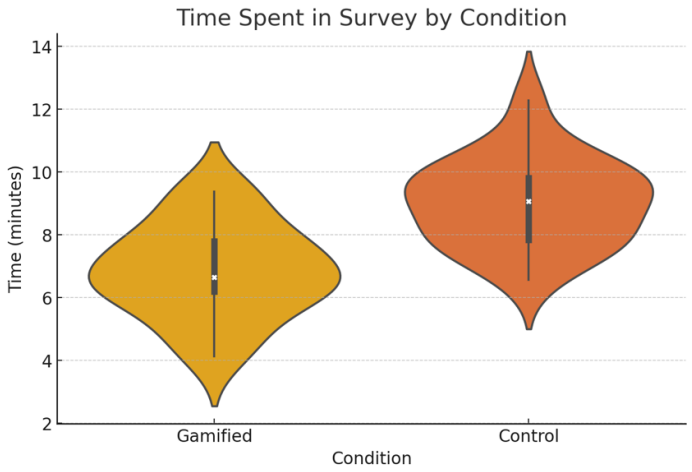

Figure 2: Shows the distribution of total time spent (in minutes) by participants in the gamified and non-gamified (control) survey conditions. Although the gamified group completed the survey more quickly on average (median ≈ 7 minutes) than the control group (median ≈ 9.5 minutes), the range and variability of time spent were similar across groups

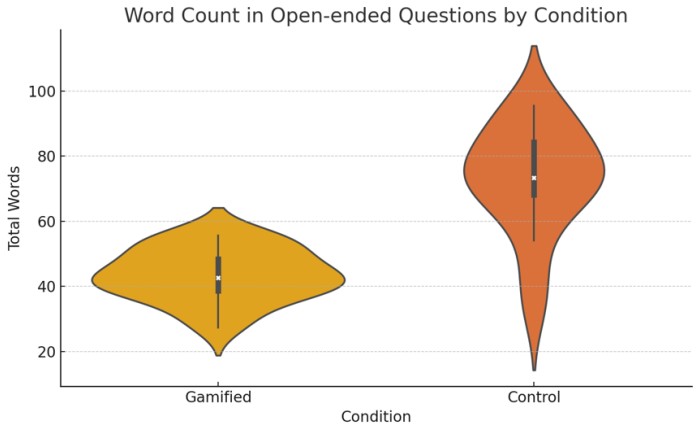

Figure 3: Illustrates the total word count in open-ended responses for each condition. Participants in the control group contributed longer written responses (median ≈ 72 words) compared to those in the gamified group (median ≈ 45 words), suggesting deeper cognitive engagement in the absence of gamification. These findings support the interpretation that while badges may expedite task completion, they may not enhance and could potentially reduce response depth in intrinsically motivated populations

4.2 Response Quality

Participants in both groups answered a similar number of questions (median of 22–23), but control participants provided substantially longer open-ended responses. As illustrated in Figure 2, the control group had a median word count of 72 words per respondent, while the gamified group produced a median of 45 words. This difference, although not statistically significant, supports the hypothesis that gamification may not enhance and could potentially reduce cognitive investment when applied in settings where intrinsic motivation is already high (Ryan & Deci, 2020; Harms et al., 2015).

4.3 Badge Acquisition and Interaction

All participants in the gamified condition received at least three badges for completing mandatory sections. Despite this, only three individuals actively clicked to read badge descriptions during the survey. This behavior is visualized in Figure 3, which maps individual interaction traces across badge icons. Notably, post-hoc analysis showed that control group participants, who had no visual exposure to the badges, would have earned more badges on average (3.95) than those in the gamified group (3.76), based purely on their behavior. This unexpected reversal, captured in Figure 4, illustrates the limited motivational value of badges in this volunteer context.

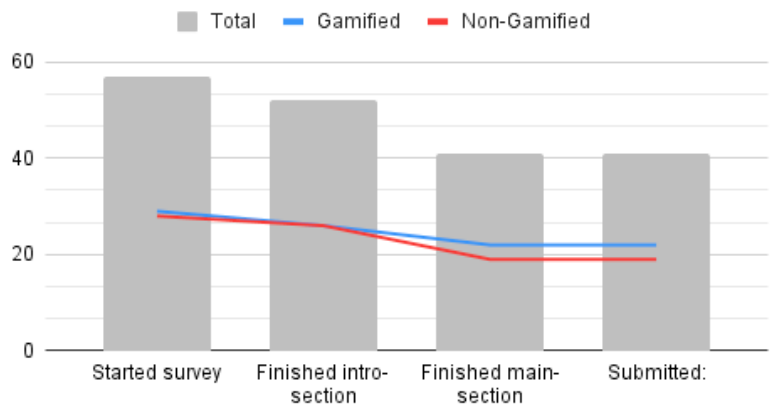

Figure 4: Shows participant retention through the four main stages of the survey: started, completed introduction, completed main section, and final submission. Gray bars indicate total participants, while the blue and red lines represent gamified (N = 29) and non-gamified (N = 28) groups respectively. Both groups followed a similar dropout pattern, with slightly better retention in the gamified group between the introduction and main sections. However, overall completion rates converged by the final submission, suggesting gamification had limited impact on survey completion

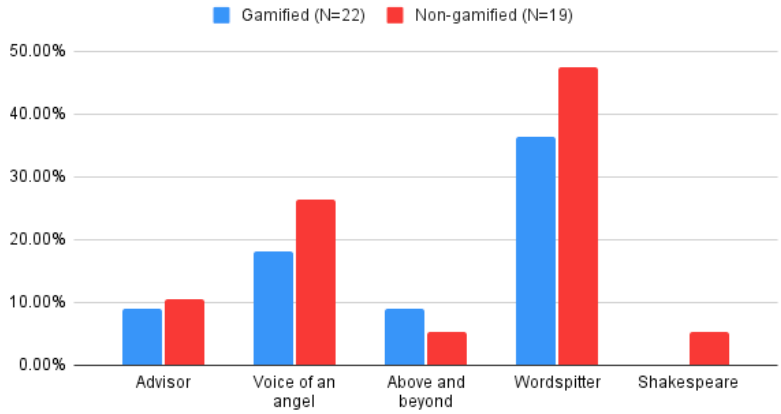

Figure 5: Illustrates the percentage of participants in each group who fulfilled criteria for five non-mandatory achievement badges: Advisor, Voice of an Angel, Above and Beyond, Wordspitter, and Shakespeare. While all participants who completed the survey received the three mandatory progression badges (not shown), this figure focuses on behavioral engagement beyond minimum requirements. The non-gamified group met more badge conditions in several categories, especially Wordspitter and Voice of an Angel, suggesting that badge visibility alone did not strongly influence deeper engagement. Only one non-gamified respondent met the criteria for the most demanding badge (Shakespeare)

4.4 Dimensionality Reduction: Behavioral Patterns

To gain deeper insight into participant engagement, Principal Component Analysis (PCA) was conducted on a multidimensional dataset comprising total time spent in the survey, word count across open-text responses, number of page transitions, badge unlock count, badge click events, and binary completion status. The resulting visualization, shown in Figure 5, reveals a modest clustering pattern based on whether participants completed the survey. Those who dropped out clustered more tightly and were generally associated with shorter durations and lower interaction levels, while participants who completed the survey displayed a wider behavioral spread, indicating more varied and engaged survey activity.

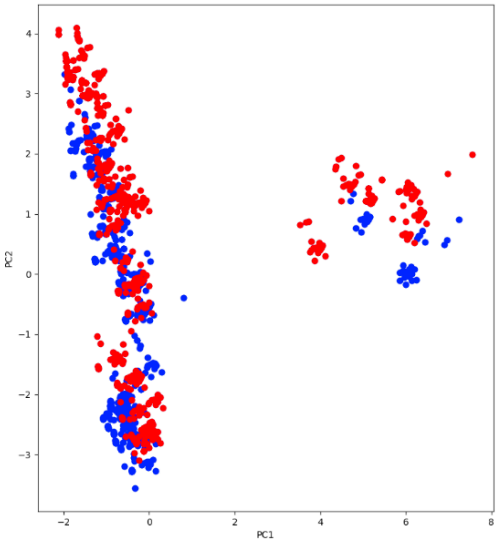

Figure 6: Presents the PCA space of the mentioned features colored by survey condition: blue for gamified participants and red for non-gamified. No distinct clusters emerge, suggesting that the introduction of achievement badges did not substantially differentiate behavioral patterns between the two groups

4.5 User Experience

Qualitative feedback revealed meaningful differences in how participants experienced the survey. Respondents in the control group frequently described their experience using terms such as “thoughtful,” “reflective,” or “meaningful,” indicating a higher level of cognitive engagement. In contrast, participants in the gamified condition occasionally referred to the badges as “fun,” but also characterized the survey as “long” or “repetitive,” suggesting that the gamification elements may not have enhanced and may have even detracted from the overall experience. When asked to compare this survey to others they had taken, 36.4% of gamified respondents rated it as “better,” and 63.6% as “similar,” while in the control group, 38.9% rated it as “better” or “much better,” and 61.1% as “similar.” These nearly identical distributions indicate that the presence of badges had no notable impact on perceived survey quality.

4.6 Summary of Observations

Despite their visual presence, badges had limited impact on both behavior and perception. While the gamified group spent less time completing the survey, they provided shorter responses and interacted minimally with the gamification features. PCA confirmed that engagement patterns were more closely tied to completion status than to condition or device type. Qualitative feedback further revealed that control participants reported deeper reflection and meaning. Together, these findings suggest that intrinsic motivation was the primary driver of engagement, and that badges, at least in isolation, did not provide sufficient external incentive to improve outcomes.

5. Discussion

This study examined whether digital achievement badges could enhance volunteer engagement and response quality in online surveys distributed by Swedish non-profits. The findings offer valuable insight into the limitations of gamification in intrinsically motivated populations, particularly where participants are driven by purpose rather than external incentives. The results support Self-Determination Theory (Ryan & Deci, 2020), which suggests that when intrinsic motivation is strong, as in the case of non-profit volunteers, extrinsic rewards like badges may not only be ineffective but potentially counterproductive. Although badges aimed to provide visual feedback and recognize participation, their presence did not result in higher completion rates, longer responses, or greater satisfaction. Behavioral data revealed that gamified respondents spent less time on the survey and provided shorter open-text answers. While the completion rates between groups were similar, badge interaction was minimal. Only three participants clicked to explore badge descriptions, indicating limited engagement with the gamification feature. Future research should investigate ways to increase participant interaction with badges, such as integrating narrative framing, peer comparison, or explicit prompts encouraging

exploration. This may help determine whether badges can function more effectively when combined with richer or socially embedded gamification strategies. PCA results further showed that engagement patterns were shaped more by completion status than by the presence of badges or device type. Together, these findings suggest that simple visual rewards may fail to engage users whose motivation is already rooted in internal values.

5.1 Practical Implications for Non-profit Survey Design

The findings of this study offer practical guidance for non-profits seeking to design effective feedback mechanisms. First, while gamification may seem appealing, its implementation must align with participants' underlying motivations. In contexts where volunteers are intrinsically driven by purpose, digital badges may not enhance engagement, and may even detract from the sense of autonomy. Instead, designers should consider non-reward-based motivators such as communicating how feedback will be used, providing personalized acknowledgments, or creating opportunities for reflection. Additionally, keeping surveys concise and meaningful appears more critical than adding superficial incentives. These results encourage a shift from gamified survey tools to mission-aligned, empathetic design, where respect for the respondent's values takes precedence over engagement gimmicks. Practitioners should also test any digital feedback intervention for unintended effects, especially when working with intrinsically motivated populations.

6. Conclusions and Future Work

This study has several limitations that should be acknowledged. First, the sample size (n = 57, with 41 completions) was relatively small, which reduces the statistical power of the findings. Second, the study was conducted within a population of highly intrinsically motivated non-profit volunteers. As a result, the conclusions may not generalize to less intrinsically motivated groups, where gamification effects could be stronger. Third, only a minority of participants interacted with the badge system, which may have limited the ability to detect meaningful engagement effects. Future studies should address these limitations by recruiting larger and more diverse samples, testing in low-motivation contexts, and combining badges with additional gamification elements.

The experiment found no significant benefits from using achievement badges in online surveys for non-profit volunteers. Rather than enhancing engagement, badges had little effect on behavior and were largely ignored. These findings reaffirm previous research suggesting that extrinsic motivators may not add value where intrinsic motivation dominates. Drawing on both Self-Determination Theory and Expectancy-Value Theory, we conclude that badges, at least in isolation, do not effectively enhance cognitive engagement or response quality in highly motivated groups. For digital feedback tools in the non-profit sector, fostering autonomy, relevance, and impact awareness is likely more effective than superficial game elements.

This study also highlights the potential of a lightweight, customizable survey platform capable of tracking user behavior in real time. Such tools enable the creation of controlled experimental conditions and offer rich behavioral data for analysis. To advance this line of research, future studies should explore multi-element gamification strategies that combine badges with narratives, peer collaboration, and adaptive feedback systems. Social dynamics, such as shared progress or public recognition, may play a stronger role in engagement. Additionally, the integration of qualitative methods, such as interviews or reflective prompts, would help capture how participants interpret and respond to gamified experiences. Longitudinal studies are especially important for evaluating sustained engagement over time. As digital feedback becomes increasingly essential for non-profits, gamification must be reimagined to align with the values and motivations of volunteer communities.

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AI declaration: This paper was written and analysed by the authors. Generative AI tools were used only in a very limited capacity for language refinement and editing suggestions. All core ideas, data interpretation, and writing decisions were made by the authors.

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AmendMe: A Tabletop Game to Teach the European Parliament's Legislative Process

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Abstract: The European Parliament Role-Play Game (EP RPG) is a multiplayer simulation in which the players take on the role of Members of the European Parliament (MEP). The game aims to help young European citizens understand the EU law-making process and to increase their interest in politics. It exists in a physical version, available to play on-site in Brussels and in many other capital cities all over Europe, as well as a virtual version that can be played in any suitably sized location, provided there are at least 16 players and a stable Internet connection. While the existing versions of the EP RPG strive to reach different audiences, they may still not be equally accessible to all players. For example, playing the physical game requires advance planning and travel, which may be a challenge for schools in rural and remote areas. Meanwhile, the virtual game may be difficult to play at schools with an unstable internet connection or limited hardware resources, or by smaller groups who would like to play outside of class. This paper focuses on developing a tabletop version of the EP RPG optimised for accessibility to a broader range of players. The game design focuses on game elements that support discussion among players and has them reenact key aspects of the EU legislative process, such as decision-making, compromise, and voting. Feedback from the pilot playtesting was encouraging and confirmed that the game was engaging and educational, but revealed that its content and mechanics require further adjustment.

Keywords: European Parliament, Role-play game, Legislative process, Educational tabletop game

1. Introduction

> *Apart from the sanitation, medicine, education, wine, public order, irrigation, roads, the freshwater system and public health, what have the Romans ever done for us?*
>
> *(Monty Python, 1979)*

Amid the rise of populist nationalism, many European citizens have voiced criticism of the EU for a perceived loss of member states' sovereignty, questioning: "What has the EU done for us?" This scepticism largely stems from a lack of understanding of how the European Union works, what its main institutions are, and what responsibilities they have. To protect the EU and its democracy, its governing institutions must therefore educate the public on how they work (Cowley & Stuart, 2015). Against the backdrop of political disengagement among youth, games have shown tremendous pedagogical potential to "impact motivation … and … foster civic competences" (Delgado, 2021).

A prominent example is The European Parliament Role-Play Game (EP RPG): a simulation of the EU legislative process, in which players take the role of Members of European Parliament (MEP). The goal of the game is to help young citizens understand the law-making process and increase their interest in politics. The game is available in two versions: physical (https://visiting.europarl.europa.eu/et/education-learning/role-play-game), developed by Media Farm in 2010, and virtual (https://virtual-role-play-game.digital-journey.europarl.europa.eu), initiated by ICF NEXT and continued by SGI. Despite the name, the physical game is powered by several computers and smartphones. However, it can only be played on the premises of the Parliamentarium in Brussels and Europa Experience centres in state capitals all over Europe, subject to advance reservation. The virtual game is more flexible, yet it requires a large group of players (16–40), a big enough physical space (typically, a classroom), a stable Internet connection, and a reasonably up-to-date smartphone for each player. This limits the game's accessibility, for example, for rural youth, who traditionally face more access barriers to civic participation (Trivelli & Morel, 2021), and for those interested in playing the game as an extracurricular or home activity.

To address this issue, this study focuses on creating a low-cost, accessible version of the EP RPG titled *AmendMe*. The study is guided by a design question: how to design a tabletop game that teaches the EU legislation process and is engaging to play? The paper presents the initial design, as well as player feedback gathered during testing.

2. Background

As Sillaots and Fiadotau (2023) demonstrate, parliaments across Europe and beyond have used physical and digital games in their educational outreach, including to teach the legislative process and increase citizens' interest towards politics—the two central goals of this study. Among these examples, tabletop games are particularly relevant due to their higher accessibility, in terms of both technology requirements and suitability for players with limited game experience (Sousa et al., 2023). At the same time, despite their apparent simplicity compared to videogames, "board games can express very nuanced political positions and stimulate a critical reflection" (Quasdorf, 2020), and have been shown to increase both player motivation and understanding of politics (Thananithichot, 2025).

A common approach in civic education is to use existing commercial board games to foster discussion of political concepts and processes (Bridge, 2014). Some educators take it further, modifying (or having students modify) classic games for educational purposes (Castronova, 2015; Mattlin, 2018; Kuo et al., 2023). An alternative approach is to develop an original board game tailored to the intended learning content, for example, local and national elections (Thananithichot, 2025; Anggraeni, 2023), foreign policy (Hemmert, 2021), migration (Medda-Windischer, 2021), or environmental policy (Chen, 2022). The approach taken in this paper lies between these two poles: it is an adaptation not of a commercial game but of the original EP RPG, tailored to a different mode of play.

The physical and virtual versions of the EP RPG share similar features. Players take on the roles of Members of the European Parliament and are assigned to one of four political groups. In this capacity, they are tasked with working on a legislative proposal, balancing their political group's agenda with the demands of various stakeholders. Players discuss the legislative proposals in committees, present their views, vote on amendments and make decisions in plenary sessions (EP, 2025). The target audience is young people (14–18 for the physical game and 16–20 for the virtual one), though the games can also be played by older users. Both versions are playable in all 24 EU languages and rely heavily on technology. The physical game synchronously utilises 18 computers, up to 32 smartphones, and various multimedia devices. The virtual game requires an internet connection, a facilitator's computer and screen, loudspeakers, and a personal smartphone for every player.

A somewhat similar game is *Legislate?!*, "a board game to teach UK civil servants how a bill is created, debated, and implemented" (Cabinet Office, 2018). The game takes a group of 2–8 players through the legislative process from initial idea to implementing the law. Similar to a traditional roll-and-move game, players roll dice to advance along a board that represents the full cycle of the legislative process, picking up cards that either hinder or facilitate their progress. The first player to reach the final space—a fully implemented bill—is the winner. *Legislate?!* serves as a useful reference due to its smaller scale and relative simplicity, which are key design requirements for the accessible adaptation of EP RPG. Yet, progress in the game is based on luck rather than player skill, which diminishes its engagement and learning value.

verall, there is a shortage of research into the design of parliamentary games, and this is a gap this paper aims to address.

3. Methodology

This study follows the principles of **research for design** (Downton, 2003) and consists of three main phases: (1) ideation, (2) game design, and (3) game piloting.

For ideation, a project-based course was conducted at Tallinn University in autumn 2022. After playing the physical EP RPG, students from various disciplines were invited to generate and prototype alternative game ideas to convey the same learning content. The resulting prototypes served as a source of inspiration for the board game adaptation.

The design of the adaptation followed the approach outlined by Adams (2014). After a game concept was established, the game's core mechanics were defined, for which game content was created (game events, bill amendments, etc.) A spreadsheet was used for game balancing. Finally, a paper prototype was created using placeholder art.

The piloting phase involved students from the Digital Learning Games MSc programme at Tallinn University. To give participants a point of reference, they were invited to play both the physical and virtual versions of the EP RPG prior to the prototype. 15 students of various nationalities playtested the game in four groups, with an

average playtime of 45 minutes. While the sample size was small and participants' age range is higher than that of the intended end users (16–20 years), piloting with a small, more experienced group of players with expertise in game design was essential to identify potential issues before testing with end users.

An online questionnaire was used to assess the suitability of the overall game design, activities, and content were, and to gather ideas for future iterations. Most questions consisted of a predefined list of options related to specific game activities; participants were also encouraged to elaborate using free-form responses. The full questionnaire is available at https://forms.gle/WvEvqCMhvsDXrtbu9. Abductive content analysis (Ulla, 2017) was used to process qualitative responses through open coding and quantification of codes. The full dataset is accessible at: https://docs.google.com/spreadsheets/d/1oQ_4l4puIagdQVwUMQs9OsfO9XY0SVheSUTkvxfI1c8/edit?gid=2008244401#gid=2008244401

4. Game Design

4.1 Game Idea and Concept

During the ideation phase, university students designed four prototypes of a board game adaptation aimed at making the EP RPG accessible to a wider audience. Some of these were accurate from an educational perspective but too complex for young players. Others reused the mechanics of popular games (e.g., *Monopoly*) but sacrificed essential parts of the learning content in the process. Ultimately, an original game design was created that drew on successful elements from different prototypes.

The main premise of *AmendMe* is similar to the original EP RPGs: a group of players assume the role of MEPs and must navigate a challenge facing EU member states (in this case, Russia's threat to European security). Players must tackle the challenge by negotiating a legislative proposal: a directive on strengthening EU defence cooperation and security policy. Each player represents one of four political groups—Ecology, Tradition, Liberty, Solidarity—and receives a set of predetermined amendments to the legislative proposal. Players deliver public speeches to present their viewpoints, discuss the merits of each amendment, and make decisions by voting. In addition, they must respond to unforeseen in-game events (breaking news, change requests from other EU institutions, etc).

Like the original EP RPG, the adaptation seeks to explain the EU legislative process and to promote democratic values and civic engagement, targeting young people: students aged 16–20. Unlike the original game, it is playable in a much smaller group (2–4 players) to make it more accessible.

4.2 Game Rules

1. Each player is randomly assigned to a political group (Ecology, Tradition, Liberty, Solidarity).
2. A legislative proposal (directive) is placed on the table.
3. All amendment cards are randomly dealt among players (9 cards per player).
4. Players may exchange amendment cards to assemble a hand of amendments that best represent their political group's values.
5. Each player starts with an equal number of political credits (5 coins).
6. The youngest player begins by playing an amendment card that they believe to have the highest chance of passing and generating the most fame. The player must deliver a speech to promote the amendment.
7. Other players discuss the amendment's pros and cons. After the discussion, players vote on whether to accept the amendment. In the case of a tie, the outcome is decided by a coin flip.
8. If the amendment is accepted, the player who proposed it earns political credit according to the number specified on the card. The accepted amendment card remains on the table as part of the legislative proposal.
9. If the amendment is rejected, the card is removed from play.
10. The same player draws and plays an event card from the deck. Events can positively or negatively impact one or all players (e.g., lose or earn political credit or trigger extra actions). The relevance of the response to the event is decided by voting.
11. Play proceeds to the next player in clockwise order.
12. The game ends once all articles of the legislative proposal have at least one accepted amendment. The final step is a vote on whether to accept or reject the resulting legislative proposal with all its accumulated amendments.
13. Winning condition: The player who earned the most political credit is declared the winner.
14. Losing condition: If a player runs out of political credit, they are expelled from the EP.

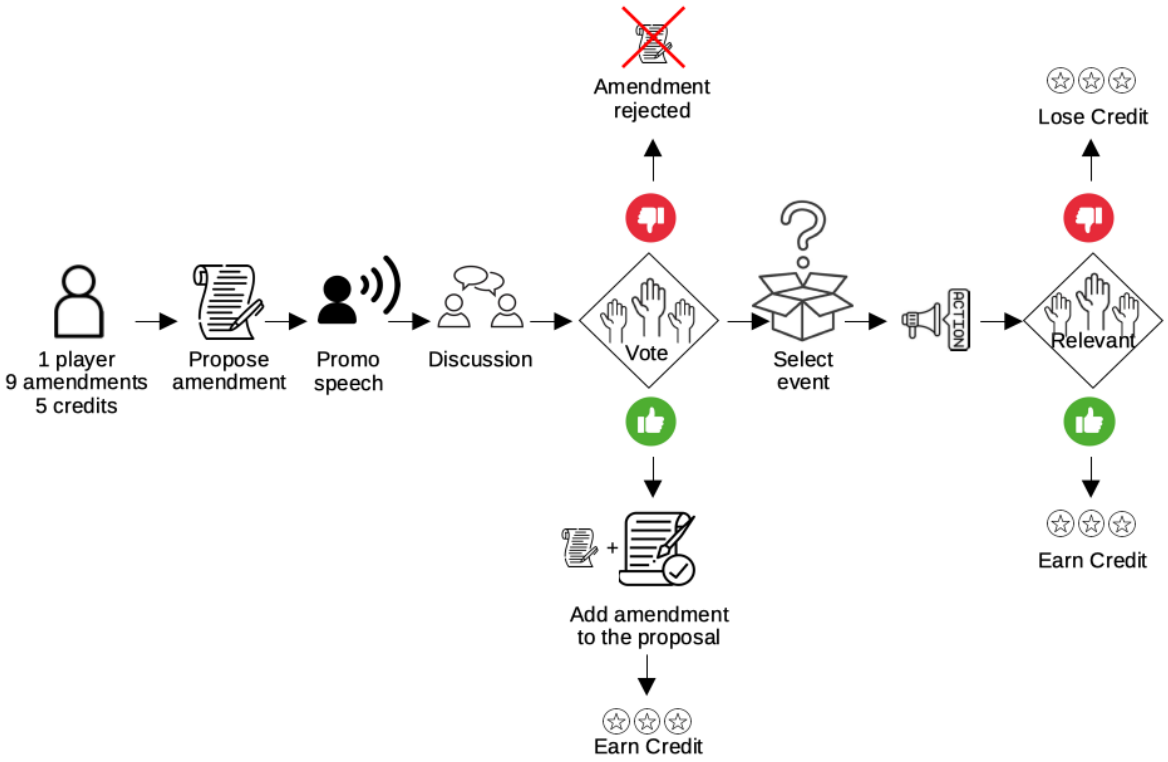

Figure 1: Visual representation of the game turn for an individual player

4.3 Game Content

The game includes the following components:

- 4 political group profile cards
- 1 legislative proposal card
- 36 amendment cards
- 36 event cards
- 100 political credit coins

Amendments are divided into seven categories, corresponding to the articles of the legislative proposal:

- 1. Collective Security
- 2. Resource Sharing
- 3. Defence Innovation
- 4. Crisis Response Mechanisms
- 5. Energy Security
- 6. Diplomacy
- 7. Unity, Awareness, and Resilience

The list of amendments underwent several iterations; a spreadsheet was used to ensure that each political group had a balanced number of usable amendments. The current version is available here: https://docs.google.com/spreadsheets/d/1g4X0FMODass3R1Ex8t7pxoqyD7V6waTQqWjxi0Ln3bo/edit?usp=sharing

Game event cards are divided into seven categories, each with distinct mechanic:

- 1. Political scandals: all players, or the one who picked the card, lose points.
- 2. Good news: all players, or one player, earn points.
- 3. Council intervention: players exchange amendments, with no effect on points.
- 4. Stakeholders' intervention: players vote on whether to accept the intervention. If accepted, a coin flip decides the outcome (earning or losing points).
- 5. Question from a stakeholder: the player who drew the card must respond. Other players decide if the answer merits one point.

- 6. Question from the media: the player who drew the card must answer, earning one point if the answer is at least one full sentence.
- 7 .Breaking news: all players must comment on the course of action. Each player earns one point (or avoids losing one point) if their comment is convincing.

The full set of game assets is available online:

https://docs.google.com/document/d/1_EWceirptdYQ4zC7bU_qTGFxOBrdKsW9jBIue9OfLdo/edit?tab=t.0.

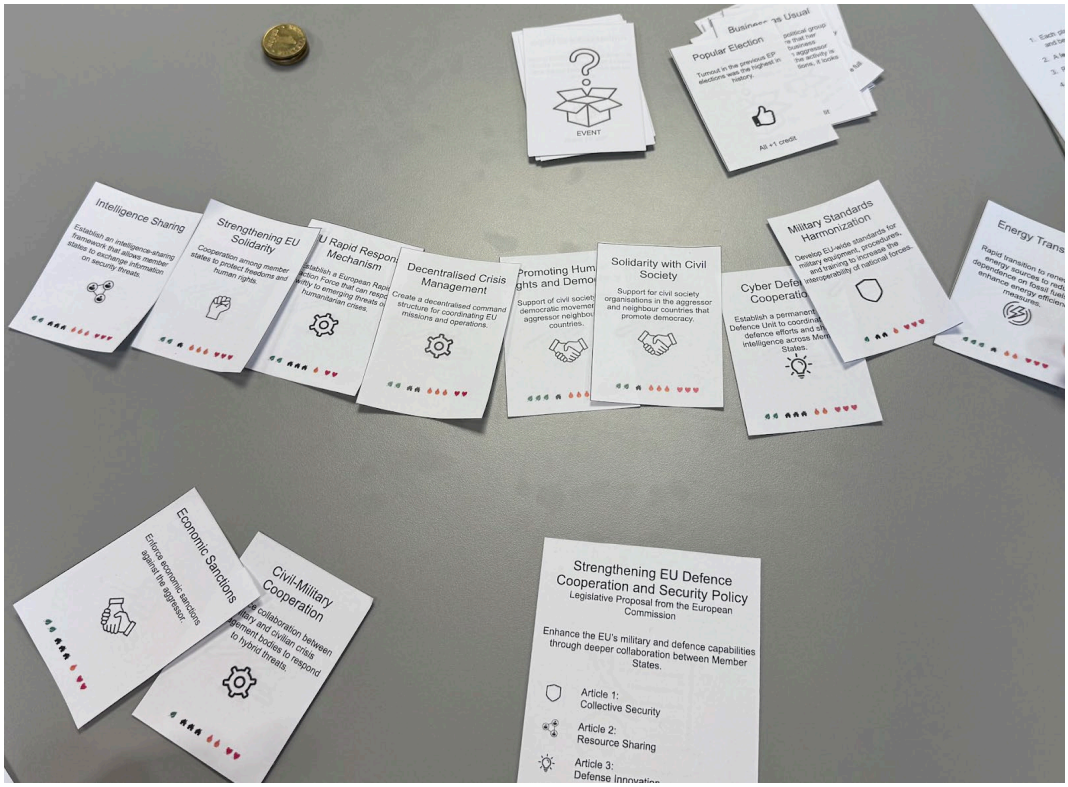

Figure 2: Game playtest: Accepted amendments (centre), legislative proposal (bottom centre), game events (top), one player's cards (bottom left), and some political credit (top left)

5. Playtesting Results and Discussion

In general, players expressed satisfaction with the game experience (4.07/5), with most players reporting enjoying the game session. By comparison, the same students rated their satisfaction slightly higher for the physical game (4.45) and marginally lower for the virtual one (4.04).

Only one out of 15 students was not satisfied with the tabletop game (rating their experience 1/5). In their freeform feedback, this player described the experience as boring and involving too much reading. While this response was an outlier among the current playtester group (postgraduate students specialising in learning game design), it highlights a potential risk when testing with its intended target audience of younger players.

5.1 Feedback on the Game Components

Table 1: Players' feedback on the game components

Game Component	Like	Dislike	Total
Suggesting amendments	0	-1	-1
Giving speeches	1	-4	-3
Discussions	4	-2	2
Voting	1	-3	-2
Game events	6	-1	5

Game Component	Like	Dislike	Total
Creating new amendments or events	2	-1	1
Collecting political fame	1	0	1

When asked to evaluate individual game components, players appreciated the game **event system** the most (6 out of 15 players selected it as their favourite), with four respondents citing unpredictability as a key factor in maintaining engagement. One player commented: "The Game Events bring the interesting aspect of unpredictability into the game. Sudden interviews or uncovered political scandals make the game feel more alive and engaging to play". Another player pointed out that events ensured that there was "action going on… not just verbal discussions". Conversely, one player mentioned the game events as the least appealing game component, citing her frustration with the point loss mechanic due to negative events. This suggests that the number of events where players lack control over the outcome may need reducing.

Players also enjoyed the **discussions** (4/15) because they allowed them to dig deeper into the topic (mentioned twice), were fun, and got everybody involved. At the same time, two of the players did not enjoy the discussions, because they did not relate to their political group's positions on the issue and/or specific amendments. One player stated: "Theoretically, the discussions are a very engaging and important part of this game. In practice … sometimes I didn't know why the party I belonged to would rate a suggested amendment very low". She explained this was because "the info cards of the parties only highlighted what I had to stand for and not what I was opposed to, which made taking a stand a bit confusing at times". This lack of transparency was in fact an intentional design choice, mirroring how real-world political groups tend to imply, rather than clearly state, what they oppose to avoid alienating potential voters.

One player enjoyed the opportunity to **create** new amendments or game events using empty cards because "it allows the player to let their creativity run loose". Another player, however, lamented that they "never actually got the chance to suggest any new amendments or events". This suggests a need to provide a more clearly-defined opportunity for players to create new game content.

Public speaking was the least favoured game component (four players mentioned disliking it), with one participant commenting that "it did not feel very necessary". They added that "it was sometimes difficult to know how the amendments related to our party's political standpoints". This suggests that, even though the political groups' stances on amendments were presented to players through the game content, the game was not always successful at getting players to deeply engage with the content. As such, despite public speaking being an integral part of an MEP's job, it may be beneficial to limit speeches in the game to specific occasions such as event responses.

Some students (3/15) did not enjoy the **voting** activity, citing the imbalance of the game content whereby amendments were rarely rejected. One player commented: "People tend to choose the amendment with more support, which makes the game less fun. And people will be more focused on the numbers than the actual amendment". In contrast, another player pointed out that she liked the voting the most because "it gave the impression of 'winning' when an amendment I suggested was accepted". These contrasting views suggest that, for further iterations of the game, amendments should be designed to be more ambivalent and not equally attractive to most political groups. An alternative solution is to change the scoring mechanics to a system where political groups may lose points if amendments unfavourable to their agenda are accepted. Limiting the number of amendments available to a player at any given time can also force them to find a way to argue for worse options, encouraging persuasion and negotiation.

5.2 Feedback on Game Content

To evaluate the suitability of the game content, players were asked to provide feedback on the content of the amendments and game events. (It is possible that some content was not drawn during the playtest and thus is not reflected in the evaluation. This can be addressed by additional testing.) It was interesting to observe that some students, despite their game-design background, evaluated the content through the prism of its realism (how well does it represent solving a security crisis in real life) rather than gameplay (how to create an engaging and varied game experience). In future iterations, the feedback questionnaire should include clearer instructions.

Two of the amendments were singled out by two players as their favourites:

- Cyber Defence Cooperation: "As cyberattacks are a growing threat to our real everyday life, we had a really active discussion on this topic, trying to figure out where the line is between cyber freedom and security".
- Promoting Human Rights and Democracy: "I think this is such a global goal for all societies".

Several other amendments (Decentralised Crisis Management, Diplomatic Engagement, Disarming and Peacebuilding, Encouraging Resilience, European Defence Fund, Innovation in Defence Technologies, Strengthening EU Solidarity) were highlighted by individual players.

Three amendments were received less positively:

- EU Battlegroups (mentioned by three players): e.g., one of the players complained about "not understanding why my party (ecology) was against this amendment. I couldn't figure out how to make my position clear in the discussion with the others, breaking the immersion we had until then".
- Decentralised Crisis Management (mentioned 2 times): "When crisis hit [sic], there is need for swift decision to be taken [and decentralised crisis management prevents that]".
- Cultural Exchange and Heritage Protection: "Everyone agreed [on this amendment]".

The last example points to the game's biggest issue: if the amendment is universally appealing, it is not good from a game design perspective. Content should create more controversy, discussion, and variety in voting. In this sense, the other two examples are in fact valuable in that they generate debate.

Two game events were highlighted as positive by multiple players. The Sauna event was mentioned three times, as it was deemed funny. The Bribery event (where the player had a choice whether to accept the bribe) was mentioned by two players, one of whom described it as an unexpected opportunity to benefit. Conversely, another player did not like this event because "it promotes corruption". Six other game events were listed as their favourite by one player each (Anti-Corruption, Council's Amendment, Fake Jobs, Interview, Nepotism, and People for Peace). This suggests that the current events are largely balanced and accommodate different player preferences (some events generated both positive and negative feedback). Two of the players responded that they enjoyed all of the game events.

One event that may need calibration in the next iteration is the Interview, which two respondents criticised ("It didn't really work as intended. No real discussion was brought up for learning potential"), pointing to a need for more guiding questions and scaffolding.

5.3 General Feedback

Players provided conflicting feedback on the **clarity** of the game's rules. Most found the game rules to be sufficiently clear, with one player stating: "I liked that overall the rules were easy to remember, so we could come into a kind of flow while playing". The game facilitator took extra care to make sure that the game rules were communicated clearly, explaining them and guiding the players during the first turn rather than requiring them to read the rules on paper. However, at least one player found the rules to be too complicated:

> *There were too many mechanics that the players had to keep in mind, so I guess it was difficult for the players to enjoy the game. Even after one hour, it seemed that the cards had to be explained to the players.*

Two players pointed out that the game's **scoring mechanics**—especially the value of amendments for different political groups—required better balance. (As noted earlier, most of the proposed amendments were accepted, making it too easy to earn points. One of the players commented: "In our group, we ended up voting almost everything through".) Although point variation did in fact exist, players often failed to perceive it. One player suggested changing the scoring mechanics to include both positive and negative feedback:

> *Make people lose political fame when an amendment their party is opposed to actually wins the vote. This would lead to more heated discussions, making the game more interesting. Or just make people gain/lose more political fame through the game events to provide more fluctuation in points, therefore more concern for one's own position.*

One concern that game authors had before the game testing session—the theme of the game (Strengthening EU Defence Cooperation and Security Policy) being perceived by players as overly serious and anxiety-inducing—was not borne out by player responses. One player summed it up: "I like that the game reflects the reality of the modern world as the topic is very serious".

In conclusion, despite the need to adjust the game content and balance some mechanics, players generally enjoyed the game. One player even remarked: "I'd buy it".

6. Summary

This study contributes to a growing body of literature on civic education through serious games. Specifically, it explores the design and pilot testing of *AmendMe*, a tabletop game aimed at teaching the legislative process of the European Parliament. The game offers an accessible alternative to the existing physical and virtual versions of the European Parliament Role Playing Game. Feedback from pilot testing indicated a generally positive reception, with the game considered enjoyable, informative, and clear in terms of gameplay. Game events and group discussions were the most appreciated mechanics, due to the unpredictability of the former and the player interaction facilitated by the latter. However, the feedback also points to a need for further balancing, as the amendments were deemed too uncontroversial and winning too easy.

Overall, the findings support the argument that tabletop games can foster political interest, soft skills, and collaborative learning, and that they can be an accessible alternative to digital formats. Thanks to being freely distributable and easy to set up and play, *AmendMe* can be used in classrooms, youth workshops, or extracurricular settings without the need for advanced infrastructure. This sets it apart among the limited number of learning games focused on EU-level governance and legislative process.

Several areas require further investigation to fully validate and refine *AmendMe*. One of these pertains to balancing the game mechanics—particularly voting dynamics, scoring system, and amendment content—to make decision-making more meaningful and the game more challenging. The next iteration of the game should be tested with its intended audience (16–20-year-old students) to evaluate its accessibility, engagement, and content comprehension among younger players. A further step would be to empirically assess game's impact on learning outcomes and attitudes toward civic participation.

While the starting point for the project was to make the EP RPG accessible to wider audiences, *AmendMe*'s own accessibility (for example, for dyslexic players, colourblind players, etc.) needs to be tested. Once the game content is finalised, it should be translated into multiple languages, have professional art assets integrated, and have playing instructions and marketing materials prepared for broader release.

The fact that piloting outside of the primary target group produced positive feedback suggests that *AmendMe* has the potential to be generalised to a wider audience. The modular structure of the game's content (amendment, rules, political groups, etc.) supports adaptation to different complexity levels and legislative areas, as well as integration into broader civic education curricula.

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Ethics Declaration The game was tested with university students. No personal or demographic data were collected. Therefore, ethical clearance was not required.

AI Declaration: Generative artificial intelligence (Grammarly, ChatGPT) was used to proofread and edit the text of the article.

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Co-Designing Visual Novels in Literary Education Classes: Instruments for Measuring Learner Engagement

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Abstract: Immersive didactic resources have been gaining popularity, with researchers and educators seeking to align their practices with students' affinity for technology. Digital Game-based Learning (DGBL) has emerged as a promising learning opportunity, occupying a prominent place in the global discussion about the modernisation of education. This stems from the benefits of educational video games, namely their ability to foster learner engagement, an igniter of meaningful learning experiences. Nonetheless, their use and rigorous assessment in Humanities subjects, in interventions where secondary education students co-design didactic material, remain a gap in current investigation. There is also a tendency for research to describe standardised instruments for each subject. As such, this study seeks to describe instruments specifically created to assess students' level of engagement in co-designing a type of story-driven video games – Visual Novels – in the context of Literary Education. The underlying goal is to present tools that evaluate actions devoted to engaging students in a domain which is often perceived as demotivating. The resulting instruments will be used in a case study aimed at fostering Portuguese secondary education learners' engagement in Literary Education by having them co-design educational Visual Novels inspired by a Portuguese classic literary work, "Os Maias" by Eça de Queirós. To meet our goals, we subjected two questionnaires (pre- and post-intervention) and a class observation grid to a qualitative analysis. We considered the feedback of a multidisciplinary team of experts and implemented their suggested changes. Afterwards, we conducted a pretest of the first questionnaire with a sample of students, obtaining their feedback and calculating Cronbach's alpha for measuring reliability. The second questionnaire, identical to the first but centred on the upcoming video game intervention was not pretested. Experts and students' perspectives suggested a favourable appraisal of the instruments, while contributing to its improvement. Concerning the questionnaire, the Cronbach's alpha obtained is above 0.7, implying a high level of consistency among items. By making these instruments available, we endeavour to promote more efforts of implementation of rigorously designed activities destined to the co-design of video games in the field of Humanities.

Keywords: Instruments' validation, Educational visual novels, Co-Design, Secondary education, Literary education

1. Introduction

The intersection between technology and education is transforming teaching practices, challenging traditional methods through innovative and digital approaches. In this context, educational video games have emerged as promising tools to enhance student engagement, fostering interactive learning experiences. Among them, Visual Novels, a genre of narrative video games, stand out for their potential to bring students closer to literature, offering them an active role in shaping and transforming stories.

Considering this reality, the present study aims to validate instruments to be used in a case study, inserted in a doctoral project centred on designing educational Visual Novels as a strategy to promote engagement in Literary Education among secondary education students (with ages ranging from 15 to 17). Acknowledging the central role of affect in learning, with engagement at its core, and the need to adapt school practices to the reality of the new generation, increasingly linked to technology, we seek to evaluate a process for creating authentic digital materials, in a way that reflects students' interests while improving their attitudes towards a field commonly seen as demotivating.

Despite the popularity of video games as educational resources, empirical studies aimed at finding rigorously built or adapted instruments that measure the impact of these immersive technologies on the affective dimension of learning remain scarce, especially in the field of Humanities.

In Literary Education, where it is essential that the methods and objects of teaching reflect the advances that have revolutionised society and the ways we now consume literature, it makes special sense to organise activities centred on video games, as they are favourable to exercising one's critical spirit, creativity and aesthetic fruition. However, it is crucial to use reliable tools to assess their potential and ensure a meaningful and engaging learning experience.

The instruments this study describes draw on validated engagement scales (e.g., Flow State Scale, Four-Dimensional Scale) to address the specificities of co-designing Visual Novels within Literary Education. Nonetheless, by incorporating Humanities-related concepts, they are transferable to other subjects of that domain. Likewise, the instruments are adaptable to activities involving other narrative game genres that emphasise storytelling, role-play, and choice-making.

2. Theoretical Framework

In this section, we elucidate the structuring concepts of our study. We also refer to instruments that have already been validated, which served as a basis for the surveys and class observation grid created.

2.1 Co-Design of Educational Visual Novels: Potentialities for Literary Education

Visual Novels are a genre of narrative video games resembling digital books, which offer an interactive and immersive experience (Camingue et al, 2020). When playing a Visual Novel, the player takes on the role of the protagonist of a story, responsible for making decisions and solving challenges, which mark a sequence of events, graphically represented through scenarios and dominated by text (in the form of descriptions and dialogues). This story appears in parallel with other graphic elements – the characters and clickable objects, for example – evolving according to the player's behaviour (Øygardslia et al, 2020).

When designed for pedagogical purposes, Visual Novels qualify as educational or serious video games. Practices based on the use of these resources correspond to DGBL – Digital Game-based Learning – a concept proposed by Prensky (2001). Since then, this notion has been enriched by empirical, more current and comprehensive approaches, recognising the risk associated with the use of the term "digital native", introduced by the author, to name the members of Generation Z (Khan et al, 2017).

Indeed, despite their high degree of exposure to technology and preference for using it, this does not necessarily translate into digital proficiency (Ball et al, 2020). To acquire such skill, it is important to be inserted in contexts which cultivate attitudes and knowledge conducive to the effective, creative and responsible use of technology.

In turn, the collaborative design of digital artifacts is an innovative practice, favourable to the development of skills of co-negotiation of meaning, self-regulation of learning, creative problem solving and interpersonal skills (Thumlert et al, 2018). According to Järvenoja et al (2020), collaborative learning helps students to assess their understanding of an activity, and the contents inherent to it, as a team. This allows them to find solutions to possible issues, while discerning the best ways to act, in terms of maintaining their enthusiasm for learning.

Designing educational Visual Novels for learning literature is of special significance, as narrative video games share characteristics with literary works. As a distinctive trait, they have an interactive and agentive character, since the way the narrative evolves in Visual Novels depends on the player's interaction with the game. This results in a rewarding reading experience, promoting learner engagement.

Engagement, as defined by Csikszentmihalyi (1990), is a driving force for learning, as it enables students to immerse themselves in a task recognised as relevant and pleasurable. Knowing that they will be rewarded with enjoyment and opportunities for personal development, during an arduous activity, helps to carry out time-consuming and complex cognitive exercises, such as abstraction and the discovery of hidden meanings, actions that characterise the act of reading (Calvino, 2015). As explained by Glessner and Olufemi, (2019), engagement leads to effective learning experiences, as it is characterised by joyful feelings stemming from “a potpourri of minds-on and hands-on activities […] beyond mere completion of worksheets” (p. 1). For Shernoff et al (2014), who delved into optimal learning in high school contexts, “if engagement with learning arises from the reciprocal interaction between learners and a learning environment […] then teachers’ potency to engage students may lie in their ability to create, shape, and influence the whole learning environment” (p. 167).

Thus, one can infer the advantages of integrating in a complex area such as Literary Education, which many students face with disinterest, initiatives that encourage them to be active, by creating and interacting with resources while learning. This is conducive to a continuum of cognitive and affective investment in the subject, which prevents students from giving up when tasks become challenging. Given this, promoting the co-design of Visual Novels to increase engagement, by encouraging teamwork and valuing students’ interests and agency, allows to build effective didactic material, which results in optimal learning environments.

2.2 Instruments Dedicated to Measuring Engagement in Literary Education

According to Nkomo and Nat (2021), most research assessing engagement in using educational digital tools describes standardised instruments for each subject. Furthermore, they tend to focus on student behaviour and do not combine instruments and techniques for assessing engagement, which jeopardises rigour. The instruments we built aim to address that gap, while intersecting concepts specific to Literary Education, such as aesthetic fruition and written comprehension, with characteristics of educational video games (their interactivity and multisensorial nature, for example) and collaborative game making. These tools will be used in a study case aimed at measuring engagement stemming from co-designing Visual Novels inspired by an important work by Eça de Queirós, "Os Maias". For consultation and adaptation, an English translation of the instruments is available: https://shorturl.at/N62o4. The table below summarises the structure of the survey, the instrument we pretested, including the studies which informed it and examples of questions or scale items:

Table 1: Summary of the structure, constructs to be assessed and samples of questions/items characterising the pre-intervention survey

Sections of the survey	Constructs to assess	Type of questions	Examples of questions/items
My engagement in classes dedicated to Literary Education	Learner engagement, based on the "Four-Dimensional Scale of Student Engagement at School scale" (Silva et al, 2016) and "The Flow State Scale" (Csikszentmihalyi, 1990; Jackson and Marsh, 1996)	7-point Likert scales	Cognitive dimension: "I identify the themes and messages present in the works I am studying with ease"
			Affective dimension: "My perception of time changes when I do activities centred on narrative texts (time passes more slowly or faster)"
			Behavioural dimension: "I follow the teacher's instructions in classes dedicated to Literary Education"
			Agentive dimension: "I like it when I can choose what Literary Education activities to do"
My habits, preferences and perceptions related to video games	Perceptions and habits related to narrative video games (Alrajhi, 2020)	Multiple choice	"What types of narrative video games do I like to play?"
	Perceptions of educational video games (Fu et al, 2009) and their compatibility with Literary Education (Silva et al, 2023)	7-point Likert scales	"Video games can make learning fun and engaging/immersive"
			"Narrative video games can be used to learn about narrative texts, as both tell a story"
	Perceptions of designing educational video games and collaborative work (Järvenoja et al, 2020; Thumlert et al, 2018)	7-point Likert scales	"It is more fun to carry out activities centred on narrative works in a group, with the possibility of interacting and talking with colleagues"

The survey, whose administered online version is two-pages, comprises 11 questions, divided into two sections. The first contains 7-point Likert scales relating to the multidimensional nature of engagement. These categories, extracted from the "Four-Dimensional Scale of Student Engagement at School (EAE-E4D)" (Silva et al, 2016), include items that range from the cognitive work dedicated to achieving a task (cognitive dimension) to the emotional relationships established with the activities, the teachers who promote them and the colleagues with whom the student collaborates (affective dimension). The scales also cover the behaviours manifested by students (positive or disruptive) – behavioural dimension – as well as the degree of initiative they exhibit – agentive dimension (Veiga and Abreu, 2014). Although this system of classifying engagement pertains to the experiences inside and outside the classroom, we decided to apply it exclusively to classroom activities, to ensure greater adequacy to our project.

From the definition of engagement proposed by Csikszentmihalyi (1990), later used on a scale – The Flow State Scale (Jackson and Marsh, 1996) – we derived characteristics such as the balance between students' abilities

and the level of challenge of the task they are fulfilling ("I carry out activities on a narrative work autonomously, without significant difficulties"), as well as the level of immersion in a task ("When I read or study a narrative work, I imagine myself experiencing the adventures of the characters"). Other items correspond to reported changes in their perception of time ("My perception of time changes when I do activities centred on narrative texts") and a sense of intrinsic reward ("I do not feel rewarded on a personal level when I successfully perform activities centred on narrative works"). We opted for first-person phrasing and 7-point Likert scales to guarantee relatability and a nuanced range of responses, improving data quality (Kusmaryono et al, 2022).

As for the second section of the questionnaire, it features three multiple-choice questions, based on a survey by Alrajhi (2020), aimed at ascertaining students' perceptions concerning educational video games. Such questions deal with students' contact with narrative video games; the time they dedicate to them and the genre they prefer. This is followed by four Likert scales. The first, informed by the concept of "egameflow" by Fu et al (2009), refers to the "the learner's cognition of enjoyment during the playing of e-learning games" (p. 111). It determines whether students consider that video games can be effective and immersive learning tools, as seen in the item "Video games can be educational if their design is appropriate for the established learning goals". The second scale, which determines whether, from students' perspective, learning based on narrative video games is compatible with Literary Education, is anchored in the premise that video games can elevate the reading experience by materialising plots "through the use of written text, sounds and imagery, which give video games a multimodal and diegetic nature" (Silva et al, 2023). The item "Narrative video games contain aspects (visual, interactive, sound-related) that generate immersion/engagement in learning" is illustrative of this idea.

The third and fourth scale gauge students' interest in video game design, their perception of activity's relevance and students' predisposition towards collaborative work. To build those, we resorted to Thumlert et al (2018), who address the importance of designing artefacts with value for the makers ("It is rewarding to know that I am responsible for designing a creative and educational digital resource") and Järvenoja et al (2020), who describe high-order thinking skills enriched by teamwork, such as problem-solving ("Exchanging ideas with colleagues increases my problem-solving skills").

The post-intervention questionnaire is similar to the pre-intervention survey, replacing, however, "narrative video games" with "educational Visual Novels" (now familiar to participants) while removing gaming-habit questions. To triangulate data, we also created a yes/no observation grid, from the researcher's standpoint, to be administered before the game making intervention. Based on the described survey's first section, its items concern engagement dimensions. Throughout the activities, where participant observation will take place, we plan to make descriptive field notes.

3. Methodology

To assess the reliability (the consistency of a test's results) and validity (the accuracy of the test's object and its ability to measure it) of the data collection instruments to be used (Furr, 2017), we followed the steps of a pretest (Hashim et al, 2022).

3.1 Validation of the Instruments by Experts

Both questionnaires and class observation grid were sent to four experts in the areas that our project combines: Literary Education, Educational Psychology and Educational Technologies. The goal was to compare their opinions to obtain a comprehensive interdisciplinary assessment. This qualitative analysis – linked to construct validity (evident in the relationship between the instrument and the measured construct) and content validity (associated with the ability of the instrument's content to reflect the measured construct) (Furr, 2017) – resulted in the improvement of the instruments, so that they became more scientifically rigorous and intelligible (Coutinho, 2014).

3.2 Pretest of the First Questionnaire

We selected as the main object of the pretest, to be administered to a sample of students, the first questionnaire. We aimed to get feedback from a group of students with a similar profile to the one that will participate in the project. In doing this, it is possible to ensure the intelligibility of the questions, scales and items, through a qualitative analysis. To complement it, a statistical evaluation of its reliability was carried out. Since the second questionnaire evaluates an experiment that, at the time of the pretest, did not occur, we

chose not to include it. Because they are identical in terms of content, formulation of items and structure, one can infer that the validity and reliability of the first extends to the second.

3.2.1 Approval by the ethics council

The procedures described were approved by the Data Protection Officer of the University of Aveiro, as well as the Ethics and Deontology Committee of the university. It is thus ensured that the project follows the ethical guidelines relating to GDPR and DPIA.

3.2.2 Selection of respondents

The pretest sample comprises 18 eleventh-grade students, attending a private school in Portugal, indicated by the school's principal and the class's Portuguese teacher, given the availability and interest of the latter, the interest expressed by this class, and the high degree of similarity between the profile of this class and that of the group involved in the intervention (in terms of age and school year). To determine whether its size is adequate, we followed the recommendation of Perneger et al (2015), based on the calculation of the ability of a pretest to identify problems in an instrument. According to the authors, it is important to have a sample of more than 15 elements to avoid difficulties in filling out a questionnaire (occurring in 10% of the participants). Thus, a sample of 18 elements is admissible, suggesting the pretest is likely to succeed.

3.2.3 Applying the pretest

The questionnaire was completed by the respondents in the classroom, in the presence of the researcher, through the FormsUA platform. To avoid collecting personal data, we displayed a QR Code on the board, instructing students to access it through their mobile phones. We opted for the online modality, due to the access of respondents to mobile phones and the ease with which the data obtained can be organised and processed. This test took place in December and lasted about 20 minutes.

The students were instructed to identify problems of intelligibility in the different items, in terms of syntax and lexis. At the end of each section of the questionnaire, as proposed by Hashim et al (2022), we included closed-answer questions: "Are the questions and scale items easy to understand?", followed by a comment box with the indication: If the answer is no, identify the questions/scale items and explain why it was difficult to understand them".

4. Results

A total of 18 complete responses were collected, corresponding to all respondents. Their feedback was used to assess the validity of our questionnaire, more specifically their ability to measure the targeted construct (Marôco, 2018). All students, concerning the questions related to their level of comprehension of questionnaire, selected the option stating the items were easy to understand. In the comment box, some stressed this idea, adding that the scales and questions were clear, diverse enough to accommodate respondents with different profiles, and well-structured. A student suggested, however, that it is important to define "narrative video game", to avoid misinterpretation of the term.

To assess the internal consistency of the instrument and contribute to its reliability, we calculated Cronbach's alpha, using SPSS (Furr, 2017). Regarding the first part of the questionnaire, we selected all items, in other words, the scales relating to the four dimensions of engagement – cognitive, affective, behavioural and agentive. The resulting number was 0.876, higher than the minimum recommended (0.7). As for the second part of the questionnaire, we selected all questions and scales, except for the ones addressing students' preferred video game genres and preferred ways of working inside the classroom (individually or in group). This decision was due to our intention to limit our calculation of Cronbach's alpha to items measuring the same construct – students' perceptions on educational video games. The resulting number, 0.925, suggests a good consistency among items.

5. Discussion

The need for data collection instruments specifically targeting learner engagement in the co-design of educational Visual Novels in Literary Education led to the creation and validation of two questionnaires and one class observation grid. The steps followed – literature review, creation of the instruments, obtainment of expert feedback and the execution of a pretest of the first questionnaire – were completed with success, resulting in adaptations that contributed to the instruments' rigour in terms of validity and reliability. Regarding the pretest, the number of responses received from our sample, comprised by Portuguese students

attending 11th grade in a private school, corresponds to 18. According to Perneger et al (2015), it is an admissible number as it abides by their recommendation that sample size should be above 15 to prevent difficulties related to the intelligibility of a questionnaire.

In turn, 7 students, despite having already checked the box stating the questionnaire easy to understand, decided to leave a positive comment, which reinforces their favourable appraisal of the instrument. One student wrote a suggestion for improvement – clarifying the term "narrative video game". This feedback will be used for improving the questionnaire before it is applied in the intervention relating to our doctoral project. As explained by Hashim (2022), respondents' feedback in pretests is important for making the items clearer for the population represented by the sample. Given this, we seek to add a short clarification, by writing "a story-driven video game" next to the term when it is first introduced in the questionnaire. After assessing the questionnaire's validity, in other words, how the questions and scale's items are related to the measured constructs, we performed a Cronbach's alpha test to calculate the instrument's internal consistency. The obtained results were higher than 0.7, which indicate that the items are related and measuring the same constructs: engagement in Literary Education (for the first part of the questionnaire), and students' perceptions related to educational video games (for the second part of the questionnaire).

Concerning their usefulness, although these tools respond to the intrinsic demands of our study, they hold potential for being adapted across various Humanities subjects, with a focus on interdisciplinarity and narrative-based pedagogies. By incorporating narrative game making practices into educational contexts, teachers can have their students create authentic and immersive didactic resources while increasing their engagement with written text. Besides allowing to rigorously assess such practices, this work brings greater visibility to Visual Novels, video games with a choice-based structure, whose design process aligns with key educational goals in the Humanities (creative writing, reading comprehension, and critical thinking, for example). The agency they give designers and players, when reflecting on and shaping the characters' path, is linked to an improvement of engagement and higher-order thinking skills, which can be enriched by teamwork. This makes a case for these video games, or similar genres, to be the target product of activities dedicated to collaborative game design.

6. Conclusion

To help filling in a gap in investigation, we validated instruments dedicated to assessing learner engagement in Literary Education, stemming from the co-design of narrative video games, more specifically Visual Novels. By creating and sending two questionnaires, to be used in a study case following a pre- and post- test design, and a class observation grid, to a multidisciplinary team of experts, we were able to adapt them according to their feedback, contributing to the instruments' validity in terms of the scientific fields it intertwines – Educational Psychology, Educational Technology and Literary Education. Concerning the first questionnaire, by subjecting it to a pretest, it was possible to collect a group of students' perceptions of its intelligibility, strengthening the instruments' validity. This is a crucial step, as it helps making these instruments more accessible to the target audience – students in secondary education. Given its similar content and structure, one can deduce that its validity extends to the second questionnaire, ensuring robustness across both instruments. The results of the Cronbach's alpha test add to the instruments' rigour, suggesting that they are reliable.

The qualitative and quantitative assessments support the adaptation of the questionnaires and observation grid to different interventions, in Humanities' subjects, articulating narrative video games and affective learning constructs, namely engagement. It is, indeed, important to include immersive technology and collaborative digital creation in subjects such as Literary Education, as this makes learning more consonant with students' profiles, interests and preferred ways of consuming art in written form. By evaluating such practices' effectiveness, we counter the tendency for embodying technology in the classroom without critically reflecting on its outcomes and the central role of rigorous pedagogical actions in engaging and meaningful learning. Concerning limitations, one should point out the small size of our pretest sample (despite being enough for identifying problems and improving the instruments accordingly) and the specific context in which the study took place – a Portuguese private school. As such, it is expected that this study encourages practitioners and researchers to adapt or replicate it with larger samples in different educational settings.

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AI declaration: Microsoft Word was used for obtaining a translated draft of our instruments (manually refined) and DeepSeek was used for obtaining revision suggestions.

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Bridging Virtual and Real: Gamification in Teaching Architectural Features with Assassin's Creed Odyssey

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Abstract: This study investigates the potential of gamification in architectural education by examining how immersive video games, such as Assassin's Creed Odyssey, influence the retention of architectural details and spatial understanding. The research aims to determine whether experiencing architectural spaces in a virtual environment enhances learning outcomes compared to traditional methods. The present study was conducted with a total of 20 participants from diverse professional backgrounds and undergraduate degrees, in order to ensure a heterogeneous sample and to more accurately assess the effectiveness of different instructional modalities in conveying architectural concepts to individuals without specialized training in the field. Participants were randomly assigned to one of two groups, each comprising 10 individuals. The experimental group interacted with the Assassin's Creed Discovery Mode, engaging with the game environment for a 30-minute-long predetermined period and exploring architectural features as presented within the game. In contrast, the control group was provided with a transcript of the in-game narration, allowing them to access the same informational content exclusively in textual form, without any interactive or visual elements. No preliminary information regarding the subject matter was given to either group prior to the intervention, thereby establishing an unbiased baseline. Following the intervention, both groups completed post-test assessments consisting of multiple-choice questions designed to evaluate their knowledge acquisition. Although the tests administered to each group were distinct, the questions were identical in content, ensuring comparability of results. The collected data were analyzed, and the findings were subsequently transformed into graphical representations to facilitate interpretation. The results were then evaluated to determine the relative efficacy of game-based versus text-based learning environments in fostering the recognition and understanding of architectural features. The findings of this research have important implications for both educators and game developers, underscoring the potential of video games and alternative instructional methods as effective tools in architectural education. This study contributes to the expanding literature on educational methodologies and offers valuable insights into the impact of immersive and text-based environments on the learning of complex subject matter.

Keywords: Gamification, Architectural education, Spatial cognition, Experiential learning, Assassin's Creed Odyssey

1. Introduction

The integration of gamification into educational practices has gained significant attention in recent years, particularly in fields requiring spatial cognition and experiential learning. Gamification, defined as the use of game design elements in non-game contexts, has been shown to enhance engagement, motivation, and learning outcomes across various disciplines (Deterding, 2011). In architectural education, where understanding spatial relationships and retaining visual details are critical, immersive video games offer a unique opportunity to bridge the gap between theoretical knowledge and experiential learning. Assassin's Creed Odyssey, with its Discovery Mode designed for educational purposes, provides a virtual environment where users can explore historically accurate reconstructions of ancient Greek architecture, making it an ideal tool for studying the impact of gamification on learning.

Experiential learning theory, as proposed by Kolb (1984), emphasizes the importance of learning through experience, particularly in disciplines that require the development of practical and spatial skills. Virtual environments, such as those provided by video games, align closely with this theory by offering learners the opportunity to interact with and explore architectural spaces in a way that traditional methods, such as reading or watching videos, cannot replicate. Research has demonstrated that immersive environments can improve spatial memory and understanding, as well as increase engagement and interest in the subject matter (Gee 2003; Poggiolesi 2016). However, the effectiveness of such methods compared to traditional approaches remains underexplored, particularly in the context of architectural education.

This study investigated the potential of gamification in teaching architectural features by comparing the learning outcomes of participants who engaged with the Discovery Mode of Assassin's Creed Odyssey to those who learned through traditional methods, such as reading educational texts. Additionally, the study examined how participants' diverse professional backgrounds and undergraduate degrees influenced the effectiveness of these learning methods. By employing a mixed-methods approach, the research provided a nuanced understanding of how immersive environments impacted the retention of architectural details, spatial cognition, and engagement. The findings contributed to the growing body of literature on game-based learning and offered insights into the role of gamification in architectural education.

2. Methodology

This study employs a mixed-methods approach to investigate the effectiveness of game-based learning compared to traditional learning methods in teaching architectural features, focusing exclusively on participants without prior design knowledge. The participants (n=20) are divided into two groups: an experimental group (n=10) and a control group (n=10). No prior information or materials are provided to participants before the intervention to ensure an unbiased baseline for both groups.

Participants in the experimental group engage with the Discovery Mode of Assassin's Creed Odyssey for approximately 30 minutes, during which they are guided to explore three features of discovery moods which are, 1: "The Akropolis of Athens"; 2: "The Agora of Athens" parts under "Famous Cities" and 3: "The Urban Household" under "Daily Life" part.

Participants in the control group (n=10) learn through traditional methods by reading a transcripted text from the game about three features of discovery moods mentioned above. The text is designed to cover the same architectural content as the game, ensuring comparable exposure to the material across both groups.

After the intervention, a post-test survey was conducted to measure participants' knowledge of architectural features and spatial understanding. The survey consisted of multiple-choice questions divided into two sections. The first section comprised 9 questions focused on theoretical knowledge, assessing participants' understanding of key architectural concepts. The second section included 20 questions designed to evaluate spatial understanding and the ability to comprehend architectural spaces. These questions aimed to evaluate participants' ability to recall and recognize key architectural concepts presented during the learning process, providing a clear and objective measure of their understanding. Quantitative data from the post-test are analyzed to test knowledge gains between the two learning methods.

This methodology allows for a focused comparison of game-based and traditional learning methods in teaching architectural features to individuals without specialized training in the field. By integrating quantitative data, the study provides valuable insights into how immersive environments and traditional approaches impact the retention of architectural details, spatial understanding, and engagement.

3. Study Design and Implementation

3.1 Participants

The study involved a total of 20 participants aged between 18 and 35, all of whom were selected from diverse professional backgrounds and undergraduate degrees to ensure a heterogeneous sample for evaluating the effectiveness of the learning methods. This approach was adopted to eliminate potential biases stemming from pre-existing familiarity with architectural concepts. Participants were divided into two groups: an experimental group (n=10) and a control group (n=10). Gender distribution was balanced to avoid gender-related biases in learning preferences or outcomes. All participants were graduate students from non-design-related disciplines, ensuring that their exposure to architectural concepts was limited to the interventions provided during the study.

3.2 Test Design

The test design was structured to compare the learning outcomes of game-based and traditional text-based methods in teaching architectural features. The experimental group played the Discovery Mode of Assassin's Creed Odyssey. They group explored three distinct features designed to provide an immersive understanding of Ancient Greek architecture and daily life.

A common critique of game-based learning studies is the suggestion that similar educational outcomes could be achieved simply by presenting the same content through video, without the need for interactive gameplay. However, this perspective overlooks the fundamental differences between passive observation and active engagement. In the context of this study, the Discovery Mode of Assassin's Creed offers a level of interactivity that cannot be replicated by video alone. Participants are not merely passive recipients of information; instead, they actively navigate the virtual environment, make decisions about where to go, and engage directly with architectural spaces.

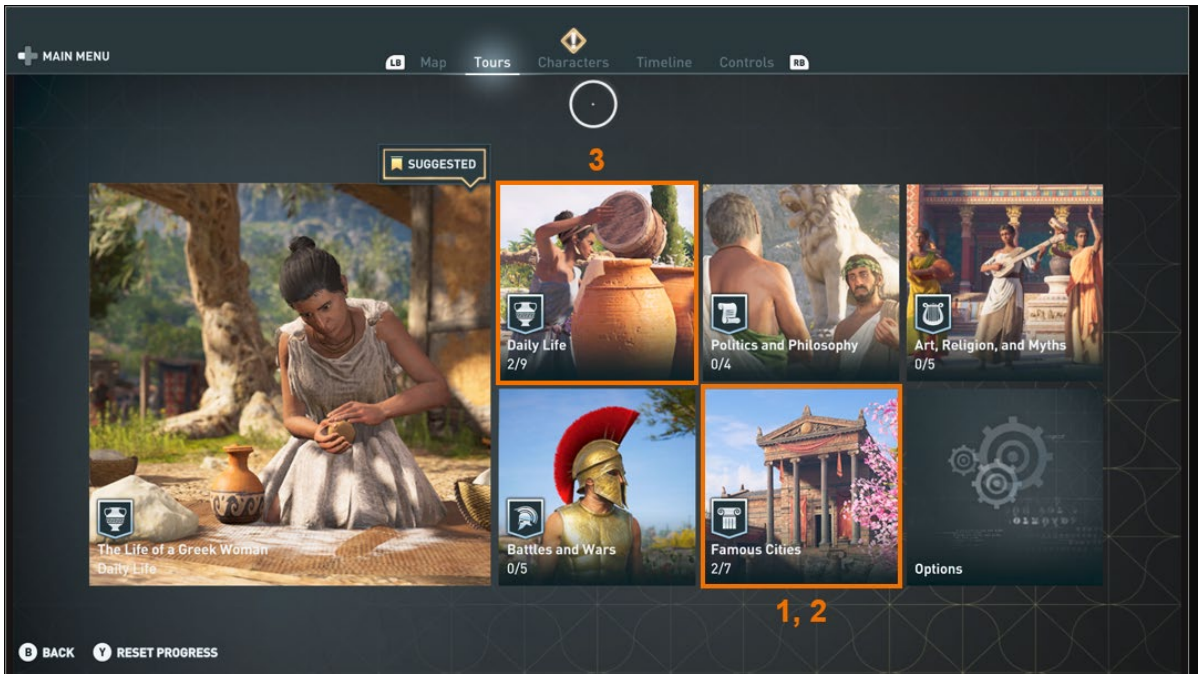

Figure 1: Main screen, displaying all the features that can be discovered within the discovery mode

The first feature, "The Akropolis of Athens," which can be found under the Famous Cities, focused on the Parthenon, a monumental symbol of Ancient Greek civilization. Participants examined its intricately carved exterior, depicting mythological scenes such as the birth of Athena and the Panathenaic procession, as well as its interior, which housed a statue of Athena, emphasizing the artistic and cultural significance of Athens.

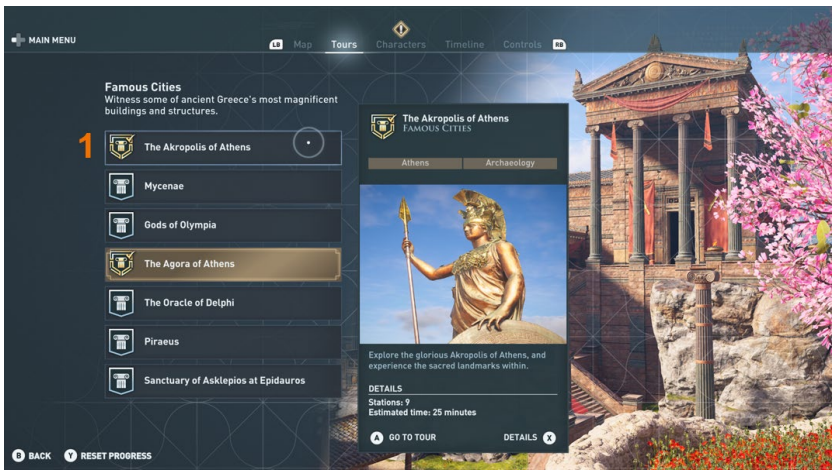

Figure 2: "The Akropolis of Athens" section under the main title "Famous Cities"

In the virtual environment of the Acropolis, participants are initially presented with a wide-angle overview that highlights the areas to be explored. Specific locations within the Acropolis are marked with a yellow tube, indicating the points where participants are required to pause. At these highlighted spots, users stop and engage in an exploration of space, allowing for a focused examination of architectural and historical features.

Figure 2: Wide angle view of the Akropolis of Athens

Figure 3: One of the spot that needs to be stopped

After pausing at these designated points, participants continue their journey through the environment, interacting with the surroundings and various features. For example, they can enter the Parthenon, where they are able to perceive the scale of the structure and directly experience its architectural elements. This process of moving through the space, stopping at key locations, and interacting with the environment provides a dynamic and immersive learning experience that enables participants to develop a deeper understanding of both the spatial organization and the distinctive features of the Acropolis.

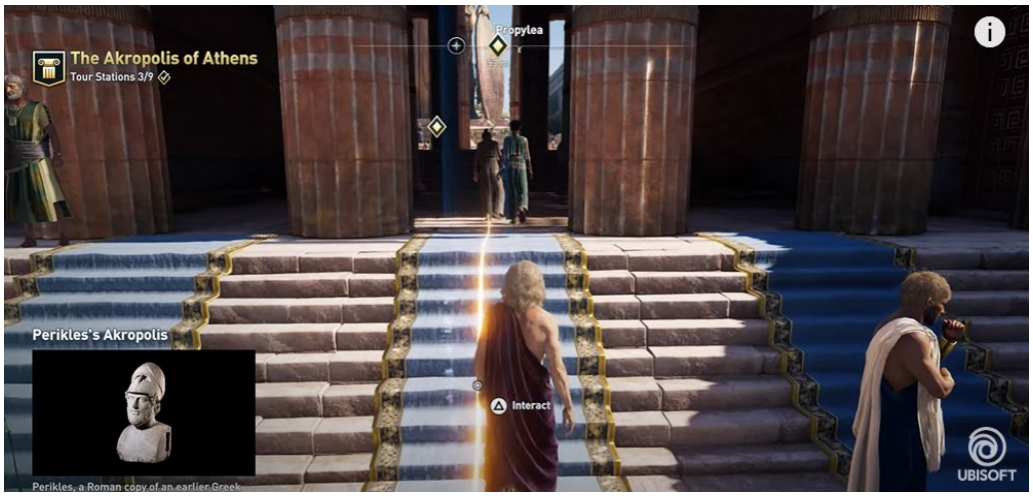

Figure 4: Entrance to the Akropolis of Athens

The second feature, “The Agora of Athens,” under Famous Cities, introduced participants to the civic and social hub of the city, where citizens, merchants, and philosophers gathered. Key elements included the Painted Stoa, renowned for its military-themed artwork and philosophical importance, the Hephaisteion temple dedicated to Hephaistos and Athena, and the Bouleuterion, the meeting place of the Athenian council, showcasing the democratic and cultural life of the city.

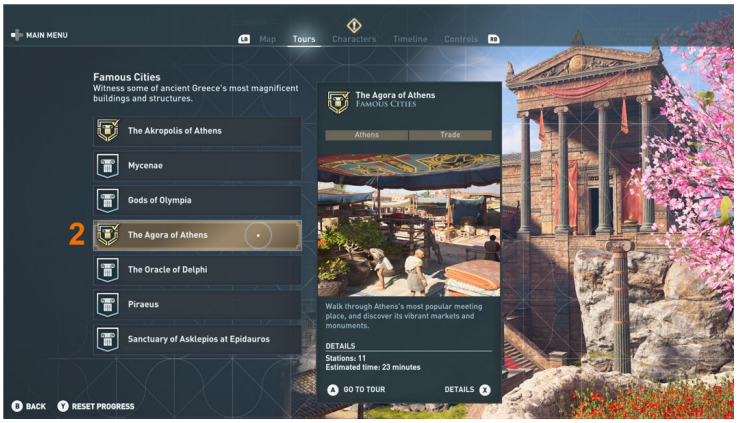

Figure 5: “The Agora of Athens” sections under the main title “Famous Cities”

For example, when exploring the Painted Stoa, participants can approach the murals, observe details from different angles, and interact with the environment in ways that foster a deeper spatial and experiential understanding. This kind of embodied interaction allows users to construct knowledge through direct experience, aligning with experiential learning theories that emphasize the importance of active participation in the learning process.

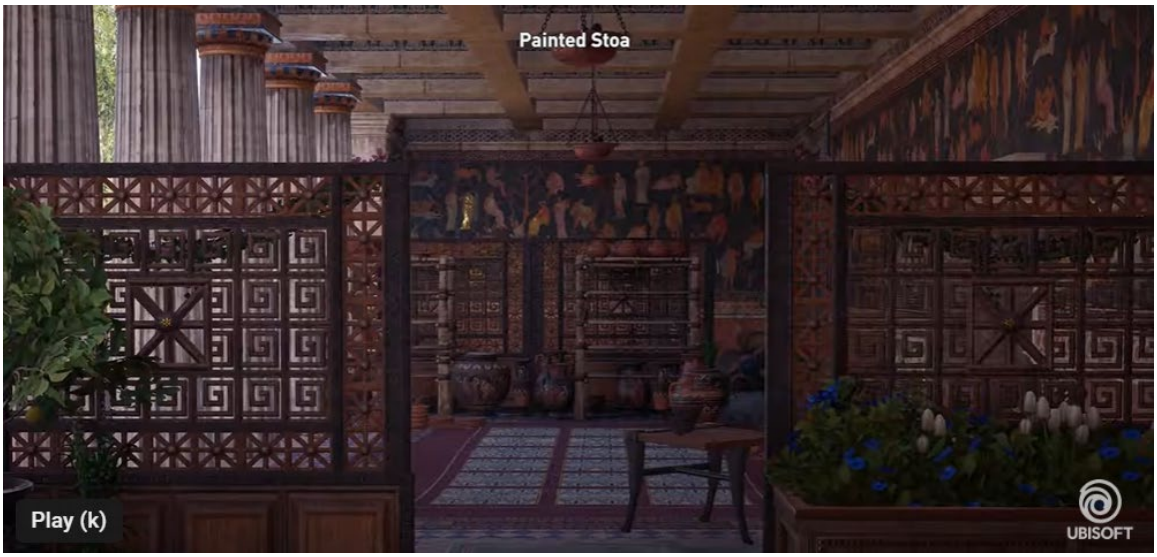

Figure 6: Painted Stoa under the Agora of Athens

Within the Agora of Athens, participants are able to move freely through the marketplace, as shown in the image. They can navigate among the stalls, observe the activities of various vendors, and experience the spatial organization and social dynamics of the agora in real time. This real-time exploration allows learners to choose their own paths, pause to examine specific details, and immerse themselves in the everyday life of the ancient city. The presence of animated vendors and market-goers, as depicted visually, provides a dynamic and authentic atmosphere that cannot be conveyed through static video footage. The learner’s ability to control their movement and perspective within the space fosters a sense of presence and engagement that is fundamentally different from watching a pre-recorded sequence.

Additionally, the experience within the Bouleuterion, as illustrated in the second image, further demonstrates the depth of interaction possible in the game environment. Participants can enter the Bouleuterion and attend events that are taking place inside. They have the opportunity to engage in conversations with non-player characters, listen to the discussions and debates occurring among the citizens, and observe the rituals and

procedures of civic life. This interactive participation allows learners to not only witness but also take part in the social and political processes of ancient Athens. The ability to listen to conversations and interact with historical figures provides a level of immersion and contextual understanding that is unattainable through video alone. The images reinforce these points by visually representing the learner's perspective within these spaces. In the agora, the participant's viewpoint is situated among the market stalls, surrounded by vendors and goods, highlighting the immediacy and authenticity of the experience. In the Bouleuterion, the participant is positioned within the assembly, able to observe and listen to the proceedings, further emphasizing the participatory nature of the environment.

Figure 7: Market under the Agora of Athens

Figure 8: Bouleuterion and judicial court under the Agora of Athens

The third feature, "The Urban Household," provided insights into the design and function of Greek homes, or oikos, which revolved around a central courtyard. Participants explored spaces such as the andron (men's quarters for symposia), the gynaikonitis (women's quarters), and functional areas like the kitchen and bathroom, reflecting the social structure, gender roles, and practical aspects of domestic life in Ancient Greece.

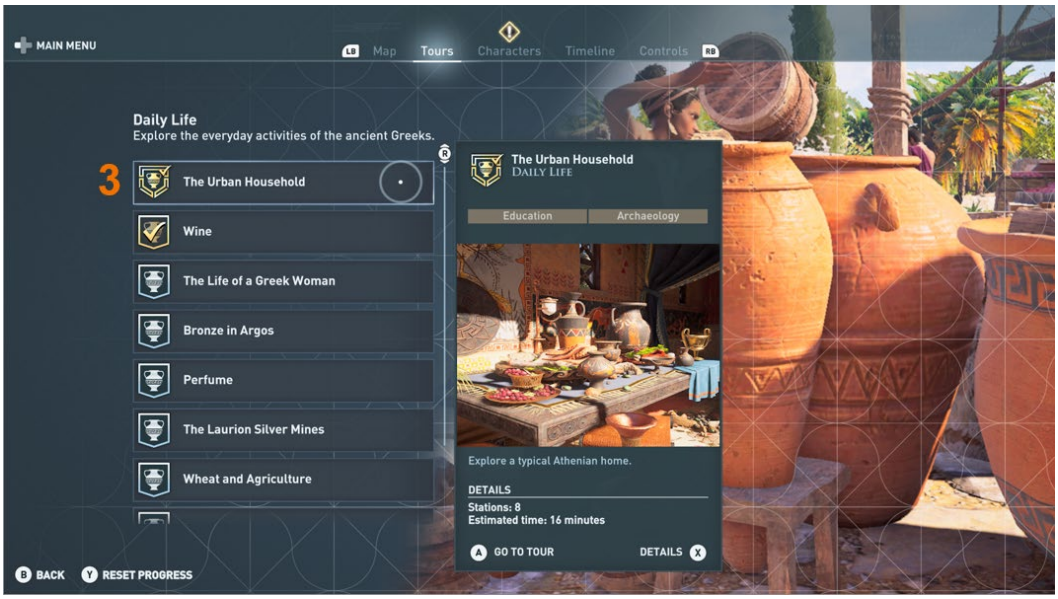

Figure 9: "The Urban Household" section under the main title "Daily Life"

Within the inner courtyard, participants can freely navigate the space, experiencing its layout and atmosphere firsthand. The environment is not static; learners can approach and interact with specific features, such as the sacred pool dedicated to Zeus located at the center of the courtyard. This interaction is not merely visual—participants can pause, examine the pool's details, and receive contextual information about its religious significance, deepening their understanding of ancient Greek spiritual practices.

Figure 10: Inner courtyard under the urban household section

In the kitchen area, the experience extends beyond architectural observation to include cultural immersion. Participants can witness the preparation of food, observing the tools, ingredients, and methods used in ancient Greek cuisine. This direct exposure allows learners to gain insights into the Greek diet, culinary traditions, and daily life, which would be difficult to convey through video alone. The ability to move around the kitchen, observe the cooking process from different angles, and receive explanations about the food being prepared creates a multisensory learning experience.

Figure 11: Kitchen under the urban household section

The women's quarters, or gynaikonitis, offer another layer of interactive learning. Here, participants can observe women gathered together, engaged in conversation. The environment allows learners to not only witness these social interactions but also to join the group, listen to their discussions, and even participate in the conversation. This level of engagement provides a unique perspective on gender roles, social customs, and the private lives of women in ancient Greek society. The opportunity to interact with non-player characters in this context fosters empathy and a deeper, more nuanced understanding of historical social dynamics.

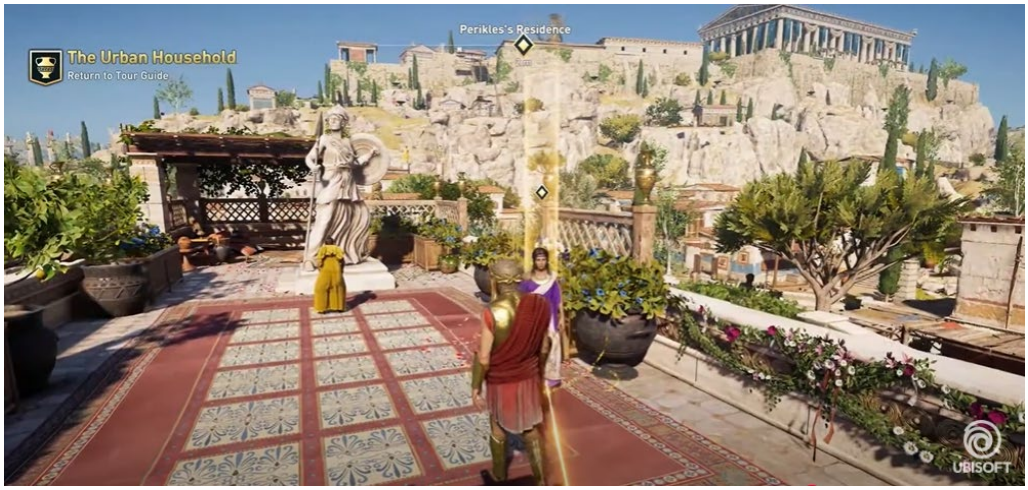

Figure 12: Upper terrace, gynaikonitis under the urban household section

The control group, in contrast, engaged with the same content presented in the game, but in the form of a transcribed text. This text was organized according to the sequence of gameplay and provided an exact, verbatim transcript of the information delivered by the in-game guide, ensuring that the control group received identical content to that experienced by the experimental group, but presented in a non-interactive, text-based format.

TEXT BASED INFO

1. Parthenon

Parthenon Exterior

The Parthenon is one of the most well-known buildings in the world and an enduring symbol of Ancient Greek civilization. While located on the Akropolis, the building is not a traditional temple. It was built by the sculptor Phidias and the architects Kallikrates and Iktinos as a great monument to the glory of the city of Athens. This glory is evident in its many carvings.

As one of the most intricately carved monuments in Greek architecture, the Parthenon's decorations depict several mythological scenes. These include the birth of Athena, her fight against Poseidon for the patronage of Athens, the gods' battle with the giants, and the procession of the Great Panathenaia.

Parthenon Interior

The Parthenon's inner chamber, or cella, contained a massive statue of Athena, considered one of the sculptor Phidias's greatest masterpieces. The statue was chryselephantine, a combination of gold and ivory. To justify the steep cost of its construction, Perikles told Athenians that the statue was a gold reserve that could be disassembled in times of economic distress.

The cella also allegedly contained a pool whose main purpose was to control the room's humidity, preserving the statue's ivory. Unfortunately, the statue was either destroyed by a fire or brought to Constantinople in late Roman times, where all trace of it was lost. However, descriptions from historians like Plutarch and Pausanias, as well as smaller copies like the marble Varvakeion statuette, allow for detailed reconstructions.

The goddess Athena was depicted armed with a triple-crested helmet featuring a sphinx and two griffins, a large circular shield in her left hand, and a spear. She held a winged Nike two meters tall in her right hand, while a huge sacred snake coiled between her left foot and the shield. She wore a typical peplos robe tucked into a belt, and on her chest was a snake-ridged aegis displaying the head of Medusa. Today, a modern replica of the statue stands in a copy of the Parthenon in Nashville, Tennessee.

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2. Agora

Overview

The agora was the civic center of Athens, frequented not only by politicians and city officials but also by merchants, philosophers, and citizens. It housed a market where people could purchase food and goods, and it served as a space for philosophers to establish schools and teach students. Temples dedicated to Hephaistos and Apollo were also located in the agora, along with the Altar of the Twelve Gods.

Painted Stoa

The Painted Stoa, or *Stoa Poikilè*, derived its name from the panel paintings on its walls. These paintings, created in the 5th century BCE by artists like Polygnotos, depicted Greek military victories such as the Battle of Marathon. The Stoa served as a public meeting place and was especially popular with philosophers, including Zeno of Kition, who founded the Stoic school of philosophy there.

The Hephaisteion

The Temple of Hephaistos, located on the Kolonos Agoraios hill, is one of the best-preserved temples in Greece

Figure 13: Text based info that applied to control group

3.3 Survey Design

The survey questions were structured in two distinct parts to comprehensively assess participants' knowledge and understanding of the architectural, cultural, and spatial aspects of Ancient Greek spaces explored during the intervention. Part 1 consisted of theoretical questions, while Part 2 focused on spatial comprehension. The survey, administered via Google Forms , included only multiple-choice questions and covered three main areas: the Akropolis of Athens, the Agora of Athens, and the Urban Household. To ensure consistency, the same survey was used for both groups, with separate links for the text-based and game-based learners to facilitate data collection specific to each learning method.

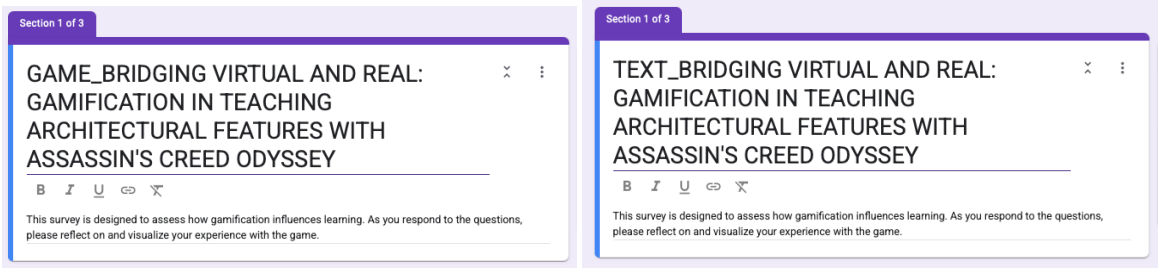

Figure 14: Game and Text based survey titles applied two different groups

In section 1, the theoretical section, questions assessed participants' recall of factual and conceptual information. For example, participants were asked about the architectural features and mythological carvings of the Parthenon, the materials and purpose of the statue of Athena, and the symbolic significance of various structures. Additional questions in this section addressed the civic, commercial, and social functions of the Agora, as well as the roles of specific buildings such as the Painted Stoa, Bouleuterion, and Heliaia. For the Urban Household, theoretical questions covered the design and layout of Greek homes, including the functions of the andron (men's quarters), gynaikonitis (women's quarters), and the significance of household spaces like the kitchen and bathroom. Cultural practices, such as the symposium and aspects of the Greek diet, were also included.

Section 2 focused on spatial comprehension and the participants' ability to understand and interpret the organization and use of space within these ancient environments. Questions in this section required participants to identify the locations of specific features within the Akropolis, Agora, and Urban Household, interpret spatial relationships, and recognize the functions of different areas based on their layout. For example, participants were asked to determine where certain activities took place, how spaces were accessed or connected, and to visualize the arrangement of architectural elements within the sites.

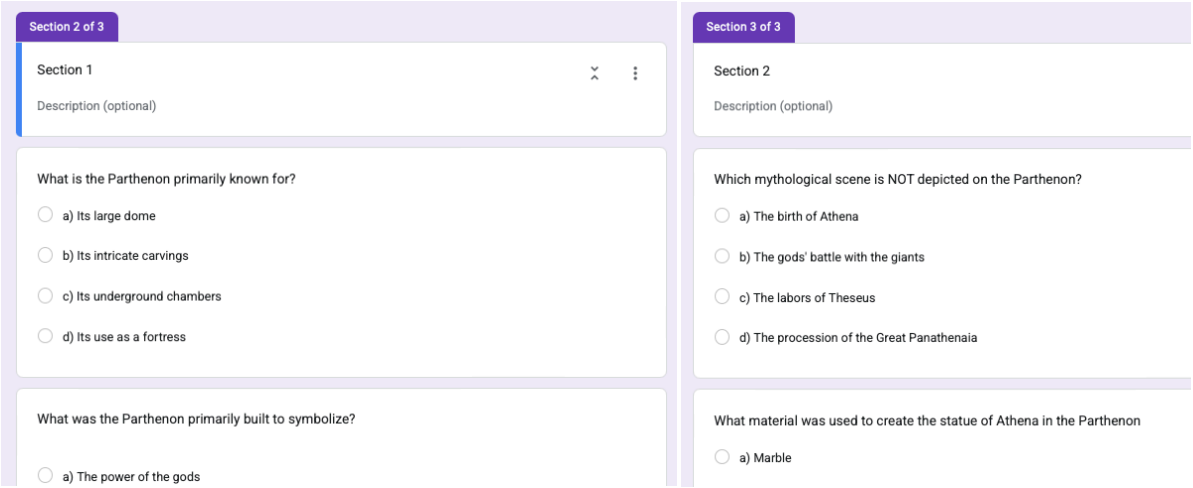

Figure 15: Insights from game and text based survey

By dividing the survey into theoretical and spatial parts, the study ensured a balanced evaluation of both factual knowledge and spatial understanding.

4. Results and analysis: Comparing Game-Based and Text-Based Learning

The results of the post-test survey, as visualized in the graphics, compare the performance of the game-based and text-based groups across two sections: Part 1 (theoretical questions) and Part 2 (visual and spatial comprehension questions).

In the game-based group, responses were notably more balanced, with most participants providing correct answers across both sections. In the visual and spatial questions (Part 2), the group achieved high overall success, with accuracy rates consistently in the 80–100% range. This indicates a strong and homogeneous understanding of spatial relationships and visual features, likely supported by the interactive and immersive nature of the game environment. In the theoretical section (Part 1), the game-based group also performed better than expected, with correct response rates generally between 60% and 90%. This suggests that the contextual and visual cues provided by the game not only supported spatial learning but also facilitated the retention of theoretical knowledge.

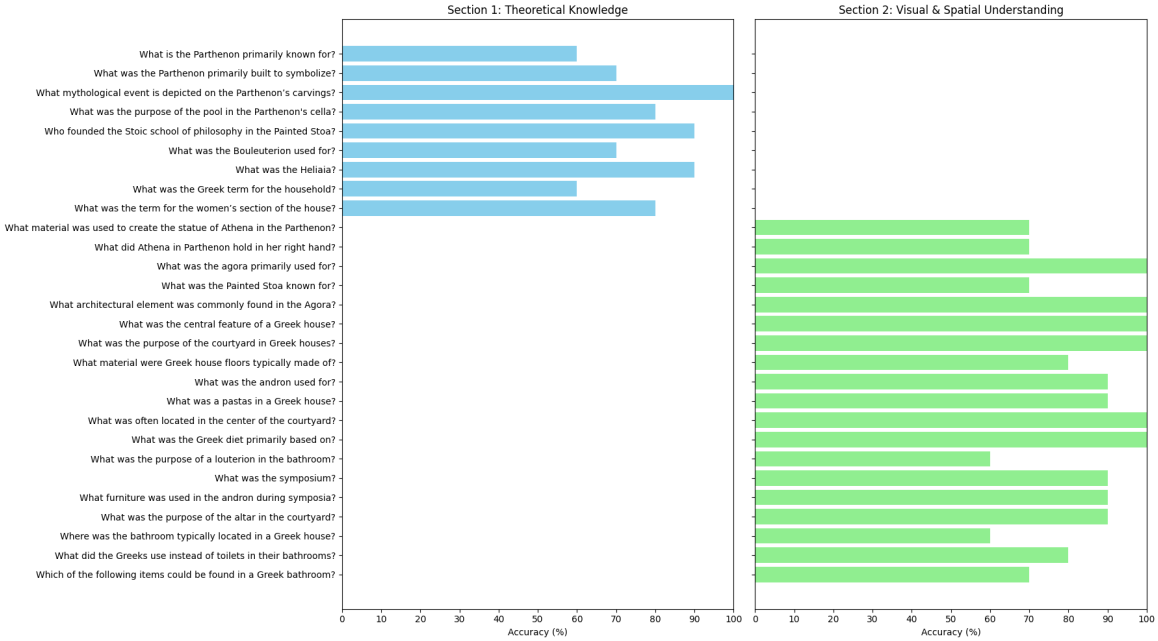

Figure 16: Gamebased, Section 1 and 2 Results - Theoretical Knowledge/Visual & Spatial Understanding

The text-based group's responses varied significantly, likely reflecting differences in individual focus and attention during reading. In the theoretical questions (Part 1), this group achieved higher success rates, with most scores falling in the 70–90% range. However, in the visual and spatial questions (Part 2), their performance was much more variable, with accuracy rates ranging widely from 40% to 100%. This variability suggests that, while some participants were able to use imagination or prior knowledge to answer spatial questions correctly, others struggled without the benefit of interactive or visual exploration.

An unexpected finding was that game-based participants performed well in theoretical questions, indicating that the game's context and visual cues may have reinforced theoretical learning. Conversely, some text-based participants achieved high scores in spatial questions, possibly by effectively visualizing and imagining the spatial concepts described in the text.

It is also likely that the interactive and enjoyable nature of the game-based learning environment contributed to higher engagement among participants, which may have supported more consistent and effective learning outcomes, particularly in the spatial section.

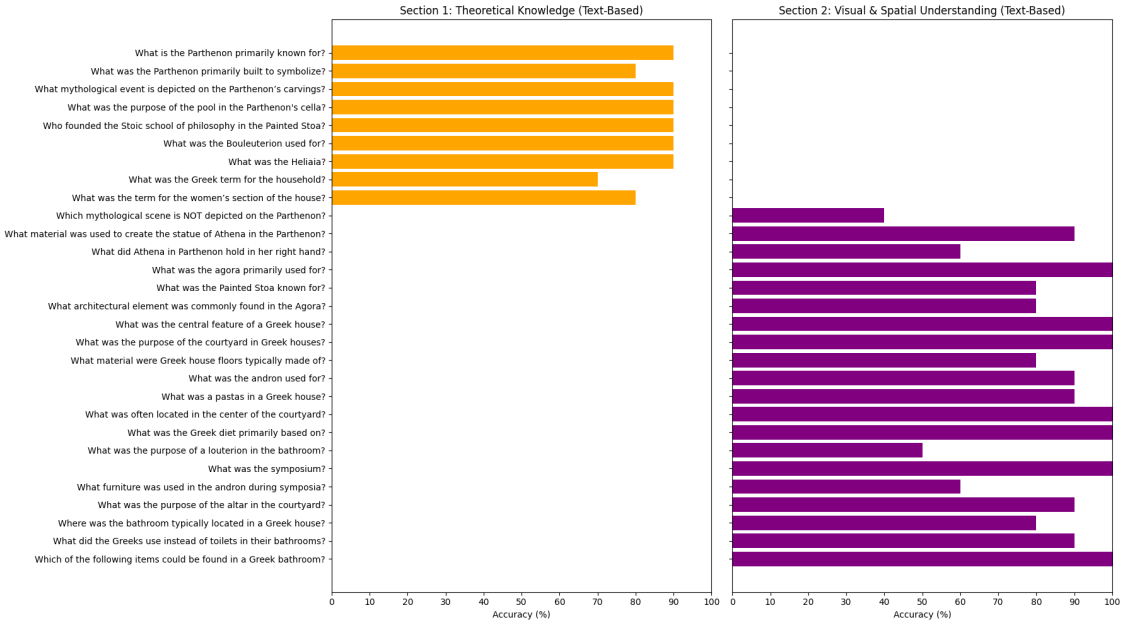

Figure 17: Text based, Part 1 and 2 Results - Theoretical Knowledge/Visual & Spatial Understanding

5. Discussion and Conclusion

The findings of this study provide important insights into the comparative effectiveness of game-based and text-based instructional methods in architectural education. The results demonstrate that while both approaches can facilitate the acquisition of theoretical knowledge, the game-based method offers distinct advantages in fostering spatial understanding and ensuring a more homogeneous distribution of learning outcomes among participants.

One of the most significant observations is the consistency and high performance of the game-based group in the visual and spatial comprehension section. The interactive and immersive nature of Assassin's Creed Odyssey's Discovery Mode enabled participants to actively engage with architectural environments, navigate spaces, and interact with features in real time. This hands-on experience appears to have supported the development of robust spatial cognition, as evidenced by the group's accuracy rates consistently falling within the 80–100% range and the notably balanced distribution of correct responses. The opportunity to pause, explore, and directly experience architectural elements likely contributed to a deeper and more uniform understanding of spatial relationships and visual details.

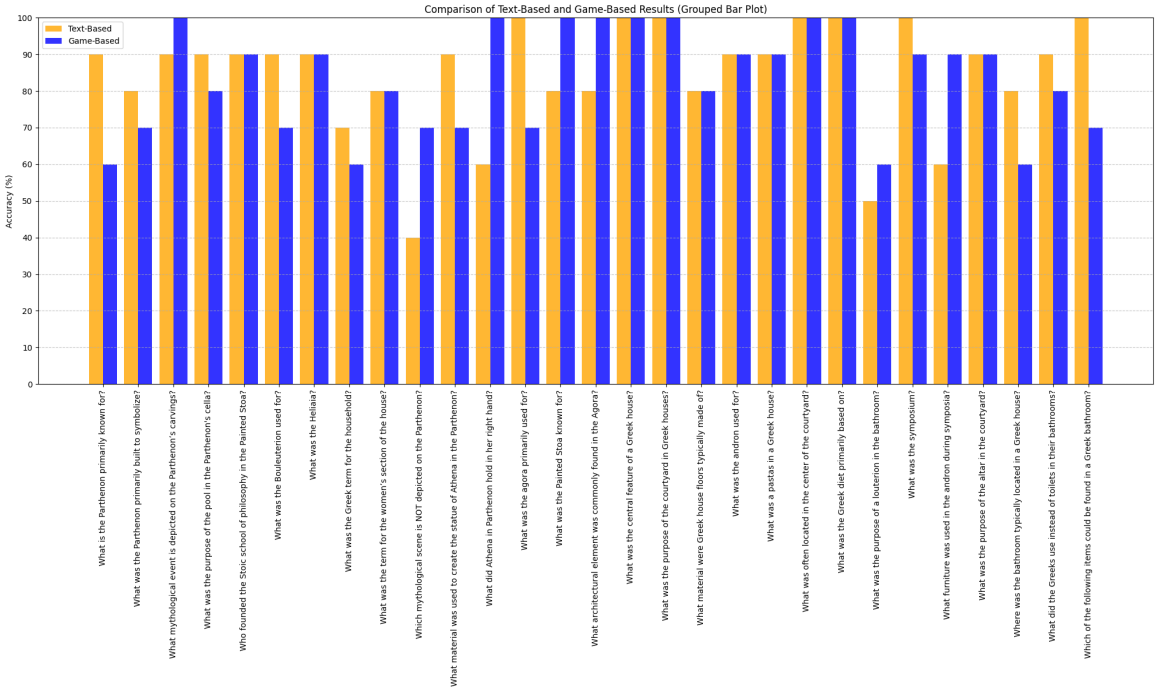

Figure 18: Bar chart comparing the responses of text-based and game-based groups

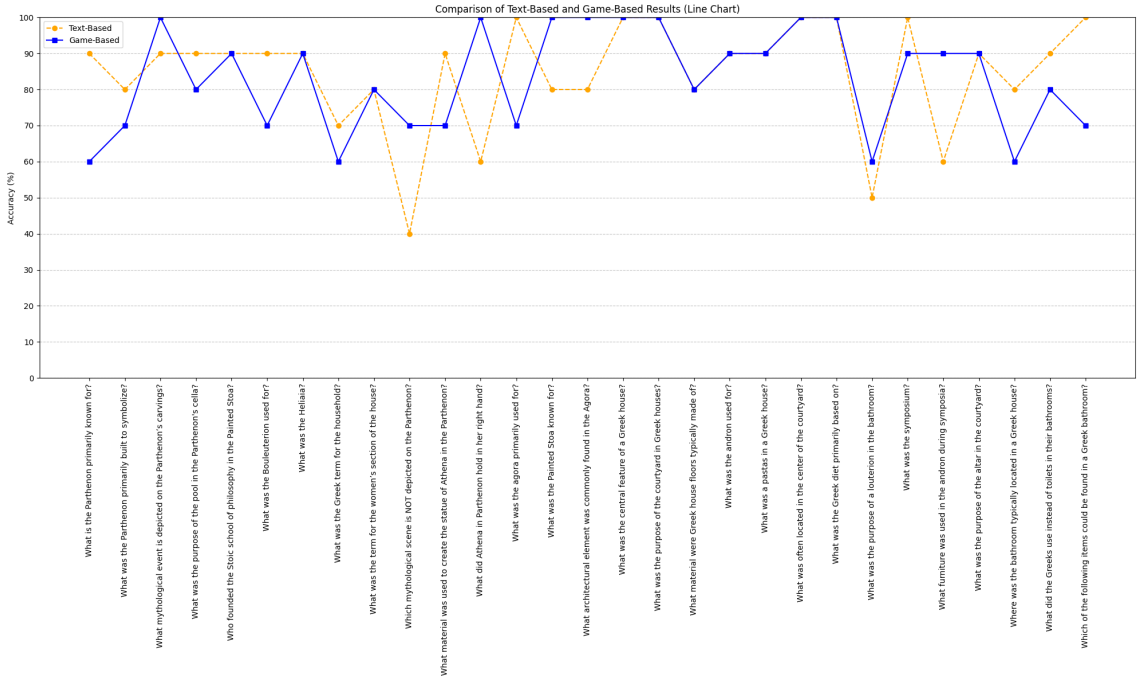

Figure 19: Line chart comparing the responses of text-based and game-based groups

The images further illustrate these experiences by placing the learner within the spaces themselves—standing beside the sacred pool, observing the kitchen activities, or sitting among the women in the gynaikonitis. Each of these scenarios demonstrates the game's capacity to offer agency, choice, and immersion, enabling participants to construct knowledge through direct, embodied experience. Through these interactive encounters—navigating the inner courtyard, engaging with sacred and domestic spaces, and participating in social life—the game facilitates a form of learning that is active, contextual, and deeply immersive. This approach aligns with experiential learning theory and underscores the unique educational value of game-based environments in teaching complex architectural, cultural, and social concepts. Unlike video-based or text-based instruction, which confines the learner to a predetermined viewpoint and sequence, the interactive environment empowers users to explore, inquire, and engage with the content in a manner that is both

personal and meaningful. The ability to interact, such as entering a space and conversing with characters, helps participants remember activities more vividly, as the act of participation reinforces memory retention.

In contrast, the text-based group, while achieving relatively high scores in theoretical questions (70–90% range), exhibited greater variability in the spatial section, with accuracy rates ranging from 40% to 100%. This suggests that passive engagement with transcribed content, even when it is comprehensive and well-structured, may not be sufficient to support all learners equally in developing spatial understanding. The variability in performance may be attributed to differences in individual imagination, prior knowledge, or attention during reading, highlighting the limitations of traditional text-based instruction for spatially complex subject matter. Watching a video or reading a text is a passive activity where the learner has no control over the pace, perspective, or sequence of exploration. The lack of agency and interaction limits the depth of engagement and the potential for meaningful learning. An unexpected but noteworthy finding is the strong performance of the game-based group in theoretical questions (60–90% range). This suggests that the contextual and visual cues embedded in the game environment not only enhance spatial learning but also reinforce the retention of factual and conceptual information. Conversely, the occasional high performance of text-based participants in spatial questions indicates that some individuals are capable of constructing mental models from text alone, though this is less consistent across the group.

The study also underscores the role of engagement in learning outcomes. The interactive, enjoyable, and exploratory qualities of the game-based environment likely contributed to sustained attention and motivation, which are critical factors in effective learning. This is particularly relevant in architectural education, where the ability to visualize and mentally manipulate spaces is essential.

In conclusion, the research highlights the potential of gamification and immersive virtual environments as powerful tools in architectural education. Game-based learning not only supports the acquisition of theoretical knowledge but, more importantly, provides a significant advantage in developing spatial understanding—a core competency in the field. While text-based methods remain valuable for conveying factual information, their limitations in supporting spatial cognition suggest that they are best used in conjunction with more interactive approaches. These findings have important implications for educators and curriculum designers, advocating for the integration of game-based and experiential learning strategies to enhance educational outcomes in architecture and related disciplines.

Future research could further explore the long-term retention of knowledge gained through game-based learning, the impact of different types of interactivity, and the applicability of these findings to other domains requiring spatial skills. Overall, this study contributes to the growing body of literature on gamification in education and demonstrates the unique value of virtual environments in bridging the gap between theoretical knowledge and real-world experience.

Ethics Declaration: This study did not require ethical clearance as it did not involve sensitive personal data, vulnerable populations, or interventions that could pose risks to participants. All participants voluntarily consented to take part in the research, and their responses were anonymized to ensure privacy and confidentiality.

AI Declaration: AI tools were utilized in the creation of this paper to assist with specific tasks, including language refinement, data visualization, and the generation of explanatory content for charts and results. However, all research design, data collection, analysis, and interpretation were conducted by the authors. The AI tools were used solely to enhance the clarity and presentation of the findings, and the intellectual contributions remain the sole responsibility of the authors.

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Mastery Learning as Gamification: Level-Up Through High-Transparency Assessments

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Abstract: Self-paced mastery learning aims to give the students more autonomy over their own learning process. Typically, such course designs have many lesser tests during the semester rather than one big exam. This pattern of repeated passing of obstacles and gradual level-up resembles a gamified approach to learning. An interesting question is to what extent a self-paced mastery learning course can be considered gamified even in cases where it does not aim to be entertaining. This paper makes a case study of an introductory programming course for first-year STEM teacher students at NTNU, Norway. The course is analyzed through the lens of gamification, using the Learning Mechanics – Game Mechanics (LM-GM) model. Relating this to student satisfaction and performance data indicates that there are many gamification-related aspects of such a course, contributing positively to student engagement. This paper provides a better understanding of how self-paced mastery learning can be considered a gamified course design and a promising approach for those looking to incorporate more explicit game elements into a course. Additionally, it shows how self-paced mastery learning could be an interesting pedagogical strategy for gamifying traditional higher education settings, especially focusing on affordances related to achievement / progression as well as social affordances.

Keywords: Mastery learning, Gamification, Learning mechanics, Game mechanics, LM-GM framework

1. Introduction

Mastery learning was proposed in the 1960s by Bloom (1971) and Keller and Sherman (1974), the latter approach called *Personalized System of Instruction* (PSI) with a focus on student self-pacing. Despite positive empirical evaluations of student outcomes (Kulik, Kulik et al. 1990), interest gradually declined (Buskist, Cush et al. 1991) but developments in e-learning technology inspire a revival (Eyre 2007), and interest in self-paced mastery learning is on the rise again (Mannion, Coyne et al. 2023, Pérez and Verdín 2023). Especially for introductory programming courses, there are several recent reports on course designs (Purao, Sein et al. 2017, Garner, Denny et al. 2019). The key idea of self-paced mastery learning is to divide a course into modules, each small enough not to become overwhelming. Students must master the first module before moving on to the second, and so forth, each going at their own pace. Mastery of a module is typically documented by tests with a high pass threshold like 90% (Keller and Sherman 1974). The students' progress through the course could resemble gameplay with levels. This comparison will be especially appropriate if the grade is determined by the number of modules passed.

At NTNU, an introductory Python programming course (CS1) using self-paced mastery learning was introduced for a class of approximately 50 first-semester STEM teacher students in the autumn of 2023, and then run again for a similar class in the autumn of 2024. The course design has several elements that align with game mechanics, such as levels and automated tests yielding quick feedback. Gamification – the addition of game elements into a non-gaming context (Deterding, Dixon et al. 2011) – has seen many uses in education. The course did not use visual gamification elements and was not "sold" as being gamified. Hence, we are not studying a course with mastery-learning plus gamification, rather investigating *mastery-learning as gamification,* and how this may have contributed to course outcomes. On an overarching level, gamification involves three primary elements situated within a certain context (Hamari, Koivisto et al. 2014): the *affordances* applied to a system or service leads to *psychological outcomes*, which subsequently lead to *behavioral outcomes – a sought effect in educational gamification might* for instance be that challenges, quests and team collaboration (affordances) might lead to increased engagement (psychological outcomes), which in turn leads to increased study effort (behavior). Our research questions are:

- RQ1: What gamification-related affordances can be found in the self-paced mastery learning course design?
- RQ2: How did the course affordances yield psychological and behavioral outcomes?
- RQ3: How can self-paced mastery learning contribute to gamified learning in higher education?

The rest of the paper is structured as follows: Section 2 presents related research and Section 3 our research method. Section 4 provides the design of the course through a lens of gamification. Section 5 analyzes the gamification-related affordances and outcomes, as evidenced through student opinion and performance. Finally, section 6 discusses the implications of the findings, providing advice on how self-paced mastery learning can be a basis for gamified course designs.

2. Related Work

There are few publications dealing with courses combining all three topics CS1, self-paced mastery learning, and gamification. One exception is (de Pontes, Guerrero et al. 2019), reporting experiences from a gamification experiment in CS1. The gamification was only used for the last four weeks, and students were randomly divided into two groups: treatment (gamified e-learning tool with badges, personal record-tracking, and leaderboards) and control (non-gamified tool). The treatment group solved more assignments than the control group, but it is unclear whether they achieved better learning. Their paper describes an experimental addition of gamification features on top of a course, while our paper analyzes a course through a lens of gamification, but without any experimental addition of gamification features.

Gamification in CS1 courses has been addressed by several researchers, showing mixed results. One review (Shahid, Wajid et al. 2019) looked at programming concepts covered by gamification approaches, another (Maryono, Budiyono et al. 2022) at what gamification elements have been used. Costa (2023) investigated the learning effect of gamification approaches in programming, finding a moderately positive learning effect from *levels*, while badges, points, avatars, and leaderboards showed no significant effect. This is particularly relevant to us since levelling is intrinsic in self-paced mastery learning. Rogers et al. (2021) discuss that some students may be motivated by gamification, others not. They found that most students either selected all game elements or none and refer to studies reporting that gamification works only in specific environments and only with certain users. Sprint and Fox (2020) found that gamification contributed to better study behavior, without significantly affecting grades. In another study, García-Iruela et al. (2022) found no significant effect on motivation from gamification.

In other disciplines than computing, several mastery learning courses have used gamification, such as (Mawson, Bodnar et al. 2020) presenting an online gamified homework portal in a first-year engineering design course, (Hou, Nagashima et al. 2022) presenting a gamified course design for high school science, and (Yang 2018) using mastery-learning with gamification in a course module about domestic and foreign food culture. A key difference with our paper is that the other papers discuss mastery learning *with gamification* as a potential add-on, while we discuss mastery learning *as gamification*. Considering the analysis of gamification approaches, there are several possible frameworks. The LM-GM (Learning Mechanics, Game Mechanics) framework (2013) is an analytical model that maps learning mechanics to game mechanics with the aim of defining serious game mechanics, and Arnab et al. (2015) argue that the LM-GM model can support serious game analysis, exemplified by an analysis of the game Re-Mission.

3. Research Method

Overall, the research method is that of a qualitative, exploratory case study (Merriam 1998) investigating to what extent the course design corresponds to gamification principles. The case study rests on two main pillars: an analytical evaluation of the course design through the lens of gamification, and investigation of empirical student data from the course.

There are many gamification frameworks that could be used for the analytical part. Mora et al. (2017) performed a systematic review of 40 design frameworks for gamification, though only a few were related to education. This paper uses the LM-GM (Learning Mechanics, Game Mechanics) framework introduced by Lim et al. (2013), which is especially suitable for educational contexts. The framework was used in an analytical way, the two authors considering which LM-GM-elements could fit which aspects of the course.

The students were all Norwegians aged 19-25, and the gender mix was about 50/50. Student satisfaction was evaluated by anonymous questionnaires (44/47 responses in 2023, 38/40 in 2024). Consent was obtained from students (27/47 in 2023, 39/40 in 2024) to use their performance data for research. All students in the course were invited to participate, only data from non-consenting students were excluded. The project was approved by SIKT, handling such applications in Norway. In this paper, only descriptive statistics are used for analyzing the results.

4. Course Design and Gamification Analysis

The course IT1001 is Python programming for beginners, given to first-year students in a degree program to become STEM teachers in secondary school. The course has 9 modules named I, H, …, A. For each module, students must pass a mastery test *and* deliver an increment of their individual programming project, as shown in Figure 1.

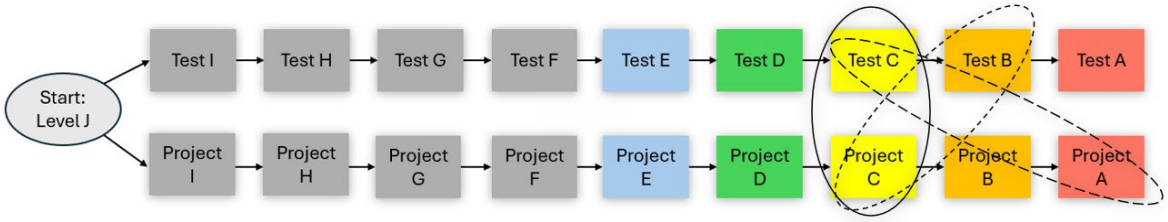


Figure 1: The mastery-path of the course, with tests and project increments per module. If ending on different levels for tests and project, the weakest grade would decide, i.e., all the three ovals on the right would give C

Graded tests were done under supervision each Friday, but each student could decide which Fridays to show. In preparation for graded tests, students watched videos explaining the relevant programming concepts and did formative practice tests. These pulled questions randomly from the same large question banks as the graded tests, thus giving students a clear idea whether their knowledge would be sufficient for passing the test. E.g., seeing a 72% score on a practice test while 90% would be needed to pass, the student could check the auto-feedback to find out where points were lost and revisit learning resources for concepts not sufficiently mastered before trying a new practice test. Random drawing would ensure they did not get the same questions repeatedly, both for practice tests and summative tests.

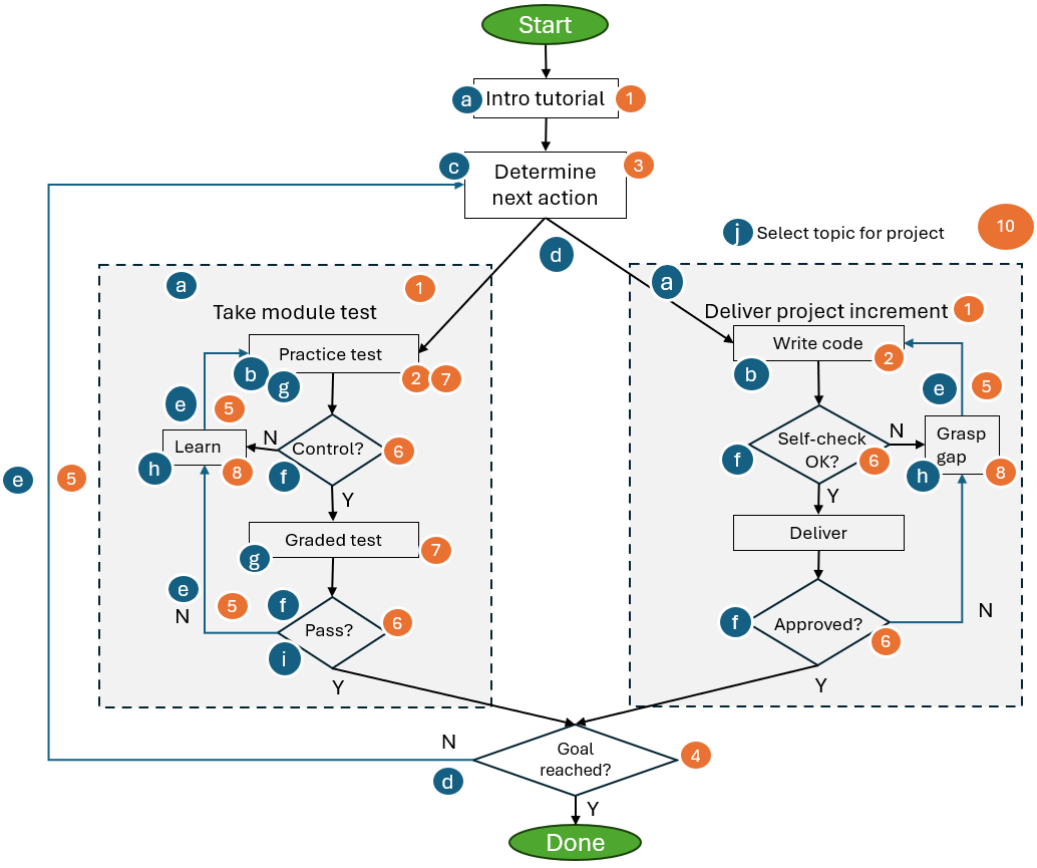
The result of the analysis using the LM-GM framework is shown in Table 1. The two leftmost columns indicate the link between game mechanics and learning mechanics, while the third explains how the mechanics were implemented in the course, and the fourth briefly indicates the purpose that the mechanic had in the course.

Table 1: Analysis of game and learning mechanics in the course, based on the LM-GM framework

Game mechanics	Learning mechanics	Implementation	Usage
Tutorial	Tutorial	1st seminar course intro, videos per module	Inform students about possible actions
Cooperation	Reflect / Discuss	Group work in seminars	Learn together, facilitate social belonging in class
Time pressure / Resource management	Plan, Responsibility	Self-pacing	Promote student agency
Levels	Guidance, Motivation	Sequence of modules	Guide students how to progress
Behavioral momentum	Repetition	Levels, auto-scored tests, unpenalized retakes	Motivation: visible progress
Assessment	Assessment	Grades derived directly from N modules taken	Give students a better sense of control
Questions and Answers	Questions and Answers	Test tasks	Divide curriculum in manageable parts
Feedback	Feedback	Auto-corrected tests, teacher review of project	Indicate mastery gaps, path for improvement
Tokens	Plan	3x “80% passes”	Smoother progress without grade inflation
Ownership	Ownership	Self-chosen project	Motivation: relate to student’s future job

Figure 2 shows how the various mechanics described in Table 1 are involved in the flow of the course, with letters a-j linking to learning mechanics and numbers 1-10 to game mechanics in the LM-GM framework.

- (1,a) The teacher explained the design of the course during the first half hour of the first seminar. Otherwise, nothing was lectured, concepts instead explained through videos and e-notebooks.
- (2,b) Cooperation was facilitated during the seminars, students grouped by level, either practicing for tests or working on their project.
- (3,c) The course lasted 14 weeks, during which 9 modules had to be passed for A, 5 for E. Students had 4 courses in parallel, so they needed to allocate their time across courses over the semester. Through self-pacing, students were encouraged to plan and take responsibility for their own learning.
- (4,d) By means of the sequence of modules I, H, …, A resembling levels in a game, students got implicit guidance on what to do next. Succeeding with one module gave motivation for the next level.
- (5,e) Repetition existed in several cycles: Nodes "Practice test" – "Control?" – "Learn" in Figure 3 show that students may take formative practice tests to improve. Outside of that, doing "Summative test" – "Pass?" – which will also give a repetition loop if failing. If passing, a new round of the outermost loop is enabled ("Goal reached?" – "Determine next action") allowing to proceed to the next level.
- (6,f) Assessment was present in each of these loops, for the inner loop self-assessment, for the graded loop teacher-assessment, and for the outer loop again self-assessment on a higher level (do I have capacity to aim for a higher grade?).
- (7,g) Q&A was present both in the test tasks, and in the self-assessment checklists that students filled in per delivery of project increments.
- (8,h) Tests provided automated feedback, while project deliveries got teacher email feedback.
- (9,i) Students had 3x "80% passes" which could be used to pass tests (threshold otherwise 90%). In 2023 this was introduced ad hoc, late in the semester, as many had gotten stuck with repeated failures of the F and E tests. In 2024, they were announced from the start, though only usable from the F-test onwards. These 80% passes are a way to achieve some smoothness in test passing, where the original PSI instead gave students opportunities to explain their knowledge orally in cases where they were just a few points short of the threshold (Keller and Sherman 1974).
- (10,j) The open project assignment let each student choose a topic related to their major subject. This created a sense of personal ownership for the project.



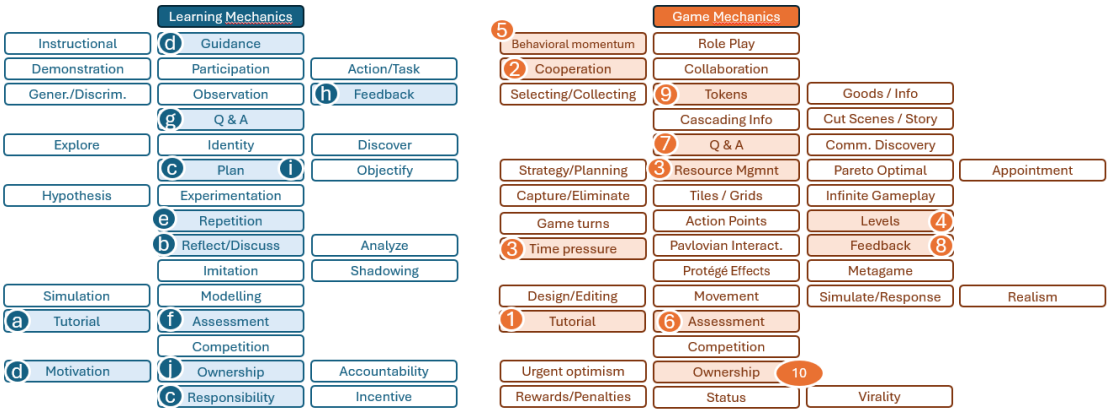


Figure 2: Illustrating how game and learning mechanics are realized in the course design. The upper part of the figure shows the flow of student activities throughout the course, where tests and projects are done in parallel, and each of these pursued module by module, with repetition loops within a module in case of failure

5. Affordances and Outcomes

The above identification of mechanics in the course design leads to an identification of affordances and outcomes as discussed by (Koivisto and Hamari 2019). They identify affordances in several groups, where the following appear most relevant in our case:

- Affordances related to achievement / progression:
- *Challenges, quests, missions, tasks, clear goals* – the modularized design made it clear for the students at any point what must be learnt next.
- *Levels, increasing difficulty* – module I was easy, thereafter gradually more challenging.
- *Performance feedback* – autoscored practice tests providing a possibility for 24/7 frequent feedback where the student could immediately compare score with threshold (e.g., got 72%, needing 90%) and be made aware which concepts needed to be learnt better.
- *Progress* – passing modules gives a clear sense of progress and the students know any time what grade they were currently at.
- Social affordances:
- *Cooperation, teams.* There were no fixed teams since the project was individual. However, in weekly seminar there were small groups of students (3-7) seated together because they were at the same level, thus with the same mission.
- *Customization, personalization*. Each student could pursue the course at their own pace and choose their favorite STEM topic for their project.

Psychological outcomes mentioned by (Koivisto and Hamari 2019) that are relevant for our analysis are:

- *Overall assessment / attitude:* Perceptions of, preferences for, and satisfaction with the course;
- *Affective outcomes*: Engagement;
- *Cognitive outcomes:*
- Perceived usefulness / effectiveness;
- Perception of learning;
- *Effort in use / Experienced challenge:*
- Effort, perceived difficulty, challenge;
- Perceived stress, cognitive load;

Evidence that the students were satisfied with the course and had positive perceptions of it can be found in the data from the questionnaire survey. Figure 3 shows results from two questions, about the overall satisfaction with the course (left), and satisfaction relative to other courses the students took in the same semester – the course coming out positively both years, and especially in 2024.

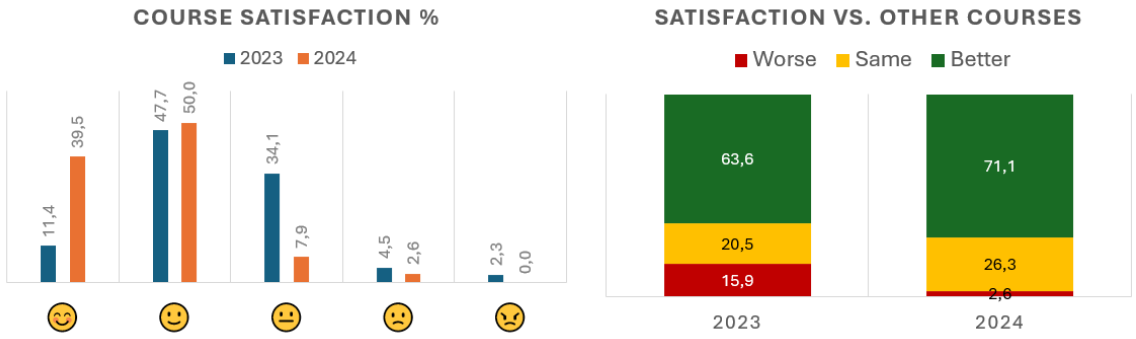


Figure 3: Course satisfaction from student survey. The left diagram summarizes responses to "Overall, how satisfied are you with this course?" with a 5-point Likert scale from "Very satisfied" (happiest emoji) to "Very dissatisfied" (angry emoji). The right diagram shows answers to "How satisfied are you with this course compared to other courses you took in the same semester?", on a 3-point scale Worse, Same, Better

The overall satisfaction as shown in Figure 3 does not, as such, imply that it was the mechanics and affordances identified above that caused this result. However, a more detailed look into other survey questions gives some indication. Figure 4 shows the answers for questions concerning experienced mastery, stress, and control. Survey questions were in full sentences in the students' native language, while shortened English labels have been used here. As can be seen, responses are dominantly positive for 2024 (with none "very dissatisfied"). Responses for 2023 lean positive for clear goals and mastery, though students felt more stressed and with less control of their grade. The ability to control one's own pace and grade (cf. Fig. 4) can be related to the personalization and customization as mentioned as social affordances above, and many students mentioned as positive in free-text responses in the questionnaire related to the seminar that they found it rewarding to collaborate with peers who were at a similar pace and level.

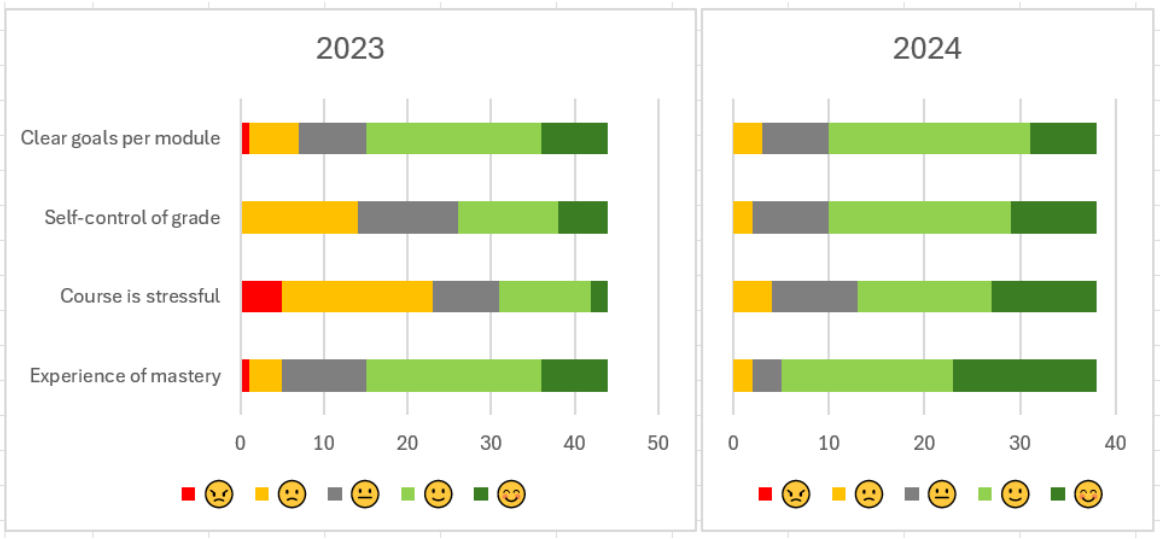


Figure 4: Students' experience of goal clarity, grade control, stress, and mastery, 2023 and 2024 on a 5-point Likert scale from Very Dissatisfied (angry emoji, red) to Very Satisfied (happiest emoji, dark green)

Some quotes from free-text responses in the questionnaire can also shed light on this:

> *I like that it has become gradually more difficult, yet clear what grade you are at. (2023)*
>
> *To avoid the end-of-course exam, rather working continually and always knowing your current grade – I love that! […] feel more in control. The mastery ladder «forces» me to work every week […] I learnt more from that than cramming for a final exam. (2023)*
>
> *I enjoy that we can progress our grade during the term, instead of having the entire curriculum in one big exam. (2024)*

> *I like the course because I can regulate my own progress, not moving on to new things before I master what I'm doing. Thus, the curriculum does not become overwhelming. (2024)*

Of course, there were also negative opinions expressed, particularly in 2023. However, the above quotes are representative in reflecting common themes among many respondents, especially that they liked the absence of an end-of-course exam to determine the grade, instead having the self-paced mastery learning with frequent testing and a laddered grading approach, which made them feel more in control of their progress.

Behavioral outcomes identified in (Koivisto and Hamari 2019) that also may be relevant to us, is behavior related to engagement: Participation in system; Participation in discussions; and Course material views / downloads. In addition, behavior related to performance is relevant to our study: Academic performance; Learning, progression; and Number of attempts.

Evidence of student behavior can be found in log data from tests of consenting students. Figure 5 shows that student participation in the summative Friday tests was highest in the early part of the semester, then gradually decreasing towards the end. Dark green shows number of 90% passes, light green is 80% passes and black are fails. The higher test participation early in the semester indicates that self-pacing did not lead to procrastination, rather many tried to achieve some progress up the mastery ladder early.

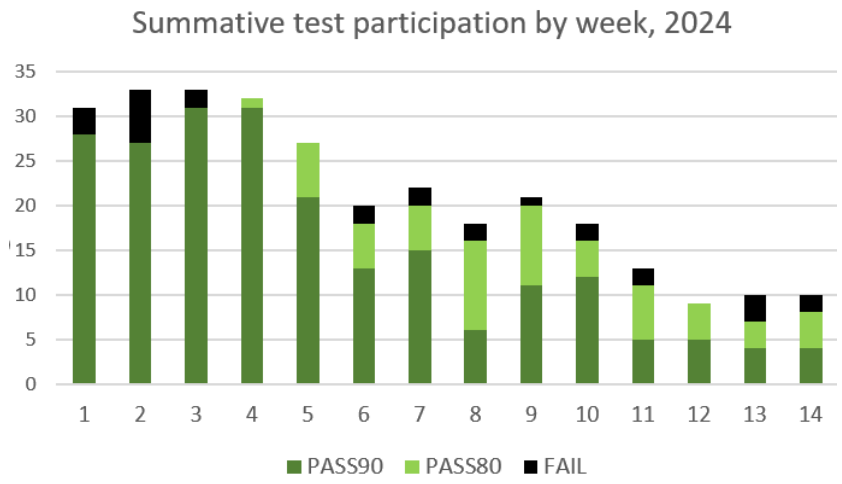


Figure 5: Students' participation in the summative Friday tests by week, 2024. Passes at the 90% threshold are dark green, 80% light green, and fails are shown as black

Another clear indication of student effort during the course is activity with the formative practice tests. Table 2 shows the number of attempts added up for students consenting to research usage of their performance data in 2024 (39/40). The bottom rows give the average number of training tests per student for that module, based on the number of students making it to or beyond that grade. The average number of training attempts is low for the I-test (below 5) but then increasing per level up to the E-test, which was the last test that was needed for the lowest passing grade. The standard deviation is quite high, as some students had previous programming knowledge and needed few practice tests, while others needed many more.

Table 2: Attempts on practice tests for consenting students, 2024

Module	I	H	G	F	E	D	C	B	A
Attempts	173	302	344	401	462	343	313	91	113
Students	39	39	39	39	39	30	23	10	7
Avg per stud.	4.4	7.7	8.8	10.3	11.8	11.1	11.6	7.0	14.1
Std. Dev.	4.3	3.9	5.0	6.5	9.5	5.5	7.6	5.8	18.2

6. Discussion

Below we reiterate our research questions, and their answers. For RQ1, we analyzed which gamification-related affordances could be found in the course design. Of performance-related affordances, the most notable seem to be levels with increasing difficulty and missions with clear goals – with quick feedback from automated tests.

Of social affordances, the most notable seem to have been the collaboration between students working on the same levels in seminars, and the personalization of being allowed to choose one's own pace and ambition level.

Related to RQ2, we studied how the course affordances yield psychological and behavioral outcomes. One evident psychological outcome was high student satisfaction with the course, related to usefulness of the module-based levels, with practice tests for gradual improvement. Students appreciated the increased sense of control and mastery, although the 2023 cohort also found the course stressful. An important behavioral outcome was high engagement with the course from the outset (cf. Figure 5 with more tests taken early in the semester). This is different from experiences in many other self-paced mastery learning courses, where procrastination among students has been a notable challenge (Ott et al., 2019).

For RQ3 we studied how self-paced mastery learning can contribute to gamified learning in higher education. This course was not "sold" as gamification, and did not use badges, trophies or similar – yet still achieved engagement and behavioural outcomes resembling those that gamification typically aims for. To some extent, the level structure of self-paced mastery learning can be considered gamification in itself – hence self-paced mastery learning and gamification could go very well together.

It is hard to know whether the course would have benefited from more explicit gamification such as badges and trophies. When the number of modules directly determines the grade, that might feel enough of a prize. Getting a badge in addition might feel as a superfluous add-on. Costa (2023) investigated the learning effects of various gamification approaches in programming and also found levels to have most effect. Our study focused on mastery learning as gamification and the students' responses from our courses were positive already in 2023 and more positive in 2024. The students particularly appreciated the absence of an end-of-course exam and favored the self-paced mastery learning with frequent testing and a laddered grading approach, which made them feel more in control of their progress.

7. Conclusion

We present a case study of CS1 for first-year STEM teacher students at NTNU, analyzed through the gamification lens using the Learning Mechanics – Game Mechanics (LM-GM) model and by examining student satisfaction and performance data. The paper gives an improved understanding of how self-paced mastery learning can be seen as a gamified course design, thus a possible basis for those who might want to add more explicit game features to a course, without necessarily using the traditional visual gamification elements like badges and trophies. Also, it indicates how self-paced mastery learning might be an interesting underlying pedagogical approach for gamification of traditional learning environments within higher education, especially regarding a ladder approach to grading.

8. Limitations

While some students are motivated by gamification, others are not (Rogers et al., 2021). García-Iruela et al. (2022) did not find that gamified elements had a significant effect on motivation. Further research should investigate effects on students' motivation in self-paced mastery learning courses to see if there are similar results as in more specifically gamified learning environments.

A limitation of this study is that neither the course nor the student satisfaction questionnaire was designed with gamification in mind, nor with the dedicated purpose to measure outcomes and affordances related to gamification so the analysis of the course and its affordances and outcomes is purely post hoc, and its interpretations must thus be taken with some caution. Interesting opportunities for further work would thus be to make more dedicated investigations with subsequent runs of the course, for instance investigating to what extent students experience the level-up feature and other aspects of the course as resembling gamification.

Another limitation is that the course had only 50 students each year, so scalability to bigger classes might be an issue. In 2023, the course had 7 teaching assistants à 100 hours, but in 2024 it had to do with just 2 TA's à 50 hours - yet student satisfaction increased. Also, it can be noted that a somewhat similar course design by (Toti, Chen et al. 2023) had about 300 students, so there is nothing inherent in mastery-learning that prevents scale.

Ethics declaration: Research was applied to SIKT, ref.no. 342944 Date of approval: 26 Jun 2024

AI declaration: No AI was used.

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Escape Room Challenges to Foster Engagement and Skills in Computer Science

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Abstract: This study presents the design, implementation, and evaluation of a gamified formative assessment in an undergraduate Computer Science course through a Harry Potter-themed escape room. Framed within the Mechanics-Dynamics-Aesthetics (MDA) framework, the activity integrated six sequential missions that blended technical skills with narrative immersion. These missions were strategically crafted to assess and promote communication, collaboration, computational thinking, and technical skills in areas such as web development, database management, and debugging in Unity. Each mission aligned with specific learning outcomes and was guided by a hypothesis exploring its impact on student engagement and skill development. A custom Unity interface delivered narrative cues, tracked progress, and supported real-time interaction. Mixed-method data from surveys revealed that students perceived the experience as engaging, motivating and skill-enhancing. Notably, the escape room succeeded in providing authentic opportunities for applied learning, particularly in communication and teamwork under time constraints. This paper contributes to the growing field of gamification by demonstrating how escape rooms can serve not only as motivational tools but also as practical, narrative-driven assessment methods. The integration of physical, digital, and collaborative components bridges the gap between theoretical knowledge and real-world application, offering compelling model for immersive learning and evaluation in computer science education.

Keywords: Escape rooms, Gamification, Computer science education, Educational innovation, Higher education, Immersive learning

1. Introduction

In recent years, the rapid advancement and widespread availability of artificial intelligence (AI) tools have significantly transformed the educational landscape. While these technologies offer powerful support for learning and creativity, they also introduce new challenges for educators: determining whether students are genuinely mastering foundational problem-solving skills has become increasingly difficult, particularly in fields like computer science. Traditional assessments, such as written exams, may offer partial insights into individual understanding but often fail to foster engagement or reflect real-world applicability. This raises a critical question: how can we design assessments that not only evaluate students' authentic capabilities but also encourage motivation, creativity, and critical thinking?

1.1 Gamification in Education

Gamification refers to the application of game-like elements in non-game contexts to enhance user engagement. (Deterding et al., 2011). This approach applies mechanics such as points, levels, and challenges to increase user engagement and motivation. Although it originated in marketing and UX, gamification is now widely adopted in diverse domains. Research suggests that gamified systems can significantly influence user behavior, by making tasks more immersive and engaging (Hamari, Koivisto and Sarsa, 2014).

Games are increasingly being used in education to enhance student interest, imagination, and academic performance. When integrated effectively, game-based elements can foster active learning, collaboration, and enjoyment (Domínguez et al., 2013). Gamified methods incorporate elements of competition, incentives, and storytelling from game design into the learning process, enhancing the learning experience (Karl, 2012). Subhash and Cudney (2018) emphasize that well-designed gamified environments can support learning outcomes by providing continuous feedback, promoting competition, and stimulating intrinsic motivation. However, implementation must align with pedagogical goals to avoid superficial engagement.

Theoretical concepts taught through traditional methods help facilitate the understanding of other theoretical concepts. Still, they are not particularly effective in developing the problem-solving and critical thinking skills necessary for computer science, which can only be learned through hands-on experience.

Recent applications of gamification in educational contexts have demonstrated its versatility and impact across diverse learning environments. For example, Narváez-Terán and Martínez Elizalde (2023) developed a turn-based card game to support the learning of regular languages in computer science education. The game incorporated core theoretical concepts—such as regular expressions, concatenation, and Kleene operators—

into its mechanics, enabling students to engage in hands-on pattern recognition and decision-making in a collaborative format. Similarly, Martínez Elizalde and Astengo Noguez (2022) implemented a gamified learning experience in a digital animation program, where students designed interactive products such as visual novels and games to promote independent literature. This challenge-based approach used narrative and game elements to make abstract programming concepts more tangible and relevant. These examples illustrate how gamification can promote motivation, deepen conceptual understanding, and foster transferable skills through engaging and context-rich activities.

This study examines the application of gamification in a Computer Science class on Software Construction and Decision Making at the undergraduate level. Principal technical fields include web development, database management, and video game creation. To foster deeper engagement and critical thinking, students participated in a collaborative storytelling activity that encouraged them to apply their knowledge in a playful, narrative-driven setting.

1.2 Escape Rooms as a Gamified Educational Tool

Escape rooms – games in which participants solve puzzles under time constraints to achieve a goal – have been increasingly adopted in educational settings to promote active learning and the practical application of knowledge. According to Cordero (n.d.), escape rooms are games that enable learners to acquire competencies and solve problems. Such experiences can be beneficial in educational settings as a means of engaging with complex ideas and promoting the practical application of knowledge.

Veldkamp et al. (2020) found that educational escape rooms can effectively promote critical thinking, teamwork, and applied learning. Similarly, Hermanns et al. (2017) reported increased motivation and knowledge retention in health sciences education through escape room experiences, suggesting broader applicability to fields such as computer science, where real-world scenarios often involve solving complex problems under pressure.

2. Methodology

2.1 Integrating the MDA Framework Into Gamified Educational Design

To deepen the theoretical foundation of gamification in education, the Mechanics–Dynamics–Aesthetics (MDA) framework offers a structured approach to game design that can be effectively applied to educational contexts. Developed by Hunicke, LeBlanc, and Zubek (2004), the authors emphasize that "from the designer's perspective, the mechanics give rise to dynamic system behavior, which in turn leads to particular aesthetic experiences".

Applying the MDA framework to educational game design allows educators to craft experiences. By carefully designing the mechanics (e.g., incorporating problem-solving challenges), educators can influence the dynamics (e.g., promoting collaboration and critical thinking), ultimately leading to positive aesthetics (e.g., increased motivation and engagement).

2.2 Design Process

This activity followed the escape room concept in that student teams took on a series of connected challenges within a time limit. Our intervention incorporated collaboration, planning, and narrative elements that promote both cognitive and interpersonal skills. The escape room was inspired by the magical universe of Harry Potter, because it offers rich thematic material for designing immersive learning environments (Rowling, 1997-2007). A fictional storyline was used to recall previously learned material while encouraging collaboration, critical thinking, and creative problem-solving.

This study builds on our previous research exploring how storytelling and gamification the learning experience and reinforce course objectives (Gonzalez and Solis, 2024). Unlike previous implementations that focused primarily on motivation, this project investigates the potential of the escape room format to function as a formative assessment tool. By embedding course content into the escape room's design, the activity aimed to assess students' practical capabilities in applying theoretical knowledge, solving problems, and working collaboratively under realistic constraints. In doing so, it offers an innovative model for evaluating student performance in higher education through immersive, game-based learning experiences.

In the context of our study, the escape room activity inspired by the Harry Potter universe exemplifies the MDA framework in action. The mechanics involved puzzles and challenges rooted in computer science concepts. The dynamics emerged as students collaborated to solve these challenges under time constraints,

fostering teamwork and critical thinking. The aesthetics were reflected in the students' heightened engagement and enjoyment, demonstrating the effectiveness of the MDA framework in educational gamification.

This study utilized a Harry Potter escape room as a gamified learning intervention in an undergraduate computer science course. It covered the design, implementation, and evaluation of an activity aimed at increasing student engagement, creativity, and problem-solving skills. The escape room featured six sequential missions that combined cognitive and physical challenges to provide an engaging, hands-on learning experience.

Two primary considerations shaped the design process: creating an engaging narrative environment and aligning game-based tasks with the course's learning objectives. The Harry Potter theme had broad cultural resonance and could motivate in a familiar context. The placement of the activity within a magical, story-driven framework increased students' enthusiasm for learning.

The educational objectives of the escape room were to enhance logical reasoning and collaboration and to provide students with real opportunities to apply the technical skills they had acquired during the course. Every mission had specific content areas, such as web development, database management, and game design, but also encouraged teamwork, strategic thinking, and effective communication.

Unique to the escape room was a custom Unity video game projected in the classroom that served as the central guiding interface. This digital component performed several key functions: It introduced the narrative and mission sequence to immerse participants in the gamified context. It enabled the tracking of 30-minute sessions and team progress in real-time, sustaining engagement and informing strategic planning. Moreover, it provided mission-specific instructions and a context-sensitive hint system to assist participants without interrupting the problem-solving process.

Figure 1: A Unity video game projected in the classroom

The following section outlines the design of the six missions and explains how each was aligned with the intended learning outcomes for the course.

3. Escape Room Design

By embedding theoretical concepts into engaging, narrative-driven tasks, the escape room format allowed students to demonstrate learning through action rather than recall. In doing so, the activity addressed the core problem outlined at the beginning of this study: how to design assessments that move beyond traditional exams to evaluate authentic capabilities while fostering motivation and critical thinking. The mission sequence served as a formative assessment tool that revealed individual and group competencies in a dynamic, low-stakes environment—providing educators with richer insights into student understanding and development within a computer science context.

3.1 Mission 1: Letters to Hogwarts

Designed to engage students with the gamified experience from the outset. This mission involved chance, teamwork, and quick decision-making—the precursor to the interactive, narrative challenges that followed.

Students encountered 10 identical envelopes hanging from the ceiling at different heights throughout the room. Every envelope had a code written inside. However, just one envelope carried the correct code to

unlock a treasure chest located in the mission area. Only one envelope at a time should be picked and opened; they had to wait for that code to be tried at the lock before choosing a different envelope.

The fact that all envelopes were visually identical was an intentional choice that added a degree of chance to the task. Randomly selecting the correct envelope meant participants could not rely on visual cues to identify the code. They instead had to try codes out by hand until they found the one that opened the chest through trial and error. This design choice introduced unpredictability, making the mission a game of chance and a test of quick decision-making.

The hypothesis for this mission was that *restricting the team to drawing one card per attempt would encourage better communication and organizational strategies.*

3.2 Mission 2: Quidditch Game

A dynamic, physical activity inspired by the wizarding sport of Quidditch from the Harry Potter universe - after completing the first mission. This mission introduced physical skill and chance while also emphasizing teamwork, coordination, and the immersive narrative.

When students opened the treasure chest at the end of the first mission, they found several ping pong balls representing the Quaffle in Quidditch. This transition between tasks kept the escape room flowing and students engaged. Discovering the ping pong balls connected the narrative elements of the escape room and created anticipation for the next challenge.

The setup included three hoops at different heights, representing the three Quidditch goals. The hoops were placed in a play area where participants stood on them. Hoops were placed at various heights to simulate competitive play in the original game.

For this mission, each student had to get a ping pong ball through one of the three Quidditch hoops. The task required participants to demonstrate accuracy, hand-eye coordination, and a competitive spirit. Rules for missions appeared on the Unity game interface, requiring all team members to take turns throwing a ball. The recorded order of successful goals was then updated on the projected leaderboard.

The hypothesis for this mission was that *faster teams, which complete this mission, demonstrate greater trust and shared motivation.*

3.3 Mission 3: Triwizard Tournament

A more technically demanding software development and debugging task. During this mission, students were assessed in both coding and problem-solving, utilizing a collaborative environment to simulate real-life team dynamics encountered in software engineering projects.

The mission started when the last student scored in the Quidditch Game. Transitions between missions were instantaneous to maintain a seamless and continuous escape room experience. A unity game interface projected on a screen during the activity announced the start time of the Triwizard Tournament and assigned roles based on previous task completion.

The order in which they scored was ranked from 1 to 6. Moreover, the role assignment was as follows:

- Programmer: That student who scored first was the programmer. This was the only team member allowed to modify the code directly on the computer.
- Assistant: A second-place student served as assistant. This participant watched the programmer on screen but was unable to modify the code.
- Tech Support: Students who scored between 3 and 6 were assigned to tech support roles. Tech support members could not see the screen directly, unlike the assistants. Then they were to answer any questions the programmer or assistant might have.

Roles rotated every 3 minutes, allowing everyone to participate in the mission in different ways. For example, the assistant became the programmer, the third position (tech support) became the assistant's role, and the programmer moved to the end of the line to take on tech support.

The hypothesis was that this *role rotation enables team members to develop technical communication skills*.

This rotating structure reinforced the collaborative nature of the task by allowing students to experience all aspects of problem-solving. Rotating roles also helped promote good communication among all team members, ensuring that the mission could depend on them working together effectively across different roles.

The Triwizard Tournament mission required participants to debug a preconfigured Unity project with various embedded errors. These included syntax errors, such as missing semicolons and incorrect function calls, as well as logical errors like faulty conditionals or loops, and missing or misconfigured scene components. The activity assessed students' programming skills, problem-solving abilities, and familiarity with the Unity development environment.

A new gameplay element was added once the programmer fixed the errors, and the Unity game ran successfully. A maze game appeared in the Unity project after debugging was finished. The programmer who had been debugging the project was now assigned to solve the maze. The transition of control stressed adaptability and ensured that each role contributed to the mission in its own way. When the labyrinth was completed, it gave a code to the next mission. This code had to be entered into the Unity-based mission control interface to advance the team.

3.4 Mission 4: The Dungeons

Explored database management concepts through a virtual reality (VR)- enabled format. Keeping the same physical room where the escape took place, the team selected a wand to attach to a spinning wheel, which would randomly select one student to be the Chosen One. A VR headset was placed on this student, who was transported into a virtual dungeon filled with a magical ambiance and enchanted books.

The hypothesis for this mission was that *using Virtual Reality in a gamified dynamic motivates the immersed user and encourages teamwork on theoretical activities, such as database management.*

Every book in the VR dungeon contained a secret question about database concepts like Data Retrieval, Data Filtering, Data Aggregation, and Joins. The Chosen One entered the virtual reality environment and read the questions from the books. Meanwhile, the rest of the team could only see the real world with a large board with a list of possible multiple-choice answers. They were required to match the questions to the correct answers on the board.

Once questions matched answers, students gathered the numbers to form a multi-digit code. This was entered into the Unity-based mission control interface for the next phase of the escape room experience.

3.5 Mission 5: Potions Class

Involved web development and debugging. This task tested their programming skills and included a puzzle-solving component that required technical problem-solving and creativity.

The hypothesis for this mission was that *cooperative error resolution encourages computational thinking and knowledge transfer among peers as students worked together to troubleshoot and fix issues in a web application.*

The same Programmer, Assistant, and Tech Support roles were used, along with a 3-minute rotation. However, in this case, the positions were inverted: the programmer was in the sixth position, the assistant in the fifth, and the tech support team moved from fourth to first.

Starting the mission, the team ran across a web application claiming to be a potion recipe tool. However, it had bugs like broken links, C# Syntax Errors, and Logical Bugs. The task was straightforward: debugging the web application and restoring its functionality. The Programmer worked through the code, the Assistant offered help or suggestions, and the Tech Support member provided technical assistance based on their understanding of the problem.

Once that was fixed and the application worked properly, the next challenge was a potion puzzle inside the web app. Every Potion Card student drew had a symbol or ingredient tied to an application action or form input. Students used these clues to "brew" the potion by selecting the correct ingredient combinations and completing the app actions. The application then displayed a code to enter the Unity-based mission control system once the potion was made. That code got them to the last mission of the escape room.

3.6 Mission 6: Helping the Snitch

A physically demanding challenge that tested students' teamwork, coordination, and problem-solving skills under pressure. It was a culminating activity that tested students' strategic thinking and collaboration in a real-life situation.

It began with retrieving the Golden Snitch, a golf ball hidden in the last treasure chest. The goal: Get this Snitch from A to B with only half-pipes - plastic channels that simulate the precise, delicate manoeuvring required in Quidditch. Any direct physical contact with the ball was prohibited, adding an extra level of difficulty and emphasizing the importance of coordination.

The hypothesis for this mission was *that cooperative physical activities would improve participants' perception of teamwork and coordination.*

Students planned and communicated as they adjusted the position and angle of the half-pipes to direct the ball into a final cup at the end. This cup had a button mechanism at its base. When it was pressed, the last code was displayed on an LCD screen. It was this code that had to be entered into the Unity-based mission control game to stop the previous countdown and exit the escape room.

This strategically embedded component was analogous to real-world engineering tasks, where teams must coordinate their actions toward a common goal. Team members each took on an active role in the task; students naturally assumed roles as navigator, communicator, and handler of the pipes, although no formal rotating roles were assigned for this mission. Teamwork requires constant verbal communication and non-verbal coordination, highlighting the importance of collaborative problem-solving.

The sixth hypothesis was demonstrated by this last challenge: cooperative physical activity enhanced participants 'perception of teamwork and coordination when faced with high-stakes, time-sensitive tasks. The mission marked an end to a magical journey that students described as a shared success.

4. Implementation

4.1 Student Teams Constraints

The escape room was set up in a specially designed room, distinct from the classroom, with theme-appropriate music playing, and each mission was assigned to a designated station. The physical setup was intended to create an immersive atmosphere, incorporating themed decorations and props that enhanced the Harry Potter experience. Students were divided into teams of 6 members to encourage active participation and maximize the opportunities for collaboration. The group size was chosen to allow all participants to contribute meaningfully while still being manageable within the time constraints.

Only one team was allowed inside the Escape Room at a time to ensure the best experience for all teams. A 30-minute time limit was enforced to simulate the pressure of an escape room scenario, encouraging quick thinking and efficient problem-solving.

4.2 Data Collection Instruments

To capture students' perceptions and assess the pedagogical impact of the escape room, data were gathered using a combination of quantitative and qualitative tools. A post-activity survey was designed and administered immediately after students completed the experience. The survey included Likert-scale questions to measure engagement, enjoyment, perceived learning, collaboration, and the overall effectiveness of the activity as a learning strategy. To enrich the quantitative findings, the survey also featured open-ended prompts inviting students to reflect on what they learned, the challenges they encountered, and their impressions of the format. This mixed-methods approach allowed for a more holistic understanding of the students' experiences, combining measurable trends with personal insights.

5. Results

5.1 Qualitative Findings

To visualize students' reflections on the escape room activity, a word cloud was generated to represent the most common terms used by participants. Key words such as "fun," "challenging," and "collaborative" suggest that students found the activity enjoyable while engaging in teamwork and problem-solving. Other frequently mentioned descriptors, including dynamic, interesting, magical, and exciting, highlight the immersive and novel nature of the tasks. Words like "Strategy," "Teamwork," and "Communication" suggest that the escape room effectively fostered essential skills in a software engineering context.

Figure 2: Word cloud of the most common terms used by participants in open-ended questions

5.2 Quantitative Findings

5.2.1 Communication and organization strategies (Mission1)

Drawing one card per attempt would encourage better communication and organization strategies within the team. This hypothesis was evaluated using two survey questions (Fig. 3):

- One letter per attempt forced us to communicate clearly
- I think that restriction helped us divide roles more evenly.

The responses confirm the hypothesis. The rule helped students clarify and organize their communication with teammates, most students said. They said it also distributed roles more evenly. This suggests that constraints promote structured teamwork and thoughtful collaboration. The figure below shows response data for these two questions.

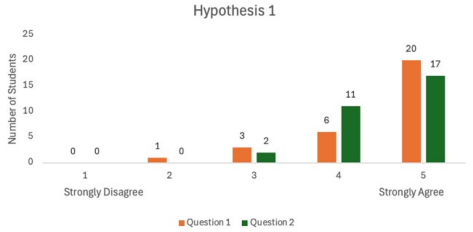

Figure 3: Distribution of the responses on a scale from 1 to 5

5.2.2 Trust and shared motivation (Mission 2)

Faster teams would exhibit greater trust and shared motivation. To test this hypothesis, three survey questions were used (Fig. 4):

- I felt like my team trusted me during this mission
- All team members were equally motivated to achieve this
- We coordinated quickly without much planning

Answers to such questions confirm our hypotheses. Most students reported feeling trusted by their teammates and that all members were equally motivated to complete the task. They said their team acted quickly without much planning. Since all teams completed the mission within two to three minutes, these results support the hypothesis that trust, motivation, and efficient collaboration contributed to their performance. The figure below shows response data for these three questions.

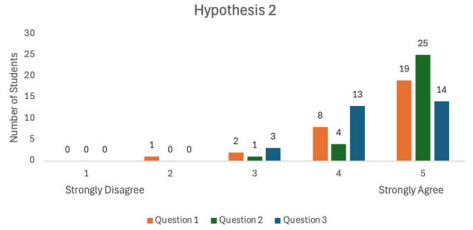

Figure 4: Distribution of the responses on a scale from 1 to 5

5.2.3 Technical communication skills (Mission 3)

Team members would develop technical communication skills by rotating through various roles. To evaluate this, three survey questions were used (Fig. 5):

- Rotating roles helped everyone participate in the solution
- I felt more comfortable communicating technical ideas by having a specific role
- The change of roles made me better understand my colleagues' ideas

The survey results support this hypothesis. Most students felt role rotation promoted full participation and helped them understand teammates' perspectives. A majority also stated that defined roles helped to express technical ideas. Such findings suggest rotating roles promote active engagement and technical communication within teams. Detailed response data for these three questions is shown in the Figure below.

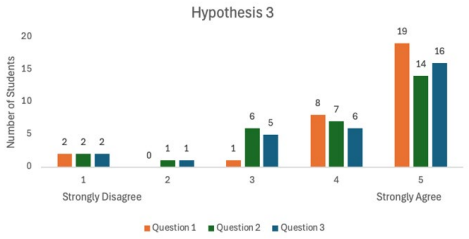

Figure 5: Distribution of the responses on a scale from 1 to 5

5.2.4 Motivation and teamwork (Mission 4)

The use of Virtual Reality in a gamified dynamic would motivate the immersed user and encourage teamwork during theoretical tasks, such as database management. To evaluate this hypothesis, the questions were different for students using the VR headset and for those who did not use it. VR users responded to (Fig. 6):

- The experience of using Virtual Reality made me feel more involved in the topic of databases
- I felt responsible for guiding and supporting my team through the VR experience

Moreover, the non-VR participants responded to (Fig. 6):

- I felt like the mission kept me motivated to participate, even when I was not wearing the headset
- I felt engaged with the team by having to answer questions

Most of the VR users agreed with the questions, which showed increased engagement with the topic and a greater sense of team responsibility. Meanwhile, almost all these students also reported being motivated and engaged, even though they were not using the VR. These results confirm our hypothesis that the VR-based dynamic was able to promote both individual and collaborative participation. Graphs of survey responses for those questions are shown below.

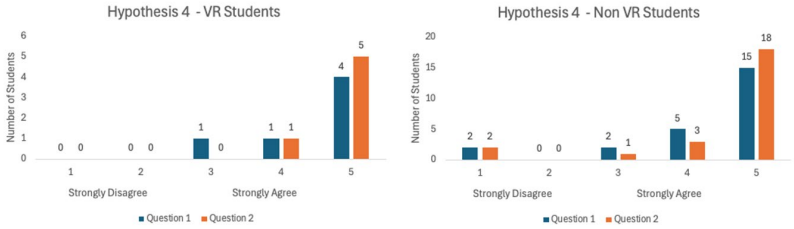

Figure 6: Distribution of the responses on a scale from 1 to 5

5.2.5 Computational thinking and peer-to-peer knowledge (Mission 5)

Cooperative error resolution would foster computational thinking and peer-to-peer knowledge transfer as students worked to troubleshoot a web application. This was assessed via three survey items (Fig. 7):

- Troubleshooting as a team helped us better understand how the web application works
- We share technical knowledge among team members during the mission
- I felt like this mission strengthened my computational thinking.

All three statements were agreed upon by most students, indicating that teamwork during debugging improved both technical comprehension and algorithmic thinking. These findings confirm the hypothesis that collaborative troubleshooting is an effective method for understanding and exchanging knowledge. The graph below shows survey responses.

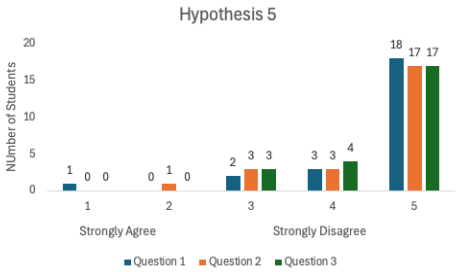

Figure 7: Distribution of the responses on a scale from 1 to 5

5.2.6 Teamwork and coordination (Mission 6)

Cooperative physical activities would increase participants' impression of teamwork and coordination. This is being evaluated using three survey questions (Fig. 8):

- This activity improved my perception of how we work as a team
- I felt that a high level of coordination was necessary to achieve the objective
- I had fun and thought it was a good way to close out the Escape Room

Most students agreed with all three statements. Additionally, the enjoyment of participants indicates that physical and playful components enhance collaborative experiences. The survey responses are shown in the Figure below:

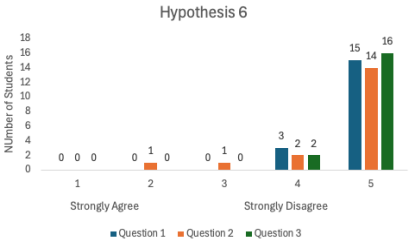

Figure 8: Distribution of the responses on a scale from 1 to 5

5.3 Teacher Findings

The hybrid design of the escape room—combining physical and digital elements—created a dynamic learning environment that fostered communication, collaboration, and application of technical knowledge. Each mission targeted specific skills: Mission 1 emphasized clear, efficient communication and task delegation; Mission 2 fostered urgency, trust, and coordinated action under pressure; Mission 3 highlighted the importance of technical communication through rotating roles; Mission 4 promoted asymmetrical collaboration and reinforced SQL concepts in a gamified setting; and Mission 5 focused on collaborative debugging, encouraging problem-solving and knowledge transfer. Collectively, these missions provided meaningful insights into how gameplay can support active, team-based learning in a technical context.

6. Conclusions

This study set out to explore how gamified assessments—specifically, an educational escape room—could provide an effective alternative to traditional evaluation methods in a computer science course. Faced with the growing challenge of assessing students' authentic problem-solving abilities in the era of AI-assisted learning, the goal was to create an assessment experience that not only tested knowledge but also encouraged creativity, engagement, and collaboration.

The results suggest that escape rooms, when grounded in pedagogical objectives and enriched with narrative-driven design, offer a promising solution. Students demonstrated high levels of motivation, enjoyment, and teamwork throughout the activity. Both qualitative and quantitative feedback indicated that the escape room

not only enhanced student engagement but also supported the development of key competencies in software construction and decision-making, such as logical reasoning, collaborative problem-solving, and critical thinking.

By aligning game mechanics with course outcomes and incorporating the MDA framework, the escape room provided an immersive and formative assessment experience. Unlike conventional tests, it evaluated students' applied skills in real time, under conditions that mirror the fast-paced, collaborative nature of real-world software development.

In conclusion, gamified assessments like educational escape rooms can serve as valuable tools in higher education—particularly in technical disciplines—by bridging the gap between content mastery and skill application. They offer an innovative and scalable model for authentic assessment that not only measures learning but also inspires it.

Ethics Declaration: Formal ethical clearance was not required for this study. Students were invited to complete an open survey voluntarily, and it was clearly stated that their responses could be used for research purposes. Participation was entirely optional, and no identifiable personal data was collected.

AI Declaration: Grammarly, an AI-powered writing assistant, was used during the preparation of this paper. The tool supported the revision process by identifying grammar, spelling, and punctuation issues and suggesting improvements for clarity and conciseness. All suggestions provided by the tool were carefully reviewed and selectively applied by the author to maintain the intended meaning and academic tone of the paper.

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Modeling Language Acquisition in Commercial Off-the-Shelf Games: A Multiple Case Study

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Abstract: Recent years have seen an increase of game-based approaches to a variety of learning contexts, including language acquisition. However, scoping literature reviews on existing games have revealed that while the learning approaches are carefully considered when creating educational games, many such games lack fundamental design elements. In this regard, educational games can learn from commercial, entertainment-oriented video games, where careful game design and maximizing player engagement are key considerations. Although niche, there is a genre of games where the core gameplay loop involves the player deciphering a language. This paper applies close reading techniques to commercial games that have learning artificial languages as their core mechanics, exploring the game design techniques those games use to foster and encourage language learning. In particular, this paper focuses on how commercial games leverage their unique characteristics, such as the ability to immerse the player in the context of the language they are learning and provide direct and indirect feedback tailored to the player's actions. This will be accomplished by analyzing the learning process through the lens of Second Language Acquisition (SLA) theory. The two games chosen for analysis are Heaven's Vault, one of the first games to have language interpretation as the main game mechanics and Chants of Sennaar, arguably the most successful commercial game based on language learning. By analyzing the games, this paper aims to chart how different commercial games facilitate language learning, and offer ideas on how those design elements can be implemented in educational games.

Keywords: Game-Based learning, Language learning, Close reading, Game design, Vocabulary

1. Introduction

In recent years, the use of video games in educational contexts has risen significantly, leading the practice to be recognized as a field of study and given the name game-based learning (GBL) (Hung et. al., 2018). GBL has been applied to a wide range of subject areas, including mathematics (Kebritchi et. al., 2010), programming (Videnovik et al., 2023), and language learning (Xu et al., 2019). Among those, language learning is considered a field particularly fit for the application of GBL, because of how game affordances enable language acquisition (Reinhardt and Thorne, 2020).

Despite the large amount of research conducted on the topic, scoping literature reviews on existing language learning games have revealed that, while the learning approaches are carefully considered when creating educational games, many such games lack fundamental design elements (Xu et. al., 2019). In this regard, educational games can learn from commercial, entertainment-oriented video games, where careful game design and maximizing player engagement are key considerations.

Although niche, there is a genre of games where the core gameplay loop involves the player deciphering a language. In these games the player's goal is to use environmental clues and previously deciphered words to connect signs to their meaning, and then leverage their understanding of the language to solve puzzles and progress in the game.

This paper applies close reading techniques and hermeneutic inquiry to commercial games that have learning fictional languages as their core mechanics, exploring the game design techniques those games use to foster and encourage language learning. Fictional languages have been defined as a subset of artificial languages that are primarily meant to create the fictional world they are a part of (Barnes & van Heerden, 2006).

The reason for choosing games that teach fictional languages rather than natural ones is that those games do not focus on any particular feature of a given language, and the way they model language learning can be abstracted to a more general, non language-specific set of observations.

In particular, this paper focuses on how commercial games leverage their unique characteristics, such as the ability to immerse the player in the context of the language they are learning and creating a space for the player to fail without consequence and receive feedback. This will be accomplished by performing a close reading of the game mechanics fostering language learning, through the lens of Second Language Acquisition (SLA) theory. The two games chosen for analysis are *Heaven's Vault,* and *Chants of Sennaar*.

By analyzing the games, this paper aims to chart how different commercial games facilitate language learning and to offer ideas on how those design elements can be implemented in educational games.

2. Background

The theoretical background for this analysis is based primarily on two fields: Game-Based Learning (GBL) and Second Language Acquisition Theory (SLA).

GBL has been defined as "a playful activity that is structured by rules for the pursuit of quantifiable outcomes (e.g., win states and points), and incorporates educational objectives (e.g., knowledge acquisition) as its own end" (Hung *et. al.,* 2018 p. 1), or, more simply, as the use of "games with specific learning goals" (Plass *et. al*., 2020)

GBL focuses on leveraging games to teach, either by themselves or as support to other modes of instruction. It differs from gamification or playful learning, which apply some game elements to non game-tasks, because it leverages all features of games, and implies a complete redesign of the learning activity into a game (Plass et.al., 2020).

While serious games, games designed and primarily used for educational purposes (Crookall 2011, Ritterferd, 2009), constitute an important section of game-based learning, there have also been studies focused on how learning can occur in commercial games (Aleksić et. al. 2016) and how they implement learning principles (Beckett 2008). Gee (2003) highlighted how games create learning, among other ways, by having a mix of explicit instructions and free exploration, helping the player perform an identity, and providing an environment for practice and immediate feedback. Identity performance is an aspect of game-based learning particularly relevant to this analysis, as it has been found to be an important factor in language learning in game (Reinhardt and Thorne 2020). Gee (2003) identified three main identities at play in a video game: a virtual identity, a real world identity and a projective identity. Virtual and real world identity refer respectively to the identity of the game character and of the player playing the game. Projective identity, on the other hand, indicates both how the player projects their values and ideas on the virtual character and how the character is a project the player has.

Second Language Acquisition theory is concerned with the acquisition of non-native languages, and how people created new language systems with only limited exposure (Gass et.al., 2020). The input hypothesis of second language acquisition posits that language is acquired by decoding inputs, and that learners advance their knowledge by decoding sentences slightly above their current level (Krashen 2003). According to this theory, explicit grammar teaching and output production can contribute to learning, but not to acquisition (Krashen 2003).

A subset of SLA theory particularly relevant to this analysis is Vocabulary Acquisition. According to Nation (2001), there are three main steps that lead to a word being remembered: noticing, retrieval and generative use. Noticing occurs when the learner pays attention to an item, and motivation and interest are important enabling conditions. The noticing process can also be triggered by negotiating the meaning of the word when it is encountered. Retrieval happens on any new encounter with an already noticed word, and it strengthens the memory of that word. Finally, generative processing occurs when previously learned words are met or used in ways that are different from previous encounters, and like retrieval can be receptive or productive. Generative processing is particularly helpful for learning, as there is "low correlation between total exposure to the word and learning, but high correlation between learning and the number of uses of the words not closely dependent on input" (Nation, 2001, p.107).

The potential for games to be used as a vehicle for language learning has attracted much attention from researchers, with a scoping literature review from 2019 finding 59 papers evaluating games to teach English (Xu et. al., 2019). Reinhardt and Thorne (2020) identify eight game-based L2 learning affordances. Out of those eight, four are particularly relevant to this analysis: Contextualization and linguistic environment, which leverage a game's ability to contextualize game mechanics in a coherent narrative, helping the player associate form, meaning and function through interaction with the game world; Games as a shelter for practice, that push learners to take more risks and practice freely; Goal orientation, purpose and feedback, which makes use of the goal-directed nature and feedback mechanisms designed into games to direct and provide timely feedback to the learner; and finally identity performance, which leverages the process of identity construction typical of games with a single protagonist to push the learner to perform an identity that will help with L2 learning.

3. Methodology

The methodology at the core of this analysis is hermeneutic inquiry, particularly in the form of close reading.

Hermeneutic inquiry is an epistemological tradition "grounded in the expert interpretation of texts from a given point of view" (Tannenbaum, 2015). In hermeneutic inquiry, knowledge does not come from an objective measuring of reality, but rather from the equilibrium between the demands of a text and the reader's situated subjectivity that emerges from reading (Føllesdal, 2001). Using close reading as the main analytical tool allows for a closer look at the specific implementation of the mechanics, considering them in the broader game context and analyzing the details of how they are created and used to foster learning.

Close reading is a hermeneutic technique developed in the context of literary theory, and consists of "a detailed examination, deconstruction, and analysis of a media text" (Bizocchi and Tannebaum, 2011). It can be used to look at the poetics of a text, meaning the mechanisms that a work uses to achieve an aesthetic effect (Tannenbaum, 2015). Close reading with a focus on poetics is oriented toward empirical and observable elements of a text, and as a consequence is closer to a form of objectivity compared to other lenses that can be applied to a close reading approach (Tannenbaum, 2015).

Although close reading is a general approach suited for a variety of disciplines and contexts, it does not always take the same form. There are unique challenges and aspects to consider when applying a close reading approach to video games, and ad hoc guides have been created to help apply hermeneutic interpretation to video games (Kłosiński, 2022).

Tannenbaum (2015) identifies four main challenges in close reading video games compared to other kinds of texts: indeterminacy, scope, difficulty, and random access. Since this analysis is primarily focused on the mechanics of the games, difficulty is the most relevant. Players of different skill levels can experience the same game differently: it is not just that unskilled players take longer to complete the game, rather, there are fundamental differences in how the players engage with the game. A player struggling with the controls will pay less attention to the aesthetic aspects of the game, and a player in a state of flow, immersed in the interplay of challenge and success (Csikszentmihalyi, 1990), will enjoy the game differently from a player for whom most mechanical challenges are trivial.

One way to address this difficulty is to approach the game from the perspective of a naive interactor, a player who has no previous knowledge and is playing the game for the first time (Tannenbaum 2015). While it is impossible to escape the scholar's subjectivity, the imagined naive interactor provides a lens to attempt to set aside the previous knowledge and experience. The theoretical construct of the naive interactor is particularly relevant when analyzing mechanics, and is similar to the concept of "new player experience" (Bycer, 2020), a game design concept used to indicate how a player new either to the game, the genre or video games in general will experience the game. Since in both games analyzed in this paper the progression is knowledge-based, employing the perspective of a naive interactor is fundamental to understanding how the language learning mechanics work.

Another solution to address common issues in the close reading of games is using analytical lenses to focus the close reading. Analytical lenses are "artificial frames that a scholar can apply to a game in order to direct his or her attention to specific phenomena, while filtering out elements of the game that are less relevant" (Tannenbaum 2015). As gameplay often provides too much information to analyze all of it in depth, analytical lenses act as a filter to focus the analysis on specific aspects. In line with the focus of this paper, the lenses applied for the analysis are "language learning mechanics" and "vocabulary progression".

The data collection method followed a mixed approach, aiming to capture both more immediate reactions to and reflections on the game, while using screenshots and recordings to ground my observations in the available data. It is inspired by the methodologies used by Tannenbaum (2015) and Kłosiński (2022) in their analyses. During play, I spoke my thoughts aloud and recorded them, while taking screenshots at both regular intervals and when any relevant puzzle or interface appeared on the screen. After each puzzle or game area I took a break to reflect on the experience and note down my thoughts on it, then wrote down a reflection and summary at the end of each play section. Finally, I returned to the notes the day after to perform a second analysis.

4. Analysis

4.1 Heaven's Vault

Heaven's Vault (2019) is an adventure game developed by Inkle, where the player takes on the role of an archeologist, uncovering the lost history of a space nebula in a sci-fi setting. The game is composed of two main modes: exploration, where the player roams around the nebula speaking to characters and collecting information, and the language puzzles. The language puzzles happen through the translation system that the

player can use to make sense of the ancient writings. For each word in the sentence the player is trying to translate, the game will offer three or more possible meanings, and show words related to the one on screen that the player has encountered previously (Figure 1).

Figure 1: The translation interface in *Heaven's Vault* (2019)

The game supports language learning in two main ways: the first one is having puzzles and a fictional language designed to encourage and reward vocabulary acquisition, and the second one is using the narrative and art to encourage identity performance and contextualize the learning.

The language puzzles are designed deliberately to encourage the player to examine each word closely, leading them to learn the language organically as they progress. The player does not have access to a glossary besides the one they build themselves by interacting with the game world, and receive no feedback on whether a world was translated correctly until they use it correctly a few times. Furthermore, while the language puzzles shine a light on the plot of the game and the history of the game world, they do not affect the exploration phase of the game in any way. As a consequence, the player cannot test their theories directly, but rather has to compare their translation of a word against other fragments and their context. For example, early in the game I read an inscription on a statue. One of the words of the inscription was *goddess*, which I had already translated, but the other one was unknown. However, the same word is also present on a well nearby, which made me infer the meaning of the word was *water*. This interpretation was reinforced when I saw the same symbol next to a riverbed later in the game, and the game confirmed that my translation was correct.

In terms of SLA theory, the game is teaching the language to the player by focusing on the first two phases of vocabulary acquisition: noticing and retrieval (Nation, 2001). Each word is highlighted separately when discovered, and the player has to input a guess for each word in the inscription to continue. The process used the most is negotiation (Nation, 2001), as the player is incentivized to not only make a guess in the moment, but return to older translations to refine them based on new information they find. Retrieval is created by having already translated words appear in new contexts and with the "related words" feature (see Figure 1). The design feature that enhances the role of negotiation and retrieval, and makes it possible for the player to learn the hundreds of words in the game in less than 40 hours, is the structure of the fictional language. Ancient, the language in the game, is an ideographic language that creates words by combining symbols. While the symbols are unique to Ancient and bear no resemblance to existing languages, the grammar is the same as English, with the same sentence structure and rules, to isolate vocabulary as the element the player has to figure out. The meaning of the single symbol is never explicitly given by the game, but the player, guided by the related words, will be able to infer it and use it to make sense of new words. Understanding the semantic field certain symbols refer to makes it easier to pick the correct translation, or even translate without any help: *palace*, for example, is made from "place" + "of" + "emperor".

The artistic and narrative compartments of the game also play a role in the learning, by encouraging identity construction and contextualizing the language fragments the player is trying to translate. The protagonist is an

archaeologist, and the player is pushed to identify with her and her research, as the plot revolves around discovering the history of the nebula the game takes place in. The mechanics also contribute to the creation of a virtual identity of the player as an archeologist, as the knowledge the character and the player have of Ancient advances at the same pace. As the player becomes able to translate more and more complex sentences the projected identity the game pushes for (the best archeologist in the nebula) becomes a source of self-efficacy, a key element for learning and motivation (Jackson 2002). The game also provides a space to the player to perform a certain identity by providing agency in the exploration phase: the player can choose which areas to explore, the dialogue options, and what to do with the artefacts they find among other things.

Heaven's Vault, then, implements language learning as a core mechanic by relying on two interrelated aspects: the language puzzles and the narrative. The language puzzles focus on teaching the player the vocabulary of a fictional language, while the narrative contextualizes the player's findings, provides motivation for the player's actions and fleshes out the identity the player performs while playing the game. While the narrative and language puzzles are not directly in contact, they are still connected: the exploration is guided by translating fragments, and in turn contextualizes them.

4.2 Chants of Sennaar

Chants of Sennaar (2023) is an adventure game developed by Rundisc. In it, the player takes the role of a cloaked figure traversing a tower inhabited by various tribes, each with its unique language. Except for some user interface elements, all writing in the game is in these fictional languages, and the player has to translate them to solve puzzles and progress the plot. To keep track of known words and input guesses, the player has access to a journal where they can write down the meaning they think a symbol has and associate symbols to images. However, the guesses are not confirmed until the whole page is filled correctly.

Figure 2: The journal in *Chants of Sennaar*

The main way *Chants of Sennaar* fosters language learning is by integrating it closely with the puzzle solving, using gameplay sections to help the player negotiate the meaning of the words and test their interpretation. Puzzles and environmental clues are the primary way for the player to test their theories, and the journal is more a quality of life feature to confirm guesses the player is almost completely certain of, rather than a consistent source of feedback. Integrating the language learning into the puzzles also helps achieve a pace of challenge optimal for learning: a game with a good difficulty curve presents a challenge that is slightly too difficult for the current skill level of the player, but possible to overcome with some practice (Cowley et. al. 2008). In the context of learning, a challenge slightly above the student's ability but within reach is called the "zone of proximal development" (Vygotsky, 1978), and is considered the optimal level of challenge to foster learning (Wass & Golding, 2014).

This pattern of gathering contextual clues from the world and refining guesses as the game progresses is present from the start: the first obstacle the player finds is a closed gate with a lever next to it, and a sign explaining the mechanism (Figure 3).

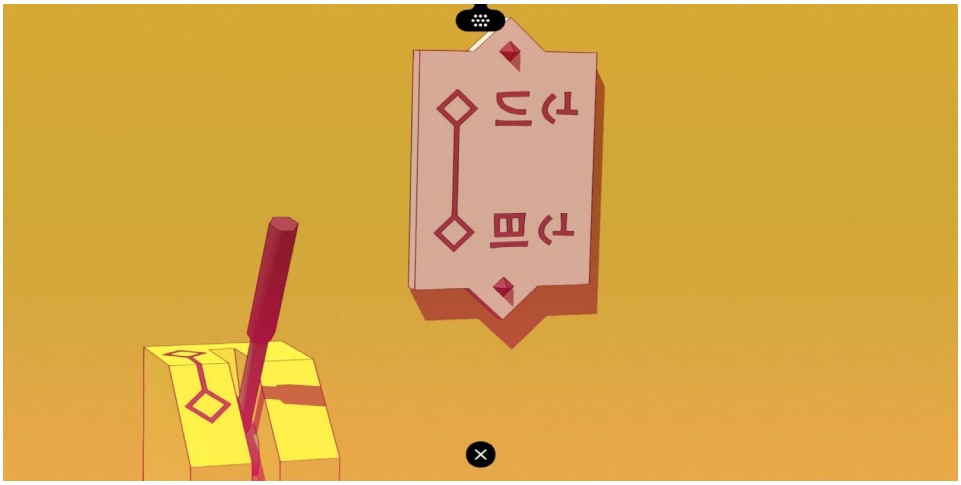

Figure 3: The first puzzle in *Chants of Sennaar*

When I first encountered the puzzle, I noted down two possible interpretations: either *open door/close door* or *lever up/lever down*. However, shortly afterwards a non-player character (npc) pointed at a closed gate, saying (in a speech bubble) the signs for *open door* (*or lever up*). As the position of the lever was not a factor in the puzzle, I refined the translation of the signs to mean "open gate" and inserted them in the journal, filling the page and receiving confirmation that my interpretation was correct.

Exploring the environment also provides information that can be used to translate new words or make inferences about the grammar of the language we are translating. Seeing the symbol for *person* repeated twice on a mural representing a crowd, for example, was key to understanding that the language uses radical-based repetition for plurality.

The languages in *Chants of Sennaar* are much simpler than Ancient in terms of their vocabulary, with each one consisting of around 40 words. However, they all have unique grammar rules the player has to figure out. Since the player relies so heavily on environmental clues for translating, the exploration of the internal logic of the various languages is almost absent: each word is represented by one symbol, with no clear similarity between symbols of the same semantic field, with a few exceptions, such as all words for places in the devotee language having a common symbol.

While the game relies heavily on having the player notice the words and negotiate their meaning, the phases of retrieval and generative use, important for long-term vocabulary learning (Nation 2001), are almost completely absent. This is mainly an effect of having the journal as a central mechanic, and how it is implemented. Once a player fills a journal page correctly, the words are given their intended meaning in English and from that point on will display that word when the symbol is hovered (Figure 4).

Figure 4: Automatic translation in *Chants of Sennaar*

The game assigning a definitive translation to the word interrupts the negotiation process the player was performing, and having the translation appear automatically makes it unnecessary for the player to retrieve the meaning of a word once it has been translated correctly once. Furthermore, the way the language is constructed makes it useless for the player to return to an already translated word in search of its etymology the same way they might do in *Heaven's Vault*.

Chants of Sennaar, then, relies mostly on integrating the language into its puzzles to both motivate the player and give feedback. Having almost no text in English makes it impossible for the game to have the same narrative and character depth as other adventure games, such as *Heaven's Vault.* However, in exchange the player is completely immersed in the language they are trying to learn, and every interaction is a source of new information.

5. Discussion

The games analyzed have language learning as their central mechanic. However, they are still commercial games and do not aim for the player to acquire the language to use it long-term or outside the context of the game. This section discusses how different design elements from the games analyzed could be adapted to be used in a game-based learning approach to language teaching.

One element that emerged from the analysis is that the games mostly help the player indirectly in their decoding work, only providing delayed feedback by confirming correct translations under specific circumstances. This choice, consistent with the input hypothesis (Krashen, 2003), also stops the player from "brute forcing" solutions and enhances the sense of mystery the player experiences from being dropped in an unknown context. This also shows that the aesthetics of the game, sometimes left to the sidelines in learning games, can affect the motivation and learning outcomes as much as the design and instructional theories.

The noticing stage of vocabulary acquisition is present in both games, with both relying heavily on negotiation to make sure the player engages with the words carefully and explores how they are used in different contexts. On the other hand, retrieval is much less prominent and generation is completely absent. The lack of retrieval comes from the automatic translation feature. While it increases quality of life for the player, it also takes away a learning opportunity. Generation is absent from both games, as having even one agent capable of meaningful conversation would require a notable time investment: *Sethian*, another language learning game based around communicating with a computer in an alien language, is fully built around a single conversation, and even then has heavy limitations to what the player can talk about.

These examples suggest that a game aiming to teach a language should look at maintaining the sense of mystery and focus on negotiation of meaning by using story and mechanics as sources of information on the language rather than direct instruction. It should also enhance the retrieval phase of vocabulary acquisition by removing automatic translation, but still keep some scaffolding to help the player and avoid confusion. Incorporating meaningful language generation in a game would probably prove a complex challenge both mechanically and narratively, but could be an important addition to learning.

6. Conclusion and Future Research

Commercial games like *Heaven's Vault* and *Chants of Sennaar* manage to integrate language learning into their core mechanics to create an engaging and immersive experience. By analyzing their design through SLA theory, this paper looks at the design elements these games employed, and proposes methods to integrate those elements into GBL approaches to language acquisition. Future work could look at other language learning commercial games such as *Sethian* or *Tunic*, or explore further how these principles can be integrated in GBL approaches and measure their effectiveness.

Ethics Declaration: Ethics clearance was not required for this research.

AI Declaration: No AI tools were used for this paper

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SOL977: Ingenious Revival, a Martian Simulation Game for STEM Engagement and Space Education

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Abstract: Interactive simulations and immersive environments offer a powerful means of enhancing education by replicating real-world challenges in virtual settings. In the context of space exploration, these tools provide learners with opportunities to engage in mission-relevant tasks, fostering exploration, problem-solving and experimentation. This paper presents *SOL977: Ingenious Revival*, a simulation-based game developed with the Unity game engine and 3D modeling tools such as Blender. The Martian environment is constructed using, among other sources, high-resolution Digital Terrain Models (DTMs) of Mars to support realism and immersion. The simulation places players in the role of a field technician responsible for restoring the functionality of NASA's Ingenuity drone after it sustains damage. The main goal is to replace a broken rotor blade in order to restore the vehicle's flight capability. This scenario is inspired by a real malfunction that occurred on Mars in January 2024. The player interacts with mechanical and electronic components by carrying out realistic maintenance procedures. They complete a series of mission-specific tasks including terrain navigation and equipment repairs within a simulated Martian environment. The repair process reflects authentic workflows with each action needing to be carried out in a specific order and under defined conditions. The player must use the right tools, follow written procedures and demonstrate a high level of attention to detail. This structure supports the development of critical thinking, problem-solving abilities and technical reasoning within a STEM-focused educational context. Preliminary evaluation that was conducted with high school students suggested that the game increased motivation, deepened conceptual understanding of STEM subjects and promoted interest in space-related careers. This project highlights the educational potential of interactive simulations to bridge theoretical knowledge with hands-on problem-solving, supporting more meaningful and applied STEM learning. It also demonstrates the transformative potential of interactive simulations in STEM education, bridging the gap between theoretical knowledge and practical experience. It finally showcases how simulation-based games can engage students and foster a deeper understanding of complex concepts, while also sparking interest in space exploration and technical careers.

Keywords: Educational technology, Immersive learning, Simulation-Based education, STEM engagement, Experiential learning

1. Introduction

As space-related industries continue to expand, the need for interdisciplinary STEM knowledge and practical skills is becoming increasingly important. Fields such as aerospace engineering, robotics and space systems demand both conceptual understanding and applied technical competence. However, traditional education often struggles to convey these domains in ways that highlight their interconnected and hands-on nature.

Interactive simulations have emerged as a promising tool to address this challenge. By offering immersive virtual learning environments, they provide a practical solution to the lack of hands-on experience among STEM students and engineers, while also enhancing engagement and deepening conceptual understanding.

To support this educational need, SOL977: Ingenious Revival was developed as a simulation-based game that replicates key aspects of space mission operations. Built with Unity and Blender, the simulation features a Martian terrain constructed using high-resolution Digital Terrain Models. Players carry out mission-relevant tasks including equipment diagnostics, terrain navigation and mechanical repairs. A central scenario involves replacing a damaged rotor blade on NASA's Ingenuity rover, inspired by real events from January 2024, when actual Ingenuity's rotor blade sustained damage permanently grounding the vehicle[1].

The game draws from space mission procedures, aviation maintenance and game-based learning strategies. It offers open-ended play without time limits, allowing players to experiment and develop technical skills at their own pace. Initial evaluations with high school students suggest the simulation effectively increases motivation and interest in space exploration and STEM fields.

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This paper outlines the development and educational impact of *SOL977*. Specifically, section 2 reviews related theory and prior work; section 3 details the simulation's structure and highlights the main aspects of its development; section 4 presents evaluation results; and section 5 offers conclusions and future directions. Figure **1** shows gameplay screenshots of. The game is available for free download and use from its repository[2].

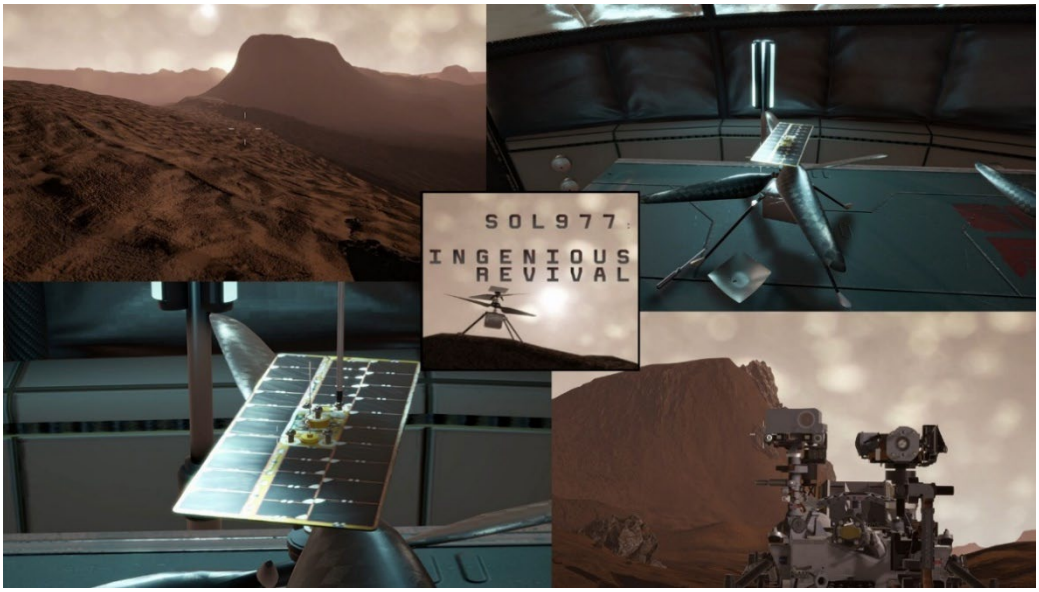

Figure 1: *SOL977: Ingenious Revival* gameplay screenshots

2. Background and Related Work

Interactive simulations and serious games have become increasingly influential in STEM education due to their ability to contextualize abstract concepts and simulate real-world problem-solving environments. They support exploratory learning by allowing learners to engage with content actively, rather than passively receiving information.

The benefits of simulation-based learning are well-supported in educational research. Active engagement with interactive systems has been shown to enhance motivation, foster conceptual understanding and improve knowledge retention (De Freitas and Jarvis, 2007)**.** These environments are particularly effective in high-stakes or technically complex domains like aerospace, where hands-on practice and contextual awareness are essential (Souza and Trivelato, 2004). In contrast to conventional didactic instruction, simulations support experimentation allowing users to learn by trial-and-error and understand concepts at their own pace.

Recent meta-analytic evidence supports the efficacy of non-immersive, PC-based educational simulations and serious games in advancing STEM learning outcomes. A 2022 meta-analysis of digital game-based learning across STEM disciplines found a moderate effect, suggesting meaningful gains in achievement over conventional instruction (Wang *et al.*, 2022). An even broader 2023 review examined 123 studies and reported clear advantages in learning outcomes when comparing digital STEM games to traditional methods, with simulation-type games (14 % of studies) contributing substantially to positive results (Gui *et al.*, 2023). Finally, a Bayesian meta-analysis of computer-based scaffolding within STEM problem-based learning found moderate effects across engineering, mathematics and technology, highlighting the value of computer environments in supporting higher-order thinking (Kim, Belland and Walker, 2017). These converging findings affirm that **screen-based simulations and serious games**, even without immersive VR, reliably bolster STEM knowledge, problem-solving skills and motivation.

Focusing on space-related educational simulations, NASA's *Mars Rover Game*[3] demonstrate how game-based environments can teach mission planning, navigation and robotics through structured, interactive tasks while

[2] https://irisot.itch.io/SOL977-ingeniousrevival

[3] Available at: https://spaceplace.nasa.gov/explore-mars/en/

Rover Mechanic Simulator[4] offers a grounded example of technical gameplay, in which players are being guided through structured rover repairs with the use of step-by-step instructions. In contrast, *SOL977* promotes exploratory learning through mission-based tasks, where players face technical challenges and receiving guidance only when they seek it. The latter design reflects real-world mission conditions and draws on Situated Cognition (Brown, Collins and Duguid, 1989) and Gee's (2007) theory of learning through meaningful engagement, independent problem-solving and learner autonomy.

Additionally, the game mechanics are designed with elements of Cognitive Apprenticeship (Collins, Brown and Newman, 1987), that is, complex tasks are being gradually introduced with embedded guidance and scaffolding. The availability of mission instructions and feedback mechanisms as well as the structured increase in difficulty emulate expert guidance, helping learners acquire domain-specific skills and knowledge.

The simulation also draws on multimedia learning theory (Mayer, 2014), which emphasizes the role of visual and interactive elements in enhancing comprehension and supporting long-term knowledge retention. In *SOL977*, tasks such as equipment diagnostics or rover route planning are grounded in meaningful contexts, thereby activating analytical and procedural thinking.

The fidelity of these environments significantly impacts their effectiveness and their contribution to the overall educational outcome. Incorporating high-resolution Digital Terrain Models (DTMs) to reconstruct an accurate Martian environment enhances visual realism and authenticity, with these qualities being essential in simulation-based learning environments and particularly in aerospace (Shaffer *et al.*, 2005). The realistic Martian terrain combined with mission-authentic tasks reinforce learners' sense of presence and relevance, which is essential for cognitive investment.

Theoretical frameworks such as the Activity Theory-based model by Carvalho *et al.* (2015), provide a structure for analysing serious games in terms of learning goals, user roles and interaction mechanics. *SOL977* is informed by these principles with task structures and interactions with the virtual environment designed to support progressive learning.

The game also draws on Problem-Based Learning (PBL) principles (Hmelo-Silver, 2004) presenting learners with mission-relevant challenges, such as identifying and repairing a broken rover blade. These tasks require critical thinking and encourage learners to explore and implement solutions.

In alignment with Experiential Learning Theory (Kolb, 2014), the simulation provides a concrete, hands-on environment where students interact directly with tools, objects and the Martian terrain. This immersive experience supports a learning cycle that includes doing, reflecting and applying, thus promoting deeper understanding through active engagement.

To sum, SOL977 is based on principles of situated, experiential and problem-based learning, with combined technical accuracy and interactivity to support engagement and transferable STEM skills.

3. Design and Development

To support meaningful gameplay and science learning, *SOL977* combines educational goals with strong technical design. The simulation encourages critical thinking and spatial reasoning while reflecting realistic Martian constraints regarding equipment repairs. This section outlines the tools, architecture and design choices behind the experience.

3.1 Tools and Asset Pipeline

The Unity game engine[5] was the primary development platform, chosen for its support for 3D graphics, user-friendly editor and active developer community. Its frequent updates ensure compatibility with the latest graphical standards, while its scene system, collision detection and input handling were essential for scripting interactions with mission equipment.

[4] https://store.steampowered.com/app/864680/Rover_Mechanic_Simulator/?l=english&curator_clanid=29519836

[5] https://unity.com/

Digital Terrain Models (DTMs) of Mars, captured by NASA's Mars Reconnaissance Orbiter and sourced from the Lunar and Planetary Laboratory at the University of Arizona[6], were processed in Blender[7], a free and open-source 3D modelling suite, in order to be optimized for Unity, maintaining also their terrain features.

3D models of Mars-origin meteorites were also used to enrich the environment, obtained from Astromaterials 3D[8] which provides free high-resolution scanned geological models.

3.2 Mission Structure and Gameplay Loop

In *SOL977*, the player's mission follows a goal-driven repair scenario. Players are presented with a high-level list of objectives through the game's User Interface (UI), which can be toggled anytime during gameplay. These include: a) locating the Ingenuity rover within the Martian landscape; b) retrieving the rover and bringing it back to the base station; c) consulting the Repair Procedure via an interface panel (Figure 2); d) diagnosing and replacing a specific faulty component; and e) completing a verification step to determine success.

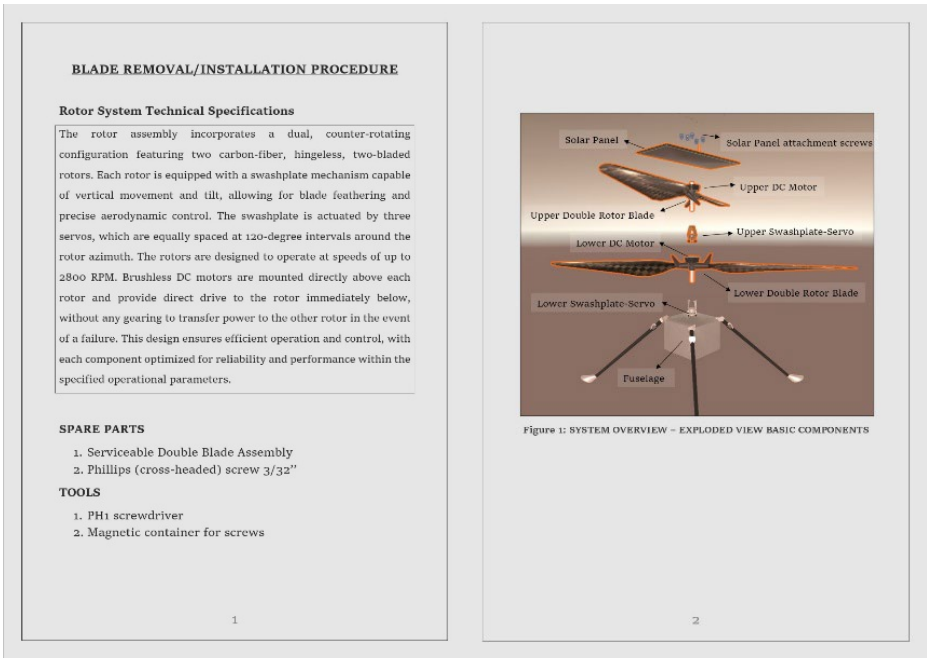

Figure 2: The first two pages of the Repair Procedure in-game manual that the user consults

This sequence, also shown diagrammatically in Figure 3, is a finite set of user-driven events. The structure supports a trial-and-error loop. If the repair is unsuccessful, feedback is provided, prompting the user to retry.

[6] https://www.lpl.arizona.edu/

[7] https://www.blender.org/

[8] https://ares.jsc.nasa.gov/astromaterials3d/

Upon success, a reward is triggered and the session ends. This design enhances engagement and incorporates engineering logic as well as spatial reasoning tasks.

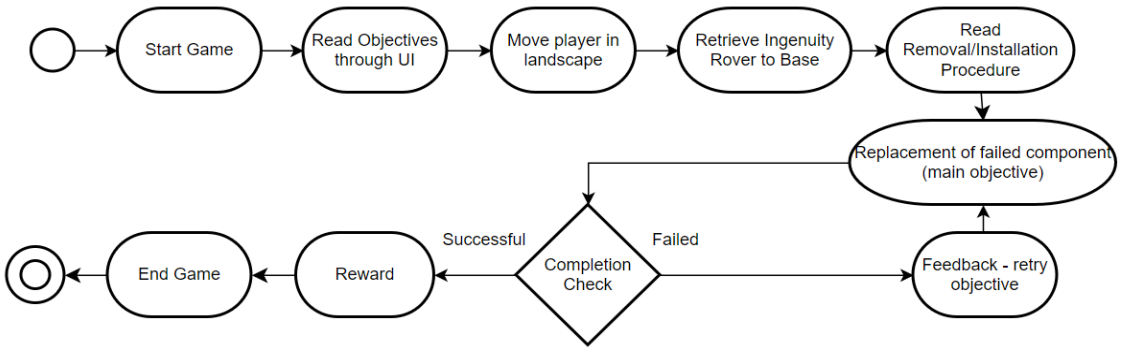

Figure 3: Flow of the simulation gameplay

In stricter terms, the simulation guides the player through a cyclical process of detection, manipulation, validation and feedback. This process encourages logical thinking and hands-on problem solving, helping players build spatial reasoning and procedural skills essential in engineering.

3.3 Object Interaction and Component Replacement Procedure

The main goal is to replace the damaged mechanical part to make Ingenuity operational again. This simulates real aerospace maintenance, where faulty components are replaced rather than repaired on-field, maintaining the mission's pace.

Players interact with essential parts (rotor blades, electronic units and fastening screws) through a first-person camera, keyboard and mouse. Unity's raycasting system ensures that only relevant, tagged objects respond to input. This helps maintain precision avoiding unwanted interactions.

Repairs follow a fixed sequence based on real engineering logic. For example, players must remove screws before detaching the solar panel or replacing the rotor blade in the correct order. Incorrect steps are blocked, prompting players to consult the manual and adjust their approach. Parts lock into place when installed correctly. The simulation checks tool use and task order, encouraging careful observation and reasoning.

3.4 Diagnostic and Feedback Systems

At the end of the repair, the system evaluates the player's work through an in-game diagnostic interface. By interacting with the Rover Communication Platform, players test the rover's condition as the system scans for missing or faulty components and checks that all screws are reattached. It then provides feedback highlighting any issues, such as a faulty part or incomplete steps. This encourages players to review their work while adding a sense of closure to the task.

4. Evaluation Methodology and Student Feedback

To assess the educational impact and user experience of SOL977, a structured evaluation was conducted with 1st-year senior high school students (ages 15–16) at a public lyceum in Pafos, Cyprus. The goal was to gather feedback from a relevant age group through a questionnaire completed after hands-on interaction with the simulation.

4.1 Participants and Procedure

No pre-screening for STEM interest was applied, ensuring a representative group of general education learners. Students participated in small teams of 6 to 8. Each session began with a short presentation introducing Ingenuity's mission and outlining the simulation's goals to provide context and encourage engagement. After each student interacted with the simulation, they anonymously filled out a digital questionnaire via Google Forms, with data collected solely for research purposes.

4.2 Evaluation Design

The questionnaire employed a 5-point Likert scale to capture student perceptions related to the simulation. The scale ranged from 1 (Strongly Disagree) to 5 (Strongly Agree).

In a game-based learning assessment setting, the structured format of Likert-type scales allows for the aggregation of users' subjective feedback, thereby producing quantitative data on their perception of a game's usability (Ifenthaler, Eseryel and Ge, 2012)**.** In general, questionnaires with 5-point Likert scales are considered useful tools for post-game evaluations by game designers, as they effectively capture user impressions of realism and learning value (Harteveld *et al.*, 2010). Particularly, they are efficacious in STEM simulations, where user experiences are compared across different design stages and measurable feedback on learning outcomes is essential (Bellotti *et al.*, 2013).

The evaluation instrument combines three established frameworks:

- **MEEGA+ (Model to Evaluate Educational Games for Computing Education)** was used to shape the learning outcomes, perceived educational value, challenge balance and STEM motivation items. MEEGA+ is specifically designed for educational games and has strong alignment with the objectives of *SOL977*, particularly in capturing cognitive and motivational impact (Petri, Gresse von Wangenheim and Borgatto, 2018).
- **EGameFlow (Educational GameFlow Model)** guided the design of items measuring engagement, immersion, autonomy and clarity of goals. It provides a structured way to assess how game elements promote focus, enjoyment and meaningful participation in educational contexts (Shu-Hui, Wann-Yih and Dennison, 2018).
- For usability and interface interaction, elements were adapted from the **System Usability Scale (SUS)** by Brooke (1996), such as ease of use, confidence in interaction and integration of system functions. Although the original SUS 10-item format was not used verbatim, the structure of statements was clearly influenced by its phrasing and focus.

The final questionnaire was presented bilingually in Greek and English for accessibility and organized into three thematic sections: (a) Usability and User Experience, (b) Engagement and Immersion and (c) Learning and Educational Value. Each section included 4–6 Likert-scale rated items, followed by two open-ended questions. A total of 28 responses were collected from the target demographic. While this modest sample size provides valuable exploratory data, the insights should be interpreted as preliminary.

4.3 Summary of Student Impressions

Preliminary analysis of the data showed that students responded positively across most dimensions. In particular:

- **Usability** received strong scores, with most participants agreeing that controls were responsive and easy to get familiar with.
- **Engagement** was also rated highly with several comments highlighting the realism of the Martian environment and the enjoyment of "fixing the drone".
- Regarding the **educational value**, a majority of students reported that they had learned something new about engineering procedures and space exploration as a whole.

No critical usability issues were identified, although a few students noted initial confusion before discovering the help menu. That suggests that minor onboarding improvements could enhance the user's experience.

These initial findings suggest that SOL977 has the potential to create a playful yet informative experience that combines science content with meaningful interaction. While the responses indicate student engagement and perceived educational value, these outcomes should be viewed as exploratory. Further evaluation with broader and more varied participant groups is needed to substantiate these impressions.

Some indicative evaluation results are shown in Figure 4.

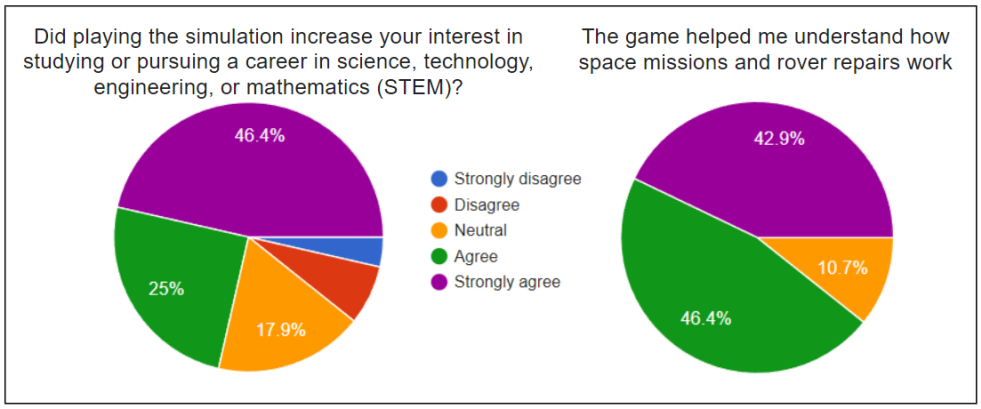

Figure 4: Indicative evaluation results of *SOL977: Ingenious Revival* by high-school students

4.4 Thematic Insights from Open-Ended Responses

To complement the quantitative evaluation, two open-ended questions were included in the post-game questionnaire to gather qualitative feedback on (a) how the simulation engaged students' critical thinking and (b) potential areas for improvement. These responses were thematically analysed to identify patterns of sentiment and recurring suggestions.

4.4.1 Engagement with critical thinking and problem-solving

Many students highlighted that the game prompted them to "think more about next steps", "solve small logical problems" and "follow a procedure carefully". The immersive design was reported to "make them think like real engineers" and enhanced their focus. Even brief responses like "It engaged me creatively" and "It made me think of what the next step is", reinforce that the procedural nature of the simulation encouraged reflective reasoning.

4.4.2 Suggested improvements

Suggestions clustered mainly around three themes:

- **Usability Enhancements**: A number of students indicated that the controls were occasionally confusing or unintuitive, suggesting the addition of a short tutorial or guide (e.g., "I would make the controls easier or add a guided tutorial").
- **Content Expansion**: Some responses expressed interest in more varied or extended gameplay (e.g., "More content and missions").
- **Feedback and Interface Cues**: Others recommended that feedback to the user should be more explicit (e.g., "It should show a warning when you're holding an object").

These qualitative insights reinforce the positive reception of the simulation's design and point to feasible improvements that could further enhance educational value and user experience in future versions.

4.5 Limitations

Although the evaluation offers useful early feedback, several limitations must be acknowledged. The sample consisted of 28 students from a single public lyceum in Cyprus, which limits the generalisability of the findings to wider populations. Participants shared similar educational backgrounds and cultural contexts, which may not reflect the diversity of secondary-level learners more broadly.

Additionally, the study did not employ a control group or pre/post-testing design, restricting the ability to infer learning gains or isolate specific effects of the simulation. The use of self-reported questionnaire data, while informative for user experience, may also be subject to bias and lacks triangulation with objective performance metrics.

5. Conclusion and Future Work

SOL977: Ingenious Revival demonstrates how simulation-based learning can support STEM education through immersive, task-oriented gameplay. By integrating realistic engineering workflows into an accessible interactive setting, the simulation encourages technical curiosity and problem-solving.

Field evaluation with senior high school participants produced encouraging early feedback. Students found the experience engaging and informative, with many reporting increased interest in space technology and engineering. Feedback also identified areas for improvement, such as clearer visual cues and more detailed instructions, pointing to opportunities to enhance usability and user support.

Future development will expand *SOL977*'s content and functionality, introducing new mission scenarios and mechanical challenges. One planned addition is a scoring system to provide players with real-time feedback on performance, based on accuracy and efficiency. A multiplayer mode would allow users to collaborate on diagnostics and repairs, more accurately reflecting real-world engineering teamwork and further promoting problem-solving skills.

From a research perspective, future studies should adopt more rigorous methodologies to better evaluate SOL977's educational effectiveness. This includes pre- and post-testing designs, control groups and the use of analog environments (e.g., physical Martian repair simulations) to compare experiential outcomes. For example, future experiments might involve one group performing a repair in a Mars analog suit after using the simulation, while a control group attempts the same task without prior digital training.

Moreover, expanding participant recruitment to include students from technical or vocational schools could reveal how such simulations support learners with more hands-on engineering backgrounds. These learners may find particular value in the procedural and mechanical aspects of SOL977, regardless of whether they intend to pursue space-related careers.

In conclusion, while SOL977 shows clear promise, its educational impact cannot yet be definitively established. Further large-scale, multi-institutional studies are needed to validate its applicability across diverse learner populations and settings. Nonetheless, with ongoing refinement and evidence-based design, SOL977 has the potential to become a valuable tool for both formal and informal STEM learning environments focused on space exploration and applied engineering.

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Ethics Declaration: No ethical clearance was needed for the research referred to in this paper.

AI Declaration: Generative AI was used to check whether particular English phrases in the authors' work were grammatically or syntactically correct.

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Using AI and Cognitive Taxonomies to map Learning Processes in Board Games

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Abstract: Board Game-Based Learning (bGBL) has gained increasing attention as an innovative approach to foster active engagement and holistic cognitive development. However, integrating board games into effective practice is challenging, partly because of the lack of an established instructional framework. The implementation of bGBL often relies on teachers' personal initiative and familiarity with games, rather than on shared design practices. One of the main obstacles to implementing GBL lies in properly aligning learning goals with the actions that take place during gameplay, and the related learning processes. In this study, we develop a theoretical framework for aligning learning goals and the cognitive processes elicited by game mechanisms. We use this framework to train a GenAI assistant (GADbot) to assist bGBL instructional design, assessing its performance through human expert evaluation. Given the ever-increasing number of available board games and the constant innovation in game mechanics, this approach can revolutionize the field of bGBL, leveraging AI as an assistant to lower the entry barrier for teachers to choose the right game for their educational needs, thus providing the foundation to design meaningful learning experiences and advance active pedagogical practices.

Keywords: Board games, Instructional design, Artificial intelligence, Chatbot, RIZA

1. Introduction[1]

In recent years, *Board Game-Based Learning* (bGBL) has gained increasing relevance as a teaching methodology capable of combining active engagement, experiential learning, and the development of cross-cutting skills (Gee, 2003; Plass, Homer & Kinzer, 2015). Thanks to their explicit structure and transparent rules, board games offer ideal conditions for observing cognitive processes in real time, making them privileged tools for designing authentic learning environments (Andreoletti & Tinterri, 2023). However, the introduction of bGBL in formal learning environments, such as schools and universities, is still sporadic and largely dependent on individual initiatives by teachers (Persico et. al., 2019). Furthermore, most of these activities relegate games to recreational or mere exercise functions, coming short of realizing the full potential of board games as full-fledged learning environments (Cantoia, Clegg, and Tinterri, 2023). One of the main obstacles to implementing GBL lies in properly aligning (Biggs, 1996) learning goals with the actions that take place during gameplay, and the related learning processes (Arnab et al., 2015). In this sense, the cognitive functions activated by board games should not be seen as generic by-products of the activity, but as levers for achieving specific educational objectives. By identifying and mapping these functions, educators can intentionally design game experiences that target distinct learning outcomes in cognitive, disciplinary, and transversal domains. This is critical for effective implementation of bGBL, in-game and around-game assessments, and real-time calibration of the learning process (Andreoletti and Tinterri, 2023). This is the context for the contribution of Tinterri, Di Padova, and Pelizzari (2024), which proposes an integrated theoretical framework for analyzing and designing bGBL activities in an intentional and evaluable way. The model is based on three axes:

1. The taxonomy of Anderson & Krathwohl (2001), useful for classifying and designing oactivities based on the cognitive processes involved;
2. The R-I-Z-A model (Trinchero, 2017; 2018), which describes the executive functions activated in complex educational contexts (representation, interpretation, activation zone, self-regulation);
3. The concept of situated competence (Le Boterf, 2000), understood as the integrated mobilization of knowledge, skills, and attitudes in meaningful contexts.

[1]The paper was conceptualized and developed collaboratively by all authors, with each contributing to specific sections based on their expertise. A.T. was responsible for writing sections Results and Conclusion. M.d.P. authored section Material and methods and Discussion. F.P. authored section Introduction and Theoretical Framework.

These three axes make it possible to overcome reductive views of playful learning, providing an operational model for the design and evaluation of activities. In particular, the R-I-Z-A model allows us to observe play as a sequence of micro-cycles of interpretation, action, and reflection, consistent with the experiential learning paradigm (Kolb, 1984) and with the definition of open-ended problems (Trinchero, 2012). This makes play not only a space for practice, but also for the active construction of skills. Starting from this framework, the present study aims to develop a further level of formalization by proposing a generative artificial (GenAI) intelligence-based support system for the automatic mapping between game mechanics and cognitive processes. The goal is to provide a scalable tool that helps teachers and designers select games consistent with specific educational objectives, democratizing access to bGBL and facilitating instructional alignment (Biggs, 1999; Arnab et al., 2015). This approach, which combines established theory and emerging technology, represents a step towards an evidence-based pedagogy capable of harnessing the educational potential of games, not only as a motivating activity, but as a structured space for the development of critical thinking, cooperation, and self-regulation (Shute & Ventura, 2013; Barab et al., 2010).

2. Theoretical Framework

The framework is based on three theoretical axes: (1) Anderson & Krathwohl's taxonomy (2001); (2) the R-I-Z-A neuroeducational model (Trinchero, 2017; 2018); (3) Le Boterf's construct of situated competence (2000). Anderson and Krathwohl's (2001) revision of Bloom's taxonomy proposes a two-dimensional matrix that crosses cognitive process levels (remembering, understanding, applying, analyzing, evaluating, creating) with types of knowledge (factual, conceptual, procedural, metacognitive). This model allows not only the classification of educational objectives but also the design of activities consistent with them (Biggs, 1999). In the bGBL context, this taxonomy allows the mapping of cognitive processes activated by game mechanics (Engelstein & Shalev, 2019), making the link between game rules and educational objectives visible. Some mechanics—such as narrative choice, prisoner's dilemma, or simultaneous action selection—activate high levels of the taxonomy, promoting reflection, critical evaluation, and the generation of new solutions (Wouters & van Oostendorp, 2017).

The **R-I-Z-A** model, developed by Trinchero (2017; 2018), was created in the context of neuroeducation with the aim of mapping and enhancing the executive functions involved in complex educational contexts. It is divided into four dimensions:

- Resources: mental construction of patterns, rules, meanings;
- Interpretation: active decoding of the context and available information;
- Activation zone: experimentation between the known and the new;
- Self-regulation: conscious monitoring and regulation of one's own actions.

In the context of bGBL, R-I-Z-A proves to be a dual tool: descriptive and formative. On the one hand, it allows educators to observe precisely how players activate complex cognitive strategies during play; on the other hand, it stimulates metacognition, thanks to reflection on how the game was played (Trinchero, 2012). The correspondence between playful dynamics and cognitive structure is based on the idea of play as an open problem: each game involves continuous cycles of interpretation-action-reflection that mirror the experiential learning cycle (Kolb, 1984; Trinchero, 2017). In games such as *Just One* or *Dixit*, for example, the player must:

- Represent internal rules and objectives (semantic or strategic);
- Interpret ambiguous signals, implicit communications, and the movements of others;
- Act by choosing between several possible strategies with different outcomes;
- Self-regulate based on the feedback received, adapting their behavior.

This recursive sequence (interpretation, action, reflection) allows us to observe both micro-decisions (tactical) and macro-strategies (strategic), providing qualitative evidence of the learning process (Gobet, Retschitzki & De Voogt, 2004). The third theoretical axis is based on the concept of **competence as a situated construct**, proposed by Le Boterf (2000, 2006). Competence is not simply the sum of knowledge and skills, but the dynamic articulation between:

- Savoir: theoretical knowledge;
- Savoir-faire: operational skills;
- Savoir-être: relation and attitude.

In play, these aspects emerge simultaneously: the player mobilizes prior knowledge, acts in complex situations, and interacts with other subjects in a regulated but open context (Lave & Wenger, 1991). Learning takes place through legitimate and progressive participation in meaningful practices, as illustrated in the concept of *playful apprenticeship* (Barab, Gresalfi & Ingram-Goble, 2010). This theoretical framework allows us to overcome reductive views of playful learning, anchored solely in motivation or participation, and instead proposes an analytical reading of game dynamics as highly cognitive training spaces. In this perspective, the mechanical transparency of board games (i.e., the visibility of rules and the effects of actions) is a pedagogical advantage: it allows players to reflect on decisions and strategies, facilitating metacognition and formative assessment. However, the systematic adoption of bGBL in formal educational contexts remains limited. Among the main obstacles is the difficulty of aligning game mechanics with educational objectives and expected cognitive processes, often due to a lack of shared theoretical and operational tools (Sousa et al., 2023; Persico et al., 2019). The risk, therefore, is that the use of games remains confined to a motivational dimension, without effective integration into learning pathways. As highlighted by Arnab et al. (2015), one of the central hubs of Game-Based Learning consists in the alignment between game mechanics and learning mechanics (LM-GM mapping). However, in practice, this alignment remains difficult to implement in the absence of shared and accessible models to guide design and evaluation. Some notable attempts in this direction include the model by Garris, Ahlers, and Driskell (2002), the principles of evidence-centered design (Mislevy et al., 2014), and more recently, the framework proposed by Tinterri, Di Padova, and Pelizzari (2024). This work is in line with the theoretical framework outlined above, fitting into this theoretical framework with the aim of automating the process of mapping game mechanics and cognitive processes through the use of artificial intelligence. In particular, it aims to systematize and scale this process through the development of an AI assistant capable of associating game mechanics with cognitive processes according to the A&K taxonomy, automating the most intensive phase of instructional design. AI is conceived here not as a substitute for the teacher, but as a *digital scaffold* to facilitate the design of bGBL experiences consistent with stated educational objectives (Arnab et al., 2015; Gómez Niño et al., 2024). This choice is based on two main objectives: (1) board games offer a structured and iterative environment, ideal for analyzing the link between action and learning, but it is necessary to generate a database that allows, over time, to refine the alignment models between game dynamics, cognitive processes, and assessment strategies; (2) the combination of established theoretical models and advanced digital tools can break down barriers to the adoption of bGBL, providing teachers and educational designers with concrete tools to select, adapt, and evaluate games according to educational objectives. In this way, game design is no longer left to individual intuition, but anchored to validated theoretical models and observable evidence (Mislevy et al., 2014; Shute & Ventura, 2013).

3. Aim of the Study

The goal of this study is to develop a GenAI assistant to help teachers design bGBL activities that (a) fully employ the learning potential of games (b) define expected learning outcomes according to the theoretical framework described above (c) include suggestions for personalization of the activity according to the learner specific needs. This paper describes the process of designing a first prototype of the assistant Game Analysis and Design (GAD)Bot and discussion of the early outcomes of the Bot.

3.1 Material and Methods

Desired Functions of the Chatbot: GADBot was conceived as a pedagogical assistant to support teachers, educators, and instructional designers in the intentional design of board game-based learning (bGBL) activities. Its core function is to suggest appropriate games by analyzing a complex set of educational variables, including the target student profile, the subject area, the learners' previous experience with bGBL, the intended learning objectives, and the presence of students with specific learning needs. Rather than simply recommending games, GADBot activates an inferential process that maps game mechanics to cognitive processes and situated competences. The system is capable of assessing students' age, cognitive development, and familiarity with games, thereby selecting titles that are appropriate in terms of complexity, social interaction, and accessibility. By leveraging the theoretical models discussed in the article—specifically Anderson and Krathwohl's taxonomy and Trinchero's R-I-Z-A model—GADBot links in-game actions to activated cognitive operations, and formulates suggestions oriented toward measurable learning outcomes. Simultaneously, the chatbot accounts for inclusion-related constraints, offering adaptation strategies aligned with Universal Design for Learning (UDL), such as simplified rules, role redistribution, and multimodal supports (Rao, Torres & Smith, 2021).. In this way, GADBot operates as a flexible and theory-informed design tool that adapts to diverse educational contexts without compromising pedagogical rigor.

Design of the Chatbot: GADBot was developed as a Custom GPT within the OpenAI platform, following a modular architecture that supports dialogue-based educational design (Nyaaba & Zhai, 2024). The interaction begins with user input describing the learning context, goals, classroom profile, and any relevant constraints. These inputs are processed by a semantic reasoning engine that queries a structured and annotated dataset of board games, sourced from BoardGameGeek.com and enriched with educational metadata. The chatbot's inferential core enables it to select suitable games based on a cognitive matrix that links gameplay mechanics to executive functions, cognitive verbs, and situated learning processes. From this selection, GADBot generates a complete learning activity divided into phases—preparation, gameplay, and reflection—specifying for each phase the learning goals, student tasks, timing, assessment methods, and inclusive strategies. A metacognitive function is also embedded: GADBot can self-assess the coherence of its proposals with the user-defined objectives and provide a concise summary of the activity for validation (Hutson & Plate, 2023). The assistant operates in both English and Italian, adapting its technical register based on user expertise and, when appropriate, referencing relevant pedagogical frameworks such as constructivism, experiential learning, and gamification. GADBot thus functions not only as a recommender but also as a design mediator between theory and practice, between cognitive models and instructional constraints (Honig, Desu & Franklin, 2024).

Training of the Chatbot: The training of GADBot followed a multi-phase process (Liu et al., 2023; Arora et al., 2022; Bibauw et al., 2022) aimed at constructing an assistant capable of integrating validated theoretical models, structured empirical data, and realistic educational scenarios. Its knowledge base combines regulatory and pedagogical sources—including the full body of Italian school legislation, Anderson and Krathwohl's taxonomy, Trinchero's R-I-Z-A model, and Le Boterf's notion of situated competence—with a curated and continuously updated dataset of board games from BoardGameGeek.com. This dataset includes detailed information on mechanics, player interaction, age range, duration, accessibility, and community feedback. The identification and classification of game mechanics is based on the framework developed by Engelstein and Shalev (2019), which offers a comprehensive systematization of the core dynamics found in modern board games. These mechanics were used to annotate a selected subset of games, each of which was then aligned with specific cognitive processes and executive functions. This mapping enabled the chatbot to associate game structures with learning outcomes in a coherent and theory-informed manner. The assistant was refined through iterative tuning via simulated dialogues with teachers, where requests included game analyses, comparative evaluations, inclusive learning activity proposals, and assessment planning. GADBot's responses were evaluated using a dedicated rubric with four dimensions—activity structure, game selection, learning objective definition, and personalization suggestions (Table X)—which facilitated continuous improvement of its pedagogical alignment and reasoning capabilities. When the proposed game is not found in the dataset, GADBot activates an analogical reasoning protocol, requesting additional details (e.g., game mechanics, duration, number of players) and proposing comparable games for inference. As a result, the system functions as a scalable and pedagogically-grounded assistant, capable of supporting the intentional construction of meaningful and inclusive learning environments.

Analysis of Chatbot responses: To evaluate the responses obtained from GADBot, a rubric was developed including three main criteria: the structure of the proposed activity, the choice of the game, the learning objectives, and personalization suggestions. Each criterion included three indicators which were rated on a four-level scale, from "excellent" to "insufficient" (Table 1). The responses were analyzed independently by three experts with years of experience in the field of bGBL and provided as feedback to GADBot for further refinement.

Table 1: The criteria and indicators used for evaluating the output of GADBot

Criteria	Indicator
Structure of the activity	The phases of the activity are clearly defined
	The phases of the activity are aligned with the learning goal(s) provided by the user
	The activity can realistically be implemented in the given context
Choice of the game	The game of choice is appropriate for the students' age and experience
	The game mechanics are described correctly

Criteria	Indicator
	The gameplay is aligned with the learning objectives
Definition of learning objectives	The learning objectives follow the R-I-Z-A model
	The learning objectives are attainable within the proposed activity
	The learning objectives are aligned with the learning goal(s) provided by the user
Personalization	The personalizations proposed can be realistically implemented
	The personalizations proposed are coherent with the students profile
	The personalizations proposed enhance the inclusiveness of the activity

3.2 Results

The GADBot tool is still in a work in progress phase as it keeps being trained for accuracy, therefore a comprehensive analysis of its output is outside the scope of this contribution. However, this section describes a sample output for a GADBot interaction and the feedback received from the human evaluators. GADBot was asked to design an educational activity based on the following prompt:

Suggest a board game for a learning activity for students 5th class of the Primary school, on the topic of: the fall of the Occidental Roman Empire and the "romanic-barbaric reigns". The students have very limited experience with playing games in the classroom. The expected learning outcomes are "recognize the traces of the past in one's own social and geographic context" and "knowing and analyzing the main historic events". Also, the activity should be personalized for a student with mild cognitive impairment.

After the chatbot provided its answer, it was asked to self-analyze its answer by asking:

In your opinion, is this activity aligned with the learning goals which were provided?

Following this prompt, the ChatBot analyzes its output and provides corrections. In some instances, the chatbot observed that the activity was not entirely aligned with the learning goals and provided corrections. In this case, however, GADBot found that the activity was well aligned with the learning goals provided. Finally, a third prompt requested the Chatbot to summarize the activity (Table 2). The output of this prompt was provided to four human bGBL experts to evaluate the quality of the activity created by the bot.

Table 2: Summary of a sample activity proposed by GADBot

Title	**The Fall of an Empire: Building the Timeline of the Roman-Barbarian Kingdoms**
Context	Class: 5th grade primary school Setting: classroom with tables arranged in small groups (3–4 students per group) Timeframe: 2 lessons of 60 minutes each Prerequisites: basic knowledge of Roman civilization, understanding of chronological order Game experience in classroom: minimal One student with mild cognitive impairment (MCI)
Learning goals	**Key European Competences** Cultural awareness and expression Historical competence (based on Italian National Guidelines, 2012) **Learning Goals for History (5th grade)** Identify historical traces in the local environment.

<table>
<tr><td>Title</td><td colspan="3">The Fall of an Empire: Building the Timeline of the Roman-Barbarian Kingdoms</td></tr>
<tr><td></td><td colspan="3">Know and sequence key events from ancient history.
Specific Learning Objectives
Place events and civilizations in time and space.
Reconstruct simple historical sequences.
Recognize visual and material sources.</td></tr>
<tr><td rowspan="4">Expected outcomes</td><td>Learning Action</td><td>RIZA Descriptor</td><td>Cognitive Level</td></tr>
<tr><td>Recognize elements from Roman and Barbarian worlds</td><td>Recognize</td><td>Remember</td></tr>
<tr><td>Order key events related to the fall of the Empire</td><td>Select – Locate</td><td>Understand – Analyze</td></tr>
<tr><td>Build a shared timeline</td><td>Represent – Collaborate</td><td>Apply – Create</td></tr>
<tr><td>Structure of the activity</td><td colspan="3">PHASE 1 – Introduction and knowledge activation
Guided discussion with visuals (Roman soldier, Visigoth, Empire map)
Stimulus questions: “Who were the barbarians?”, “What happens when an empire falls?”
Duration: 15–20 min
PHASE 2 – Cooperative game: simplified Timeline
Each group receives historical cards (e.g. "410 AD: Sack of Rome", "476 AD: Romulus Augustulus abdicates")
Students work to place cards in chronological order
Visual aids used (icons, simple captions)
Duration: 30 min
PHASE 3 – Debriefing and collective discussion
Timeline reviewed as a class
Reflective questions: “What does this sequence tell us?”, “Who were the key figures?”
Duration: 15 min
PHASE 4 – Authentic task
Each group creates a new event card or a historical comic strip
A synthesis and creativity task with teacher support
Duration: 40–60 min</td></tr>
<tr><td>Inclusion</td><td colspan="3">Large, high-contrast images, concept maps, simplified language
Group placement with peer tutor, step-by-step instructions, extra time
Use of cut-out visuals, verbal or drawn responses instead of written</td></tr>
<tr><td>Materials</td><td colspan="3">Timeline cards (original or customized)
Physical or wall-mounted timeline
Historical maps and images
Visual aids and scaffolding sheets
Posters, scissors, markers for final task</td></tr>
<tr><td>Assessment</td><td>Formative</td><td>Ongoing observation grid</td><td>Participation, cooperation, historical vocabulary usage</td></tr>
</table>

Title	**The Fall of an Empire: Building the Timeline of the Roman-Barbarian Kingdoms**		
	Self-assessment	Simplified form	"What did I understand? Where did I need help?"
	Summative	Final product (card or comic) + oral explanation	Historical accuracy, creativity, sequence coherence

The activity was then rated independently by three human experts using the aforementioned rubric (Figure 1).

Indicator	Rating			
	Excellent	Good	Sufficient	Insufficient
The phases of the activity are clearly defined	●●●			
The phases of the activity are aligned with the learning goal(s) provided by the user	●	●●		
The activity can realistically be implemented in the given context	●●	●		
The game of choice is appropriate for the students' age and experience	●●	●		
The game mechanics are described correctly	●●●			
The gameplay is aligned with the learning objectives	●	●	●	
The learning objectives follow the R-I-Z-A model	●●●			
The learning objectives are attainable within the proposed activity	●	●●		
The learning objectives are aligned with the g learning goal(s) provided by the user	●	●	●	
The personalizations proposed can be realistically implemented	●	●●		
The personalizations proposed are coherent with the students profile	●	●●		
The personalisations proposed significantly enhance the inclusiveness of the activity	●	●	●	

Figure 1: Summary of the sample activity evaluation by independent bGBL experts

Overall, the evaluators were satisfied with the quality of the activities proposed by the tool. The chatbot was able to provide clearly structured activities, using games that were appropriate for the context, using the RIZA framework to define learning objectives in line with the learning goals and largely attainable within the activity. Still, depending on the activity, the chatbot answers were sometimes not entirely aligned with the learning objectives, or the game was tangential to the activity rather than as its focal point. Furthermore, due to the well documented variability of the technology (Tinterri et al, 2024) in a few occasions the answers of GADbot were missing parts of the required information, which could be obtained through further prompts.

4. Discussion

Despite supporting evidence by the scientific literature, board game-based learning (bGBL) is very seldom employed in schools and other formal learning environments. This is due in part to the complexity of game-based instructional design, which requires both knowledge of games and game pedagogy, and to the lack of an established pedagogical framework for bGBL instructional design. In this study, we have developed a theoretical framework and used it to train a Generative AI chatbot (GADbot) designed to support teachers. While still in a prototyping phase, the early returns of the bot have been positively rated by human bGBL experts, while providing feedback for further training of GADbot. But whereas the approach seems promising to obtain high

quality, personalised assistance for teachers trying their hand at using bGBL, there are some limitations that need to be addressed. First, the tool has not received an extensive assessment; to this aim, a more comprehensive analysis of the bot output must be realized. Second, the tool must be validated not only by bGBL experts but also by actual teachers, to understand whether its output is not only scientifically sound but also helpful for classroom implementation. Third, the bot should not be perceived as a substitute for teacher effort to develop mastery of bGBL instructional practices, but rather as an assistant and support tool to enhance its impact, allowing her to autonomously research and experiment with bGBL. Fourth, the ethical and effective use of artificial intelligence tools requires specific competence, to avoid the "garbage in, garbage out" phenomenon and obtain quality answers (Cuomo, 2023); thus, teachers and educators should receive specific training on AI functioning and prompting strategies to maximize the potential of GADbot. Finally, further research should be conducted to evaluate the effectiveness of GADbot-assisted learning activities in real-life scenarios, addressing not only teacher perceptions but also the learning outcomes that can be achieved by students and the implications of bGBL use in educational contexts. Future research is thus required to answer the following questions: a) is GADbot perceived by teachers as a helpful tool for bGBL design? b) to which measure are activities designed with GADbot effective in terms of student learning achievements? c) how can GADbot be effectively integrated in teacher bGBL training?. Taken together, this study combines advancements in the field of GBL with innovation in AI-assisted learning design, with the aim of making bGBL more appealing to educators and instructional designers; this contribution, albeit promising, is then just a first step in a path with the potential to make bGBL, and its tantalizing potential for learning, accessible to a larger audience.

5. Conclusions

As the interest of both the general public and academic research on the educational effectiveness of board games is on the rise, the potential of generative artificial intelligence for learning could provide innovative solutions to the longstanding problem of how to effectively implement board game-based learning in traditional educational settings. The GADbot assistant, built upon a solid theoretical framework, shows intriguing potential and could be a game-changer for teachers and educators with an interest in bGBL but limited by their lack of knowledge of games; however, further research and empirical validation is required to improve this tool and evaluate its effectiveness in real-life situations.

Ethics declaration: The study adheres to relevant data protection regulations and ethical guidelines governing research involving human participants.

AI declaration: Artificial intelligence (AI) tools were used to support the preparation of this manuscript. Specifically, ChatGPT (OpenAI) was used to build the GADbot tool described and analysed in the study. The body of the paper includes content generated from the chatbot to illustrate its output.

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Serious Game Design and Evaluation: Light Propagation and Reflection in Elementary Education

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Abstract: The intangible nature of light is the primary reason why children develop misconceptions in their attempts to understand phenomena related to light and its properties. The most common misconceptions among children aged 11-13, are related to what happens when light strikes a mirror. This difficulty stems from their inability to perceive light as an entity in space. Therefore, the use of various representations and experiments is necessary for children to effectively construct light-related concepts. This study reports the design and evaluation of a logic-based digital game for fifth- and sixth-grade primary school students, named "*Fotogonies*". Ten levels were developed as a minimum viable, fully functional version of the game. The player guides a laser beam from a source to a target by rotating mirrors. The game becomes progressively more challenging, with the difficulty carefully calculated and gradually increased. The main goal is to create an appealing digital game that can deliver educational value. It is designed to accurately represent key concepts of light propagation and reflection, with specially defined mechanics and rules, aligning with the relevant scientific models. At the same time, the game meets the requirements of serious educational games, balancing simplicity and low-cost development. Additionally, emphasis was placed on designing a classroom-friendly game with an easy-to-use setup to support possible widespread adoption. Surprisingly, the first tests showed that the game can be equally challenging and appealing for adults. The resulted game was evaluated in terms of usability and user satisfaction, gathering both quantitative and qualitative data. The evaluation showed that the participating students had a positive experience engaging with it - an essential precondition for supporting conceptual change regarding children's misconceptions about light. Furthermore, the evaluation revealed that self-reporting questions addressing specific aspects of the game (consistency, learnability, difficulty), may not be as reliable as qualitative results when answered by young children.

Keywords: Digital game, Physics, Optics, Primary school, Game-Based learning

1. Introduction

Serious games can have a positive impact on cognition, as playful activities can evoke interest, commitment, and fun (Lopez et al., 2023). According to Ullah et al. (2022), there are significant gains in conceptual understanding and problem-solving when serious games in education are well aligned with the critical principles of the targeted scientific concepts. Utilising them in education, however, is primarily guided by defined learning goals, while fun is a secondary objective. Indeed, most primary school studies emphasise design and evaluation in terms of learning gains, with usability and overall player experience addressed secondarily (Kara, 2021; Juhari, Hani & Bakar 2020; Cheng et al., 2015).

At the same time, not many studies report on digital games related to concepts of light. One such study is that of Huei et al. (2014), which reports on the development and evaluation of Shimmer©, a three-dimensional digital educational game designed to teach basic optical phenomena such as reflection and refraction to students aged 12-13. In the game, students solve problems by guiding laser beams through the strategic placement of mirrors and lenses across levels of increasing difficulty. The study's findings highlight a significant improvement in conceptual understanding, emphasising the importance of game-based learning and the need for educationally grounded digital game design. Regarding the participants' experience, however, that study focuses more on assessing the flow construct of the game, rather than usability aspects or students' satisfaction. Another game includes light propagation as one of its main concepts. However, it is a Virtual Reality (VR) game in which the physics principles are quite advanced, targeting young adult students. Additionally, VR equipment is not designed for children under 13 years, while the game production itself seems complex and time consuming (Zhang, Zhang & Lee, 2025).

From a design perspective, hardware costs and technical complexities can require instructional and set-up time, which may limit adoption in classrooms (Ullah et al., 2022). Moreover, games addressing specific topics are generally used only to support certain curriculum chapters, not daily or year-round. Therefore, design should balance low production costs with high quality.

Under this scope, the main objective of this work is to propose a game that provides students with an environment where they can explore two fundamental concepts related to light: propagation and reflection. More specifically, the game aims to allow students to intuitively discover that light travels in a straight line and changes direction when it strikes smooth, reflective surfaces at predictable angles (angle of incidence equals the angle of reflection). The name of the game, "*Fotogonies*" (Greek: Φωτογωνίες = Light angles), indicates exactly that. The goal is to propose a simple, relatively low-cost, yet appealing and high-quality game that not only contributes to the educational objective, but also provides a positive experience for students.

This paper reports on the design decisions made, focusing on the *Fotogonies* player experience. Section 2 outlines the relevant requirements for serious educational games, while Section 3 describes the game design, covering the gameplay, navigation, mechanics, rules, level design and accessibility. Section 4 summarises the findings from initial formative evaluations and presents the results of a summative evaluation of usability and user satisfaction conducted with fifth-grade students. Additionally, to assess learning gains, a pretest-posttest evaluation and four metrics (e.g., level completion time) were used to analyse the students' behaviour. However, although the learning impact results were positive, they are beyond the scope of this work.

2. Educational Requirements

The game should be embedded in the appropriate learning context and enriched with well-designed interactive artefacts, enabling teachers to teach and learners to learn, as with any other educational material (Dimitracopoulou, 2018). Through this lens, the game should address the key design requirements for serious educational games. Based on those defined by Al-Awadai (2024) and Asadzadeh et al. (2024), essential requirements were identified as relevant, necessary, and adequate for designing *Fotogonies* for fifth- and sixth-grade primary school classrooms. These are organised into eight axes:

- Scientific fidelity and misconceptions: graphics and rules representing scientific optics while addressing common children's misconceptions related to light (e.g., light shines but does not travel) (Driver, Guesne & Tiberghien, 1985).
- Story and goal: a game that is simple, engaging, age-appropriate, and free of cultural or gender bias.
- Mechanics: use of clear, intuitive, minimal mechanics that map directly onto the underlying physics.
- Interactivity: incorporate encouragement, provide feedback in text and audio, and allow social interaction.
- Challenge: gradually increasing difficulty with clear, attainable objectives and repetitive tasks.
- Rules: concise rules that limit player actions to support concentration and reasoning.
- User interface and usability: a visual representation that makes sense and is consistent and responsive.
- Accessibility and cost: a low-cost game, use of high-contrast colour combinations appropriate for most vision conditions.

3. Digital Game Design

3.1 Game Story, Goal and Navigation

A two-dimensional, logic-based puzzle game was designed and developed in Unity using C# for Android devices. When the application launches, the user is presented with a home page with "Play" and "Exit" options. The core gameplay is guiding a beam of light from a source (beam torch) to a target (candy) by rotating mirrors. After the player taps "Play", a brief introduction explains the objective: "Find the candy in the dark. Tap on the mirrors to turn them to the right angle and hit the candy". It is a story that most children can relate to, resembling a real-life scenario of searching for something in the dark. The player rotates mirrors by tapping them. Each tap rotates the mirror by 45 degrees clockwise and counts as a single move (Figure 1). It was intentional to exclude a "game over" tactic, which could be tiring and discourage a player after failure. Instead, if the player exhausts all available moves without hitting the target, a failure screen suggests a retry of the same level. The player can replay it until they solve it and continue to the next. Each level also includes a "Home" button for easy navigation back to the main menu. From there, the player can "Play" from the first level or "Exit" the game (Figure 2).

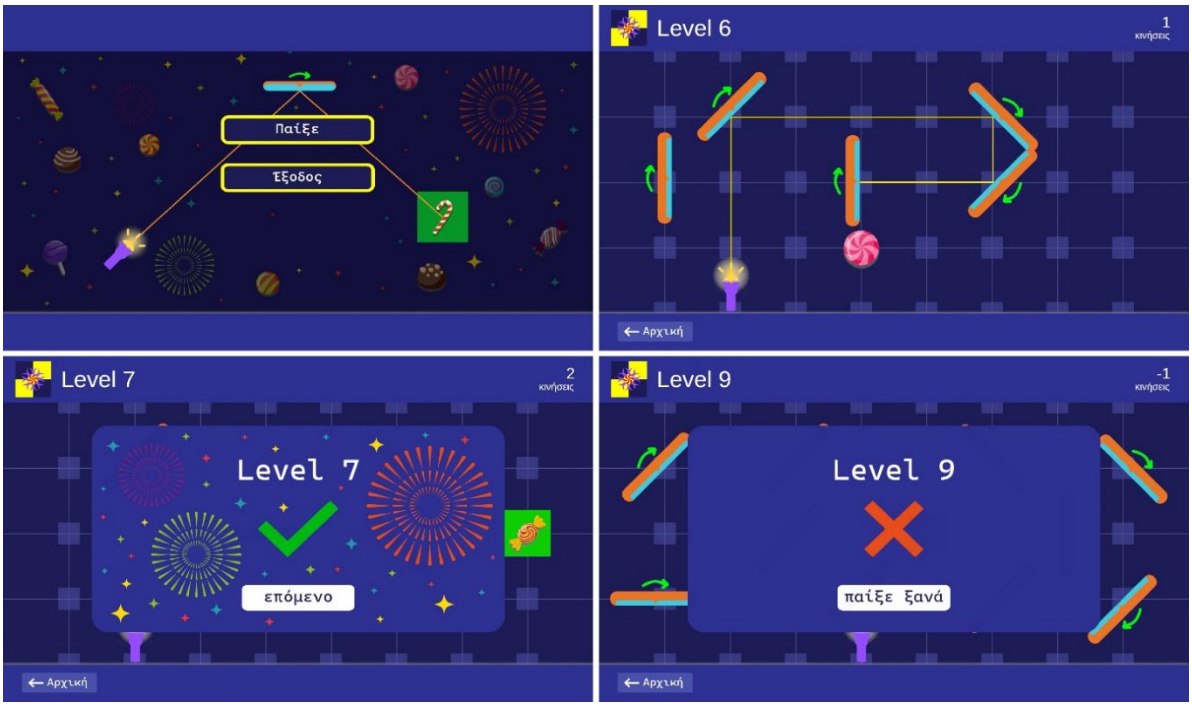

Figure 1: Screenshots – from top left to bottom right (a) home page, (b) gameplay, (c) success feedback, (d) fail feedback

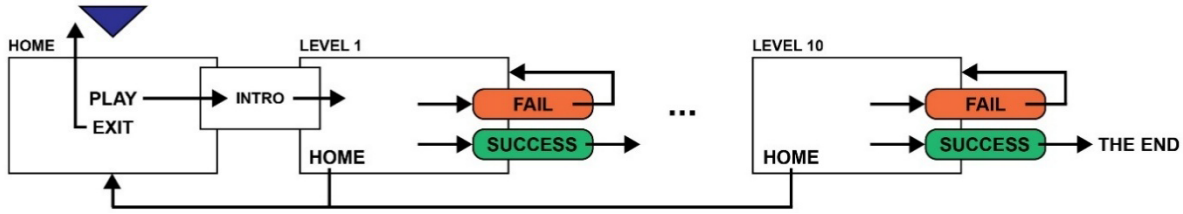

Figure 2: Navigation diagram

3.2 Game Mechanics and Rules

As the player advances, the game introduces rules by gradually providing prominent evidence of each rule. This evidence is also repeated in subsequent levels before introducing evidence of another rule. Core (CO) rules are introduced first so that the player can become familiar with the environment and the game's goal. These form the foundation of the game. Then, supplementary (SU) rules are introduced – rules that add variety and increase the difficulty. Ten levels have been built, with increasing difficulty. Table 1 outlines the game rules and the levels where the player is most likely to discover them.

As the levels progress, more mirrors are introduced, more moves are required, and fewer available moves are given. This creates more complex configurations, leaving less room for errors and requiring greater mental effort. This progression promotes strategic planning, critical thinking, and spatial reasoning, requiring the player to refine their control over their decisions and moves. The level difficulty can be expressed by the combination of three factors: the room for error between available and required moves, the number of mirrors given at each level, and the proportion of given mirrors that are required to successfully complete the level. Based on this, the difficulty of each level is defined by the following equation:

$Level\ Difficulty\ (\%) = [0.4 * MoRM + 0.4 * \mathrm{RMC} + 0.2 * (1 - \mathrm{MiRM})] * 100$, where:

$Moves\ Relative\ Margin\ (MorM) = \frac{Minimum\ Required\ Moves}{Available\ Moves}$

$Relative\ Mirror\ Count\ (RMC) = \frac{Level\ Given\ Mirrors}{Max\ Given\ Mirrors} = \frac{Given\ Mirrors}{10}$, and

$Mirrors\ Relative\ Margin\ (MiRM) = \frac{Required\ Mirrors}{Given\ Mirrors}$.

The smaller the MoRM, the more room the player has for errors, meaning they can make many unnecessary moves and still win the level. The larger this margin, the tougher the level becomes.

The larger the RMC, the more mirrors there are in a level, thus increasing the mental load and making the level tougher.

The smaller the MiRM, the greater the complexity of the level, meaning the player is more prone to mistakes as they need to identify the necessary mirrors to win the level. The smaller the margin, the harder it is to win.

Table 1: Game rules and possible levels of rule discovery by the user

No.	Rule	Level(s) of discovery	Rule Evidence
1	CO - The goal is to guide the beam to the candy by rotating mirrors.	1, 2	Torch and candy are stable. Mirrors rotate. Level 1 is impossible to lose. Level 2 has many moves available.
2	CO - The beam always reflects on 90-degree angle.	3, 4 or any of the next levels	Mirrors are positioned based on a grid. They rotate 45 degrees clockwise with each tap.
3	CO - Available moves are limited. Their number is different at each level.	3, 4	Level 3 is the first level where the player might continue taping rapidly and lose. In Level 4 the available moves are equal to the required moves. In both levels, it is quite possible for a player to lose if they are not paying attention.
4	CO - If the player exhausts all available moves, they can retry the level until they succeed.		
5	SU - Not all mirrors given in a level are necessary to complete it successfully.	5, 6 or any of the next levels	Level 5 and Level 6 each have an extra mirror placed close to the beam's path. In level 5, there are four unused mirrors for the second possible solution.
6	SU - A level may have two possible solutions.	5, 9, 10	Each of Levels 5, 9, 10 have two possible solutions.

Table 2 presents the gradual difficulty progression by level.

Table 2: Difficulty progression by level

Level	Av. Moves	Req. Moves		MoRM		Giv. Mirr.	Req. Mirr.		MiRM		RMC	Difficulty (%)	
1	20	7		0.35		1	1		1.00		0.1	18	
2	20	8		0.40		2	2		1.00		0.2	24	
3	16	11		0.68		3	3		1.00		0.3	39	
4	4	4		1.00		2	2		1.00		0.2	48	
5	13	7	12	0.53	0.92	5	1	4	0.20	0.80	0.5	57	60
6	4	4		1.00		5	4		0.80		0.5	64	
7	15	13		0.86		4	3		0.75		0.4	55	
8	5	5		1.00		6	4		0.66		0.6	70	
9	24	21	16	0.87	0.66	10	5	5	0.50	0.50	1.0	84	76
10	16	12	10	0.75	0.62	9	5	5	0.55	0.55	0.9	75	69

3.3 Expected User Experience and Accessibility Requirements

The game is designed primarily for tablet screens, even though it is responsive for all mobile devices. Larger on-screen objects with adequate spacing improve visibility and accessibility, allowing users to interact with precision. Additionally, tablets can offer flexibility in classroom settings and can accommodate collaboration between players. By allowing collaboration, no particular emphasis is placed on high competition between students, which can be a source of anxiety for some (Lopez et al., 2023; Ullah et al., 2022). Notably, this is also the reason why a time constraint was excluded from the game mechanics, so that the player does not play against time. On the contrary, the constraint of a limited number of available moves allows the player to develop their strategy at their own pace.

Visual and audio elements aim to invite engagement and sustain it. The graphics are simple yet aesthetically pleasing, minimising distractions and aiding concentration. A blue colour scheme dominates the design, chosen for maintaining focus and promoting a calm environment (AL-Ayash et al. 2016). Visual elements adhere to accessibility guidelines (WCAG 2.1 Success Criteria), ensuring proper contrast and readability, with the aim of meeting Level AA compliance. Figure 3 depicts the colour contrast levels between elements and their background (adjacent) colour for the most used combinations. TPGi Color Contrast Analyser (CCA) version 3.5.4 was used to confirm that all colour combinations pass the 3:1 ratio for graphics (criterion 1.4.11) and the 4.5:1 ratio for text (criterion 1.4.3), while real text is used instead of image (criterion 1.4.5). All screens of the game were also checked with a colour blindness simulator (Coblis) for all colour vision conditions (protanopia, achromatopsia, etc.). The graphics are complemented by sound effects that provide immediate feedback for player actions, and are present but not overwhelming, supporting a multi-sensory experience.

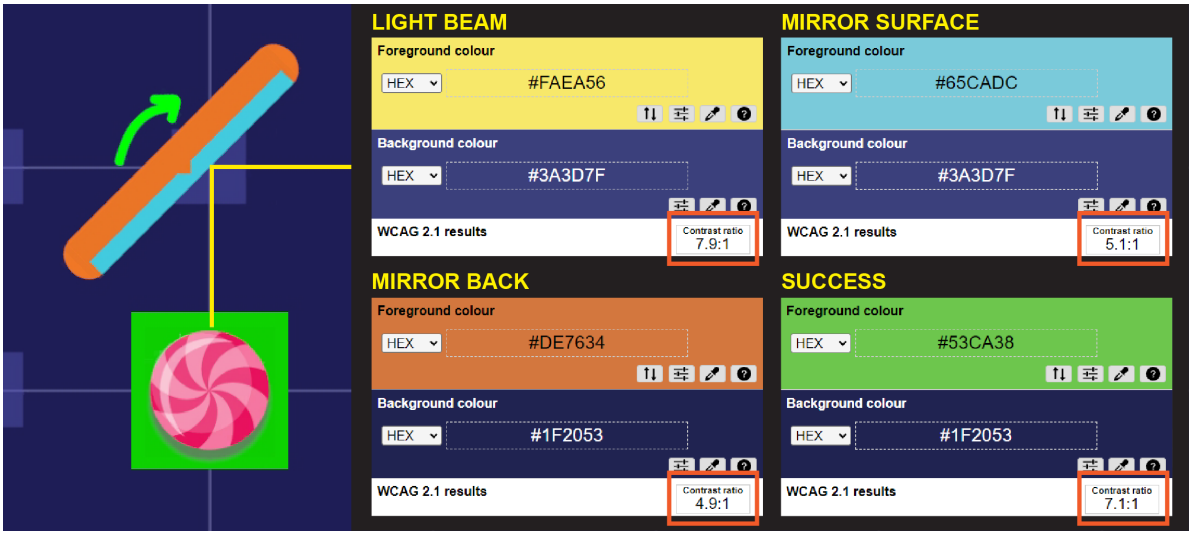

Figure 3: Main colour combinations checked for appropriate contrast in CCA

4. Evaluation, Results and Findings

4.1 Formative Evaluation

Formative evaluations are essential for refinement (Koutsabasis, 2015). Two of the first functional versions of the game were used to conduct two formative evaluations with four adults (aged 35 to 50) and four children (aged 11 to 12). These were carried out using the think-aloud protocol, direct observation, and open-ended questions to gather feedback on what was easy or confusing, as well as preferences and suggestions.

Based on the feedback, mainly visual changes (sizes, colours, shapes) were made to various elements to make them more distinguishable and to indicate their functions more intuitively. For instance, the back of the mirror was not clearly distinguishable from the front, which represents the reflective area. Additionally, level configurations and mirror placements were also adjusted, and the background was updated to a square-based grid to ensure that the light beam would always hit the centre of each mirror. This ensured that the beam's path is predictable and the gameplay is solvable in the same way across all levels, helping the player make safer assumptions about which mirror is the last to reflect the beam to the candy.

Another notable finding was that some adults tried to tap and drag a mirror to rotate it and had to try several gestures before discovering the correct one. Children, on the other hand, directly used a single tap to rotate the mirror. Moreover, although the game is designed prioritising children, feedback from adults showed that it can also be suitable and challenging for older audiences.

4.2 Research Methodology and Tools

This study adopted a mixed methodological approach, combining quantitative and qualitative data to explore the learning outcomes and usability of *Fotogonies*. The main study sample consisted of 44 students, approximately 11 years old, from two sixth-grade classes at the 4th Experimental Primary School of Ermoupolis, Syros. The sample included students from diverse socio-economic and academic backgrounds, a diversity attributed to the lottery-based admission system of Experimental Schools.

The students were introduced to the game and played in pairs using tablets, while the think-aloud protocol was applied to capture their thinking. Data were collected via screen recording applications, written notes, and audio recordings. After completing the game, students individually filled out:

- a SUS (System Usability Scale) questionnaire to evaluate usability,
- a QUIS (Questionnaire for User Interaction Satisfaction) questionnaire to assess user satisfaction, and
- open-ended questions regarding positive or negative aspects of the game.

Both SUS and QUIS were adapted for the game and translated into Greek, with their English versions provided in the Appendix. The answers were collected manually and later digitised for analysis. The SUS questionnaire can reveal whether participants are "cheating" by answering randomly, making it reliable for insights at an individual level. The QUIS questionnaire, on the other hand, can offer an overall impression across five aspects of the system being assessed. Both questionnaires are subjective as they are self-answered, reflecting opinions. Nevertheless, they can provide valuable insights when combined with qualitative data.

Importantly, before all this, students completed a pre-test to assess their prior knowledge of light propagation and reflection concepts. A final post-test, identical to the pre-test, was used at the end to detect any cognitive improvement.

4.3 Summative Evaluation

The students played the game, reaching the tenth level without requiring any support from the facilitator. As the game became more challenging, all students collaboratively overcame difficulties within their teams. They employed a variety of problem-solving strategies that evolved as the difficulty increased. In the initial levels, students primarily used a trial-and-error approach, rotating the mirrors randomly. At intermediate levels, they began to formulate action plans before adjusting the mirrors. At advanced levels, students demonstrated the ability to analyse the light's trajectory and anticipate multiple sequential reflections across several mirrors. They articulated hypotheses regarding the light's path and evaluated possible outcomes before taking action, reflecting a gradual refinement of their strategic thinking.

After playing the game, the children shared feedback. Most were unfamiliar with the SUS and QUIS instruments. Nevertheless, about half of them completed the questionnaires independently, with little or no support from the facilitator. Eighteen children completed the questionnaire with the facilitator, who read each item aloud and rephrased it to help children understand the questions and context in a short, conversational manner. Five children struggled and gave random answers. Although these children offered positive comments in the open-ended questions, it is unclear whether their enthusiasm was genuine or merely a reaction to the positive remarks of their peers. Consequently, their answers were excluded from the calculation of both the SUS and QUIS scores.

Table 3 presents the SUS results of the 39 participants. The vast majority (about 92%) achieved a total score above 68, indicating good usability. Only three children scored lower (65–67.5). All three also displayed relative indifference towards the game, as revealed by think-aloud observations and open-ended responses. One of them found the game easy, yet still needed help from teammates. The second child found the game difficult. The third could not decide how often they would play and whether the game was complicated, and was confused over the "consistency" items, which contributed to a 67.5 score. Overall, about 36% of participants scored 72.5–80, 31% scored 82.5–90, and 23% scored 92.5–100. The mean SUS score across all 39 responses was 83.53.

Table 3: Summary of the SUS Questionnaire results

SUS Score	**65 – 70**	**72.5 – 80**	**82.5 – 90**	**92.5 – 100**	**83.53**
Number of participants	4 (10.2%)	14 (35.9%)	12 (30.8%)	9 (23.1%)	Overall SUS Score

Figure 4 presents ten pie charts, showing the distribution of responses per question. Most children (32, 82%) said they would like to play the game frequently. Six (15%) were unsure about the game's complexity, and only three were uncertain whether it was easy to use (Q3), consistent with observations that most children comprehended the gameplay quite easily after experimenting with the first two or three levels. Uncertainty was likewise low regarding whether they would need help: only two students were unsure whether they would require assistance from a more experienced player (Q4). About one-third (12) could not judge the game's consistency (Q5, Q6), and 23% (9) hesitated when rating its difficulty (Q7, Q8). However, most of those participants played the game with little to no significant support from their peers. About 30% of the participants (13) were not sure how confident they felt when making their moves in the game and how much they needed to learn before playing confidently (Q9, Q10). Even though the questions referred to learning the gameplay,

many seemed to initially interpret them as relating to learning about light. In retrospect, those questions could be simplified further to make communication with children more effective. Nevertheless, with the support of the facilitator, 69% of the participants grasped the intended meaning and reported feeling that they knew what they were doing when playing the game, a finding also reflected in the qualitative results.

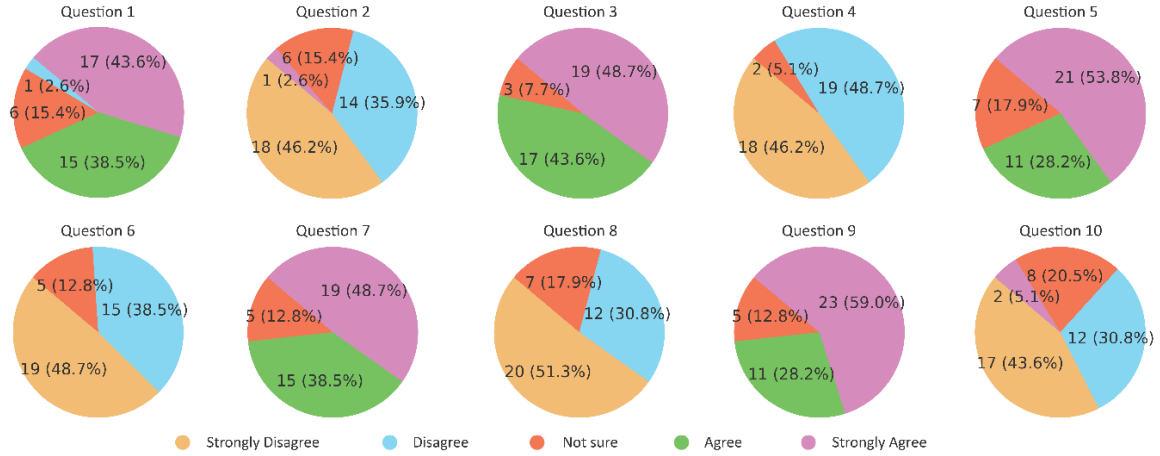

Figure 4: Participants' responses per SUS question

Table 4 summarises the QUIS questionnaire results: the mean score of all participants per question, the mean of question scores for each category, and the mean of all questions as an overall QUIS score. Category B (screen), which mainly addresses readability, indications, navigation, and layout, earned the highest mean score of 7.92, closely followed by Category C (terminology and information regarding the state of the game – terms, positions, actions, progress) with 7.88. Category A (overall reaction to the game), which addresses key aspects such as ease of use and user control, scored 7.84. Categories D (learning the game) and E (game capabilities) scored 7.81 and 7.66 respectively, largely because several participants chose the neutral midpoint (5) when unsure. Misinterpretation of learnability related items, which were largely understood as referring to physics content rather than interface mastery, also affected Category D scores. The overall mean score across all 27 questions was 7.82.

Table 4: QUIS questionnaire results per question, category and overall score

Category	**A**		**B**		**C**		**D**		**E**		
Question Score	Q1	7.77	Q7	7.87	Q11	8.00	Q17	7.87	Q23	7.69	Overall
	Q2	7.62	Q8	8.03	Q12	7.82	Q18	7.97	Q24	7.51	QUIS
	Q3	8.03	Q9	8.00	Q13	7.82	Q19	7.95	Q25	7.74	Score
	Q4	7.74	Q10	7.77	Q14	7.87	Q20	7.67	Q26	7.56	
	Q5	7.92			Q15	7.79	Q21	7.82	Q27	7.79	
	Q6	7.97			Q16	7.95	Q22	7.59			7.82
Category Score		7.84		7.92		7.88		7.81		7.66	

The responses to the open-ended questions regarding students' perceptions of the positive and negative aspects of the game were documented and compiled in Table **5**, highlighting the most frequently mentioned points.

Table 5: Open-ended questions replies

Open-ended questions	**Mentions**
1. Which feature of the game, in your opinion, is the best (liked or found most impressive)? why?	
Colors and music	21
That our goal was the candies	9
The fact that there were "traps"	7
2. Which element of the game, in your opinion, could be improved (did not like or found confusing)? why?	

Open-ended questions	**Mentions**
There are not many moves at some levels	6
That level 9 was difficult for us to solve	5
The fact that mirrors would rotate only to one direction	4
3. More thoughts and comments?	
There could be time limit	3
There could be bigger consequences when you lose. For example, to have less moves	2

Qualitative insights enriched the questionnaire data and exposed specific issues in how children interpreted some items. Children's self-reports on interface consistency, learnability, and difficulty proved less reliable than observational evidence: several students did not grasp the idea of consistency, and some confused the game's learnability with learning the underlying lesson or interface difficulty with gameplay difficulty. Additionally, technical aspects such as system speed and reliability are likewise better assessed by adult testers than by children.

An additional remark is that the children found level 9 to be the most difficult, exactly as intended (Table 2). Nine pairs discovered two solutions at least once, especially after sharing their experience with other children. Sixteen students asked for additional levels.

Last but not least, the comparison of the pre-test and post-test results revealed a shift in the students' cognitive performance regarding basic concepts of light propagation and reflection (Baziakou, Tsita & Dimitracopoulou, 2025, in press), confirming that the game strengthened students' conceptual understanding.

5. Conclusion

Unlike most educational game studies that mainly focus on learning outcomes, this work reports on a game design approach that equally values the anticipated experience. Based on requirements for serious educational games, it presents the game design decisions and the evaluation results in terms of usability and user satisfaction, linking the anticipated cognitive gains with the user experience.

By transforming abstract physics concepts into tangible, interactive elements, the proposed game can support learning while acknowledging children's pre-existing misconceptions about light propagation and reflection. Its puzzle format encourages players to formulate hypotheses and test them, while the gradual introduction of rules and increasing difficulty supports problem-solving. The game has a simple and engaging story and goal. The mechanics and feedback are clear and intuitive. The game is low-cost and accessible, and it allows social interaction through collaboration.

The results indicate that the game offered a high-quality experience and proved to be appealing and engaging to its main audience, validating the initial design decisions. All children understood the gameplay while collaborating in pairs without adult assistance. The game was well received in the school setting, and no feature posed any issues for classroom use.

Combining the think-aloud protocol with the SUS and QUIS questionnaires yielded insights not only into the game itself but also into how children perceived the evaluation process, revealing that nearly half of them needed support to provide their feedback. At the same time, items related to the consistency, learnability and difficulty of the game as an interface should be better communicated to children to provide more reliable feedback.

Because of its simplicity, the game can be used as educational material to introduce fundamental physics concepts, spark interest and engagement, probe prior knowledge, or reinforce previously learned material.

Ethics declaration: Consent was obtained from all adult participants and the parents of students according to the University of the Aegean procedures for informed consent.

AI declaration: ChatGPT was used for grammar and spelling check

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Appendix 1: SUS Questionnaire

SUS Questionnaire adapted for the game, based on SurveyLab version. (Figure 5)

No.	Question	1-Strongly Disagree, 2-Disagree, 3-Not sure, 4-Agree, 5-Strongly Agree				
		1	2	3	4	5
1	I think that I would like to play this game frequently.					
2	I found the game unnecessarily complex.					
3	I thought the game was easy to use.					
4	I think that I would need the support of a more experienced player to be able to play this game.					
5	I found the various functions in this game were well integrated.					
6	I thought there was too much inconsistency in this game.					
7	I would imagine that most people would learn to play this game very quickly.					
8	I found the game very cumbersome to use.					
9	I felt very confident playing the game.					
10	I needed to learn a lot of things before I could get going with this game.					

Figure 5: SUS Questionnaire

Appendix 2: QUIS Questionnaire

QUIS Questionnaire adapted for the game (Chin et al., 1988) (Figure 6)

A. Overall reaction to the game			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
1		terrible										wonderful
2		difficult										easy
3		annoying										satisfying
4		inadequate control										adequate control
5		dull										stimulating
6		rigid										flexible
B. Screen			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
7	Reading text on the screen	hard										easy
8	Highlighting simplifies the game	not at all										very much
9	Organization of information	confusing										very clear
10	Sequence of screens	confusing										very clear
C. Terminology and information regarding the state of the game			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
11	Same terms throughout system	inconsistent										consistent
12	Words used describe gameplay clearly	never										always
13	Position of messages on screen	inconsistent										consistent
14	The interactive objects and buttons	confusing										clear
15	The player's progress	not evident										evident
16	Failure messages	unhelpful										helpful
D. Learning the game			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
17	Learning how to play the game	difficult										easy
18	Exploring the game by trial and error is	difficult										easy
19	Remembering what the objects and buttons of the game do	difficult										easy
20	The goal of the game is clear	never										always
21	Informing messages on the screen	unhelpful										helpful
22	Supplemental explanatory materials	necessary										unnecessary
E. Game capabilities			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
23	Speed – of application using tablet	slow										smooth
24	Reliability – how the game response to my actions	unreliable										unreliable
25	The game tends to cause	anxiety										calm
26	Continue playing after a mistake	difficult										easy
27	Game felt designed for both experienced and inexperienced students	never										always

Figure 6: QUIS Questionnaire

A Preliminary Analysis of Gamification on Assembly Language Programming Education

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Abstract: Assembly language is often perceived as complex and abstract, necessitating instructional approaches that enhance student engagement and comprehension. This study presents a preliminary analysis of gamification methods in assembly programming education, focusing on the challenges of teaching low-level programming concepts. A total of 18 studies incorporating gamification strategies are reviewed to synthesize insights into the pedagogical benefits and limitations of gamification in assembly education. The analysis categorizes studies by gamification techniques, course contexts, and research methodologies, identifying recurring themes in enhancing motivation, skill acquisition, and understanding of fundamental concepts. The methodology of this study involved a structured search query across multiple academic databases, including IEEE Xplore, ACM Digital Library, and ScienceDirect. The search was iteratively refined, and a snowballing approach was adopted to identify additional studies. From an initial pool of 162 studies, 47 were considered relevant, and 18 were selected for analysis. The review follows a chronological structure, highlighting key contributions and connections between studies. Research methodologies used in studies include qualitative and quantitative analyses, experimental comparisons, and practical implementations. The reviewed studies illustrate various gamification techniques, including interactive learning environments that visualize assembly operations, commercial games incorporating assembly-like programming, badge-based learning systems that promote structured progression, and game-based project assignments that introduce assembly concepts through game development. Findings indicate that gamification enhances student engagement by integrating real-time feedback, hands-on learning, and competitive elements. Projects such as Pong, Breakout, and TetrisOS demonstrate that game-based assignments can make assembly concepts more accessible. Studies on badge-based learning highlight how structured rewards encourage students to develop assembly skills at their own pace. Some studies suggest that gamification must be complemented by additional instructional strategies to maximize long-term retention. In summary, this study underscores gamification's role as a pedagogical tool for assembly programming education, showing its effectiveness in fostering student engagement and comprehension.

Keywords: Gamification, Game-Based learning, Assembly programming, Low-Level programming, Microprocessor

1. Introduction

In recent years, gamification has emerged as a powerful pedagogical tool across numerous educational fields, enhancing engagement, motivation, and retention by incorporating game-like elements into learning experiences (Dichev & Dicheva, 2017; Koivisto & Hamari, 2019). Particularly in technical and challenging subjects such as assembly programming and its usage in microprocessor architectures, gamification has shown promising potential. These subjects, integral to computer engineering curricula, are often perceived as complex due to their abstract and intricate nature (Logozar et al, 2022). As a result, students frequently struggle with grasping low-level programming concepts, understanding hardware intricacies, and applying these in real-world contexts (Kelleher & Pausch, 2005). Gamification offers a novel approach to mitigating these challenges by transforming traditional educational frameworks into more interactive and engaging experiences.

Assembly language programming is a low-level form of coding that communicates directly with a computer's hardware. Each assembly instruction corresponds closely to an operation executed by the CPU, giving the programmer fine-grained control over what the processor does. This direct control makes assembly powerful and efficient for tasks requiring hardware-level optimization, but it also means the programmer must manage many details manually—such as *register manipulation*, which involves modifying data in the CPU's fast storage units; *conditional branching*, where program flow is controlled based on logic conditions; and *memory addressing*, where exact memory locations must be specified rather than using variable names. Unlike high-level languages (such as Python or Java) that abstract away these details, assembly requires the developer to handle every operation explicitly, demanding a deep understanding of computer architecture and resulting in a steep learning curve for newcomers.

Despite the growing adoption of gamification in various technical fields, its application within assembly programming education remains less explored. While educators and researchers have recognized its potential, the unique complexities of these subjects necessitate a more targeted analysis. Assembly language requires a distinct set of cognitive skills, involving precise logic, attention to detail, and a deep understanding of hardware-software interactions. By leveraging gamification, educators aim to create more intuitive pathways for students

to engage with these concepts, potentially enhancing both learning outcomes and students' self-efficacy in tackling these demanding topics.

This analysis examines existing research on gamification in the context of assembly programming education. By synthesizing findings from studies across computer engineering and educational psychology, this analysis aims to provide insights into how gamification can be strategically implemented in the area. It covers a range of gamification techniques, including point systems, challenges, and simulation-based exercises, and analyzes their impact on student motivation, comprehension, and skill acquisition.

The structure of this paper is organized as follows: this section outlines the significance of gamification in making complex subjects like assembly language and microprocessor architecture more accessible. Methodology explains the search process, including the initial structured query and the subsequent snowballing approach to locate relevant studies. In Analysis, key findings from the identified studies are presented, categorizing different gamification methods used in technical education and examining their impact on learning outcomes. The Discussion synthesizes the benefits and limitations observed, noting areas where gamification effectively enhances engagement. Finally, the Conclusion summarizes the contributions of this work and underscores the potential of gamified learning as a valuable educational tool in assembly programming education.

2. Methodology

The research for this analysis began with a structured search query in major academic databases, such as IEEE Xplore, ACM Digital Library, and ScienceDirect, to identify relevant studies on gamification and game-based learning usage in assembly language programming education. The initial search query, structured to capture studies that integrate gamification with low-level programming education, was:

> *(("All Metadata":gamif*) OR ("All Metadata":gamified) OR ("All Metadata":gamification) OR ("All Metadata":game-based learning)) AND (("All Metadata":assembly language) OR ("All Metadata":assembly program*) OR ("All Metadata":microcontroller) OR ("All Metadata":microprocessor) OR ("All Metadata":processor)) AND (("All Metadata":education) OR ("All Metadata":learning))*

However, this query yielded a limited number of studies directly relevant to the intersection of gamification and assembly language education, likely due to the specificity of these topics. Recognizing this limitation, the query was relaxed in stages to capture a broader range of relevant studies on gamification in technical education settings, even if they did not specifically address assembly instructions.

After getting limited results from the query, a snowballing approach was adopted, whereby key studies identified through the initial search were used as seeds to locate additional relevant research. This involved reviewing references within these studies and exploring works that cited them, a recognized method for literature reviews that aim to capture a broader scope when primary search results are limited (Wohlin, 2014). This approach allowed for a more comprehensive inclusion of literature, including works on gamification's application to similar technical subjects, such as digital systems and programming fundamentals, where assembly language principles are often indirectly addressed.

Overall results of the search query on different databases and the snowballing approach yielded a total of 162 initial studies. Out of these results, 47 of them are considered related with our work to a certain degree. Detailed analysis and readings decrease the number of reviewed studies. In final, 18 studies are analyzed in this work.

3. Analysis

In this analysis, a chronological order for reviewing the studies is followed like the similar studies (Manzano-León et al, 2021). Where applicable, the connections between the studies are explicitly pointed out.

Sprunt (2005) presents a structured, gamified approach to teaching assembly language through a Pong game project that employs problem-based learning (PBL) to engage introductory students in developing a fully functional game in assembly. By requiring interaction with microcontroller hardware and implementation of features like paddle control and ball movement using polling and interrupts, the assignment promotes deep engagement with low-level programming. Developed in structured stages aligned with Bloom's taxonomy, the project moves from basic mechanics to advanced features like collision detection and scoring, encouraging students to apply, analyze, and synthesize assembly concepts such as register manipulation, conditional branching, and memory addressing. Feedback indicates that the gamified, hands-on, and competitive format

enhances motivation and supports a deep-learning approach, making assembly programming enjoyable while fostering independent learning and improving retention.

Kawash & Collier (2013) explore the use of video game creation to teach assembly language in a second-year course at the University of Calgary, where students developed games like Space Invaders, Tetris, and Pac-Man entirely in assembly to increase engagement through a "fun factor" without reducing curriculum rigor. This approach required students to address complex hardware/software interface tasks such as programming interrupt handlers, using VESA BIOS Extensions (VBE) for graphics, and developing custom keyboard and mouse drivers via direct port and memory-mapped I/O. By building interactive games, students practically learned low-level concepts including memory management, hardware interrupts, and device interface manipulation, simulating real-time programming challenges. Survey results showed that 65% of students enjoyed the project and found the gaming focus improved their understanding and engagement with assembly programming despite its difficulty.

Jamieson (2014) examines badge-based learning in a computer architecture course to enhance assembly language instruction by replacing traditional lectures and tests with a system where students earned basic, intermediate, and advanced badges through demonstrated mastery. This format enabled self-paced learning, allowing motivated students to explore advanced assembly topics while others met minimum requirements with basic badges. Key skills included CPU operations, registers, instruction sets, memory addressing, and debugging, assessed through practical deliverables and instructor interviews. Unlike one-time assessments, students could refine their work for each badge, promoting deeper learning. While grade distributions remained similar to the traditional format, the badge-based model improved engagement and supported mastery of low-level assembly concepts, particularly among high-achieving students.

Johnson et al (2016) evaluates the use of video game methodologies, particularly gamification, to enhance assembly language education by integrating games like The Foos, Lightbot, Picobot, and especially Human Resource Machine, which uses a corporate-themed puzzle format to introduce assembly-like operations such as load, jump, and conditional branching. This game provides a visual, interactive method for understanding memory operations and sequential logic, while its "corporate ladder" structure presents progressively complex puzzles that mirror the iterative and optimization-focused nature of assembly programming. With dual-metric scoring on program length and runtime efficiency, it teaches practical trade-offs in code design. The study highlights that such gamified approaches increase engagement and deepen comprehension of low-level programming by embedding assembly concepts into gameplay, thus lowering cognitive barriers and supporting active learning of foundational skills necessary for advanced programming and hardware interaction.

Black et al (2017) outlines a lab project for teaching assembly language and computer organization through developing a simplified x86 version of Breakout, where students create game elements like the ball, paddle, and blocks with collision detection. The project extends learning by having students build an 8088-based computer on a breadboard using components like LEDs, push-buttons, and an Atmega microcontroller to emulate video and keyboard interfaces. After testing the game in assembly, students load the machine code onto an EEPROM chip, turning their breadboard into a standalone gaming device with an LED matrix display and push-button controls. This hands-on, gamified approach deepens understanding of low-level programming, hardware interfacing, and real-time code execution, with student feedback showing increased engagement and comprehension of core computer organization concepts.

Black (2017) introduces TetrisOS and BreakoutOS, two projects for computer organization courses where students build basic x86 assembly versions of Tetris and Breakout on bare-metal PCs, enabling direct hardware interaction without an operating system. These projects cover memory addressing, device communication, interrupt handling, and OS fundamentals through progressive steps; in BreakoutOS, students implement video memory, game objects, keyboard input, and collision detection, while TetrisOS adds timer interrupts and nested loops for gameplay. Each concludes with creating a bootable USB for standalone execution. Students reported high engagement and found the projects made assembly language more accessible and practical through interactive, tangible outcomes.

Cass (2017) evaluated a set of games that make assembly-like programming accessible and enjoyable by using simplified virtual assembly environments focused on low-level instructions like data movement, conditional branches, and arithmetic, helping players intuitively grasp assembly principles. Each game offers distinct scenarios: Human Resource Machine uses office-themed puzzles to teach memory and register concepts; TIS-100 simulates a retro microcomputer with parallel-processing puzzles and limited instruction sets; Shenzhen I/O challenges players to design and optimize virtual electronic circuits. These immersive, puzzle-based games

promote understanding of low-level coding by encouraging players to think like assembly programmers in an engaging, interactive way.

Black & Matta (2019) details a sophomore-level computer organization project where students develop Breakout using AVR assembly on an Arduino Uno, engaging with core assembly concepts by building a functional game with an 8x8 LED matrix display and push buttons for paddle control. Without system calls, students directly manage I/O and control logic, progressing through sequential steps that introduce wiring circuits, creating variables, handling delays with loops, implementing conditional branches and collision detection, and using hardware interrupts for paddle movement. The hands-on, gamified approach provided immediate visual feedback, helping students grasp abstract assembly concepts, face real-world challenges like timing and debugging, and gain practical insight into low-level computing, with feedback showing enhanced understanding and engagement.

Dicheva et al (2020) explores the use of badges to boost engagement and motivation in a sophomore-level computer science course that includes assembly language programming, using the OneUp platform to incentivize out-of-class exercises on core topics like assembly fundamentals. After an initial non-gamified phase, badges were introduced for achievements in areas such as quizzes and exercises, leading to increased participation, particularly in voluntary assembly tasks, and improved performance on assembly-focused assessments and overall grades. While the badges effectively encouraged extrinsically motivated engagement and consistent practice essential for mastering low-level programming, the survey based on the Basic Psychological Needs Satisfaction Scale (Deci et al, 2000) showed no significant increase in intrinsic motivation. Thus, badges functioned as external motivators, helping students internalize the value of assembly tasks over time, making them a practical gamified supplement in assembly education.

Gallego-Durán et al (2021) explore a bottom-up approach to programming education through the DEZ80 course, which uses Z80 assembly language and game development challenges to address shortcomings of teaching only high-level languages that may lead to superficial understanding. A 16-hour course with first-year students showed that early exposure to low-level programming led to similar or slightly better performance in later programming assessments, indicating deeper comprehension. The gamified, challenge-based format promoted engagement and supported low-level programming as a valuable complement to traditional methods for developing computational thinking.

Llamas-Nistal et al (2022) describes a hands-on approach to teaching computer architecture using ARM assembly on Raspberry Pi, replacing simulators with real hardware to enable tangible interaction with machine-level concepts. Students begin with foundational tasks on QtARMSim to learn basic operations, instruction sets, and memory management, then transition to Raspberry Pi projects involving GPIO control, delay loops, I/O handling, interrupts, and subroutine calls. Gamified tasks like a “Simon Says” game or traffic light controller help students observe real-time code effects, while the alignment with ARM architecture and interactive environment enhances motivation and learning by connecting assembly programming to real-world applications.

Gryphon & Chung (2023) introduces Assembly Academy, an educational game that simplifies assembly language learning through programming challenges where students control a virtual robot using commands modelled after ARM assembly. By providing real-time visual feedback, error messages, and step-by-step execution, the game demystifies abstract concepts and supports learning through immediate correction and comprehension. Each level introduces a new ARM command applied in puzzles that reinforce its use, with commands like “botmove,” “botgrab,” and “botlook” mirroring fundamental operations and registers R0 to R7 used to simulate limited memory management. The game’s scoring system, based on memory efficiency and clock cycles, fosters motivation and code optimization in a competitive, gamified environment, making assembly language more approachable and engaging.

Calvo-Morata et al (2024) investigates gamification as a strategy to attract students, particularly young women, to programming and computational thinking, aiming to make STEM more accessible and engaging. The Game4Coding Erasmus+ project is introduced, emphasizing the development of CodeQuest, a video game designed within the monster-tamer genre.

The paper briefly discusses using video games to teach programming concepts, even at low levels such as assembly language. It references games like Human Resource Machine, TIS-100, and Shenzhen I/O, which are specifically designed to introduce complex, low-level programming concepts in an engaging way. These games incorporate assembly-like programming challenges where players must solve problems using a command set

that mimic assembly language instructions. From this study, we find two other studies to be analyzed, (Kawash & Collier, 2013; Cass, 2017), using snowballing method.

Dolinsky et al (2024) reviews challenges and advancements in teaching computer science fundamentals across various educational contexts. It emphasizes the incorporation of modern methods such as gamification, virtual laboratories, and artificial intelligence-based personalized learning to address gaps in student engagement and knowledge acquisition. The article highlights key topics in computing education, including computer architecture, assembly programming, and programming languages, and presents the Computing Curriculum 2020 framework as a strategic guideline. This article also references other related works providing further insights into effective gamification strategies on assembly.

Larraza-Mendiluze et al (2024) explores game-based learning to teach foundational computer architecture and assembly language, using interactive games to engage students with concepts like instruction cycles, memory addressing, and control structures. A key example is the "SUN Game," where students manually execute instructions to understand the fetch-decode-execute cycle, using a simplified register and memory system to increment variables, control loops, and perform arithmetic, closely mirroring real assembly tasks. As the course progresses, students play various games aligned with different assembly topics, applying skills like conditional branching, loops, and stack management. The study found that this approach improved motivation, retention, and both practical and theoretical understanding compared to traditional methods.

Rivera-Alvarado & Guadamuz (2024a) argues for rigorous experimentation in assembly language education, highlighting the cognitive complexity of low-level programming and the limitations of relying on qualitative feedback without formal assessment. They introduced a hands-on method inspired by board game mechanics, where students manually adjust registers and memory to simulate instruction execution. In a control experiment with five participants, students completed an assembly challenge using this method and a similar task on a computer a week later; paired t-test analysis showed no significant performance difference, though students reported greater engagement and interactivity. The study emphasizes the need for formal evaluation of teaching methods and plans to expand participant samples to refine the hands-on approach.

Rivera-Alvarado & Guadamuz (2024b) reviews the potential of video games as tools for assembly language instruction, noting the subject's complexity despite its importance in areas like embedded systems. They analyze games such as "TIS-100", "Human Resource Machine", and "Exapunks", which use pseudo-assembly for puzzle-solving but omit essential elements like stack usage, memory addressing, and system calls, limiting their effectiveness for genuine assembly skill development. While these games offer design insights, the authors propose creating an educational assembly language game and evaluating its impact through controlled experiments assessing both theoretical and practical proficiency to establish a scientific basis for game-based learning in assembly education.

Furthermore, Rivera-Alvarado (2024) explores using video game technology to enhance assembly language learning by proposing a game that teaches real assembly through controlling an avatar with programmed instructions, translating complex tasks into interactive scenarios. The study plans a structured experiment comparing this method to traditional teaching and incorporates a multimodal feedback system—visual, haptic, and auditory—to reinforce concept understanding. Aiming to fill a gap in gamified tools for assembly, the research seeks to establish a robust framework for immersive, interactive learning in technical programming education.

To summarize, the studies analyzed in this chapter (the details of which are also given in Table 1) reveal that gamification in assembly language and microprocessor education can effectively enhance student engagement and comprehension through diverse, hands-on approaches. By integrating challenge-based learning, game-based projects, and structured progression systems, these methods help demystify complex low-level programming concepts, making them more accessible and motivating for students. While the outcomes show increased skill acquisition and motivation, they also suggest that gamification strategies alone may benefit from supplementary instructional support to fully foster long-term retention and deeper understanding in technical subjects.

Table 1: Summary of the analyzed studies with their details

Study	Gamified Element	Assembly Focus	Key Findings
Sprunt (2005)	Pong game in assembly	Problem-based learning, hardware interaction	Increased motivation and deep learning
Kawash & Collier (2013)	Space Invaders, Tetris, Pac-Man in assembly	Game development with interrupts and I/O	Enhanced understanding and engagement
Jamieson (2014)	Badge-based learning	Self-paced mastery over assembly topics	Greater depth of understanding, flexible learning
Johnson et al (2016)	Human Resource Machine	Puzzle-based assembly logic	Visual understanding, iterative optimization
Black et al (2017)	Breakout game on breadboard	Bare-metal programming with x86	Hands-on learning, deepened hardware insight
Black (2017)	TetrisOS and BreakoutOS	Bare-metal x86 game projects	High engagement, step-by-step skill building
Cass (2017)	Human Resource Machine, TIS-100, Shenzhen I/O	Simplified virtual assembly	Interactive learning, low-level instruction understanding
Black & Matta (2019)	Breakout on Arduino Uno	AVR assembly with LED matrix	Immediate feedback, hardware debugging
Dicheva et al (2020)	Badge system via OneUp	Gamified out-of-class exercises	Extrinsic motivation, increased quiz scores
Gallego-Durán et al (2021)	DEZ80 course	Z80 assembly with game challenges	Improved foundational understanding
Llamas-Nistal et al (2022)	ARM on Raspberry Pi	QtARMSim + real hardware	Visualization of real-world assembly effects
Gryphon & Chung (2023)	Assembly Academy	ARM-based robot programming	Progressive feedback, real-time visualization
Calvo-Morata et al (2024)	CodeQuest	Monster-tamer game with assembly	Gender-inclusive, challenge-based learning
Dolinsky et al (2024)	Review of CS education	Gamification, AI, virtual labs	General trends supporting gamified assembly
Larraza-Mendiluze et al (2024)	SUN Game	Manual fetch-decode-execute simulation	Improved motivation and conceptual clarity
Rivera-Alvarado & Guadamuz (2024a)	Board game mechanics	Manual register/memory manipulation	Positive feedback, no significant performance change
Rivera-Alvarado & Guadamuz (2024b)	Review of game-based learning	Human Resource Machine, Exapunks, etc.	Proposes deeper, experimental educational games
Rivera-Alvarado (2024)	Proposed a video game	Real assembly gameplay with multimodal feedback	Structured evaluation plan, immersive learning

4. Discussion

This study places itself within an emerging body of research that explores gamification in the teaching of assembly language and related technical subjects in computer engineering. The use of game-based learning techniques, ranging from virtual robots to badge-based assessments, reflects a significant shift in pedagogy aimed at mitigating the challenges traditionally associated with low-level programming concepts. The studies reviewed reveal several recurring themes, methodologies, and implementations of gamification in computer science and engineering education, with a particular focus on improving student engagement, motivation, and comprehension.

The thematic gamification areas used by the analyzed articles are:

- **Interactive Learning Environments and Visualization (ILEV):** Many studies have employed interactive environments to make assembly language and microprocessor concepts more tangible. For instance, Assembly Academy and SPIMbot use virtual robots to allow students to visualize low-level operations in real-time. By controlling robots with assembly commands, students can see immediate results of their code execution, which aids in demystifying abstract operations such as memory management and register manipulation.

- **Commercial Games as Educational Tools (CGET):** Several studies integrated commercial games like Human Resource Machine, Exapunks, Shenzhen I/O and TIS-100 to expose students to simplified, assembly-like programming environments. These games typically focus on core programming constructs which mirror assembly language skills in a more accessible format. While these games lack the full depth of assembly programming, they provide valuable introductory experiences and can enhance engagement with foundational programming logic.
- **Badge-Based Learning Systems (BBLS):** Badge-based systems, as explored in multiple studies, provide a structured framework for students to progress at their own pace. These systems reward students for mastering specific tasks, thereby promoting consistent practice and reducing the pressure of high-stakes assessments. Findings from these studies suggest that badge-based approaches are especially beneficial in courses that cover complex microprocessor architectures like ARM and x86, as they allow students to solidify foundational skills before advancing.
- **Game-Based Project Assignments (GBPA):** Assignments are centred around game creation, such as those seen in TetrisOS, BreakoutOS, and a Pong game project, introduce students to core assembly concepts in a step-by-step manner. These projects employ game mechanics to gradually introduce students to complex tasks. Such projects provide a ground-up experience by engaging students directly with hardware interfaces.

The studies utilize diverse research methodologies to examine the effectiveness of gamification in technical education. Common methods include comparative experiments, such as badge-based vs. traditional grading structures, control and experimental groups using game-based projects, and user feedback collection to gauge engagement and comprehension. Some studies, such as the work with Assembly Academy (Gryphon & Chung, 2023), implement structured tutorials followed by hands-on challenges, enabling researchers to track learning progression and identify areas where students struggle.

The evaluation techniques, including statistical analysis and qualitative feedback, offer insight into both the benefits and limitations of gamification in assembly education. For instance, while several studies report increased student engagement and skill development, some findings suggest that gamification alone may not significantly enhance intrinsic motivation (Dicheva et al, 2020). Additionally, feedback from game-based projects reveals that students often find real-time feedback and tangible outcomes, such as LED matrix displays in the Arduino Arcade Machine project (Black & Matta, 2019), helpful in overcoming the cognitive challenges associated with assembly language.

The analysis shows that most of the studies are from the last 10 years, with only one study from early 2000s. There are five different games that are recurrently used in gamification purposes of assembly language education. They are usually chosen for their similarity to assembly language or the use of assembly-like commands in commercial games type, and for their ease of modification and portability in early games such as Pong or Tetris. The gamification of the assembly education mostly occurs in introductory programming, assembly programming or microprocessor architecture courses. Five different research types are employed, including practical, experimental, quantitative, qualitative or general review studies. The most used assembler and microprocessor architectures are x86 and ARM.

Table 2 below summarizes the gamification methods, assembly lecture contexts, research types, commercial games used, and microprocessor architectures or assembler information from the studies discussed in this paper. Table uses the acronyms provided in this section for gamification methods column for easy reading. Some studies are analyzed, but removed from the summary table (i.e., Calvo-Morata et al, 2024; Dolinsky, 2024), since they are the studies that introduce other works or do not apply any gamification method to be presented in the table.

Table 2: The summary table on gamification in assembly language education. "HRM" acronym denotes the game "Human Resource Machine"

#	Gamification	Course Application	Research Type	Commercial Games	Microprocessor or Assembly Architecture
(Sprunt, 2005)	CGET & GBPA	Computer Architecture	Practical	Pong	General Assembly
(Kawash & Collier, 2013)	CGET & GBPA	Computer Architecture	Qualitative	Space Invaders, Tetris, Pac-Man	x86
(Jamieson, 2014)	BBLS	Computer Architecture	Quantitative	None	Atmel, PIC, HC11, ARM
(Johnson et al, 2016)	CGET	Computer Science Courses	Qualitative	The Foos, Lightbot, HRM	General Assembly
(Black et al, 2017)	CGET & GBPA	Computer Architecture	Practical	Breakout	x86
(Black, 2017)	CGET & GBPA	Computer Architecture	Practical	Tetris, Breakout	x86
(Cass, 2017)	Assembly-like Games	None	Review	HRM, TIS-100, Shenzhen I/O	General Assembly
(Black & Matta, 2019)	CGET & GBPA	Computer Architecture	Practical	Breakout	AVR Assembly, Arduino
(Dicheva et al, 2020)	BBLS	Introductory Programming	Experimental	None	MIPS
(Gallego-Durán et al, 2021)	GBPA	Assembly Programming	Experimental	None	Z80
(Llamas-Nistal et al, 2022)	GBPA	Computer Architecture	Practical	None	ARM
(Gryphon & Chung, 2023)	ILEV	Assembly Programming	Practical	None	ARM
(Larraza-Mendiluze et al, 2024)	ILEV	Computer Architecture	Experimental	None	General Assembly
(Rivera-Alvarado & Guadamuz, 2024a)	GBPA	Assembly Programming	Experimental	None	None
(Rivera-Alvarado & Guadamuz, 2024b)	Assembly-like Games	Assembly Programming	Review	TIS-100, HRM, Exapunks	General Assembly
(Rivera-Alvarado, 2024)	GBPA	None	Review	None	General Assembly

5. Conclusion

This analysis examined the use of gamification in assembly programming education, noting both potential benefits and limitations. The literature suggests that incorporating game-like elements (such as badge-based systems, interactive simulations, and competitive challenges) can improve student motivation and engagement, and may also support practical skill development in this traditionally complex subject. Using these techniques could make learning assembly more approachable for students by helping to lower some of the initial barriers associated with low-level programming.

However, while gamification shows promise, it also presents unique challenges. Issues such as cognitive overload, variability in student response, and the need for content-specific adaptation underscore the importance of refining gamified approaches. The impact of gamification on long-term retention and deep conceptual understanding is currently inconclusive, suggesting the need for further longitudinal studies. Addressing these gaps will require a more tailored approach to gamification, one that aligns with the distinct cognitive demands of assembly programming.

In conclusion, while gamification alone is unlikely to resolve all educational challenges in assembly programming, it represents a valuable tool in the pedagogical toolkit for technical education. Continued research into adaptive, subject-specific gamification frameworks may yield approaches that more effectively integrate game-based elements with deep technical content. This ongoing exploration will be essential to developing educational practices that both motivate students and facilitate meaningful learning in assembly programming courses.

Ethics declaration: The author declares that the present study did not require ethical approval by an institutional review board or ethics committee.

AI declaration: The author used generative AI tools to assist in improving the clarity and structure of the manuscript. All content was critically reviewed and fact-checked by the author to ensure accuracy and originality, and the final manuscript reflects the author's own interpretations and contributions.

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Designing Limes Text: Adapting an Educational Video Game into a Text-Based Format for Controlled Experimental Comparisons

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Abstract: Comparing educational video games and text-based learning presents a significant challenge when trying to ensure a fair comparison between the two formats. Their distinct natures, particularly in terms of engagement and interactivity, introduce uncontrolled variables that are often not directly comparable between a video game and a text. Many prior studies rely on static text conditions that do not account for reader engagement, decision-making, or interaction patterns. This paper therefore proposes a structured game design approach to developing a text-based application that enables a more precise and controlled comparison with video game-based learning. *Limes* is a 2D educational video game set in Roman frontier Germany, designed to teach historical knowledge through exploration and interactive learning elements. The game features a structured narrative, Codex entries with historical information, and secondary missions, all contributing to the player's engagement and learning experience. The text version of *Limes* is not a game but replicates key gameplay characteristics in a structured text-based format, providing an alternative to traditional text conditions in experimental research. Unlike passive reading conditions, this Text-app is designed to be interactive and engaging in the same ways as its video game counterpart. Moreover, like the video game, the Text-app tracks player behaviour, such as time spent reading, engagement with Codex entries, and whether secondary mission texts have been read, using a five-star rating system mirroring the game's assessment mechanics. The present paper discusses the development of the *Limes* Text-app and presents a game design framework for adapting educational games into experimentally viable text-based counterparts. The contribution is particularly relevant to research on video game effects in education adopting experimental designs. However, beyond its experimental utility, the newly developed text-app offers promising opportunities for other research areas, and we discuss how it can, for example, be used to assess and explore digital traces of learner characteristics and behaviours. To conclude, by ensuring structural comparability and capturing interaction data across formats, the *Limes* Text-app addresses a key methodological challenge in video game-based learning research: the difficulty of creating valid text-based control conditions that enable meaningful comparisons. While *Limes* has been developed in the context of history education, the impact is much broader as our design framework is adaptable and could be extended to other domains and narrative-based games.

Keywords: Game design, Text-Based learning, Educational gaming, History education, Experimental methodology

1. Introduction

Over the past two decades, educational video games have gained increasing recognition for their potential to enhance learning outcomes, particularly by fostering engagement, motivation, and deep cognitive processing (Wouters *et al.*, 2013; Clark, Tanner-Smith and Killingsworth, 2016; Ren, Xu and Liu, 2024). This growing body of research has resulted in numerous experimental comparisons of video game-based learning with more traditional learning methods, most commonly text-based formats. However, these comparisons often suffer of methodological limitations related to structural differences between formats, particularly the use of passive text conditions (e.g., slideshows or static PDFs) that lack interactivity, decision-making, or behavioural tracking—an issue repeatedly flagged in systematic reviews (Wouters *et al.*, 2013; Riopel *et al.*, 2019; Gui *et al.*, 2023). These limitations can undermine experimental validity, as they make it difficult to determine whether observed effects and differences between formats are due to the format itself or to differences in interactivity and design features (All, Castellar and Looy, 2014).

For example, Gutierrez et al. (2014) compared a video game aiming to promote perspective-taking with a text version of the same story. Even though the content was identical, the two conditions differed fundamentally in structure, and only the game offered interactivity and decision-making. The findings of the study revealed that the game condition led to reductions in implicit bias; nonetheless, given the differences between the conditions, it was impossible to disentangle whether the format (game versus text) or other features (interactivity and decision-making, which was only possible in the game condition) drove the effects. This also highlights how even content-equivalent text formats can fail to replicate the mechanisms through which games operate. More recently, Lee and Chen (2023) found that while both game and text interventions had a positive effect on intergroup attitudes, only the game condition allowed for tracking of user behaviour—a key limitation in the passive text condition, which offered no insight into decision-making, time-on-task, or interaction patterns.

Gui et al. (2023), drawing on Mayer´s (2015) framework, classify most digital game-based learning (DGBL) studies into two main types: media comparison studies—which contrast games with traditional formats such as text or lectures—and value-added studies—which compare different versions of a game to isolate the effects of specific design elements (e.g., feedback, adaptation). While Gui et al. (2021) do not focus directly on control group design, they emphasise that meaningful comparisons require attention to how learners interact with design elements rather than focusing solely on the delivery format. This perspective reinforces the need for structurally comparable experimental conditions that can capture user behaviour and engagement, even in non-game formats.

The methodological issue of comparing game versus text became evident during the design of our experimental studies, which involved *Limes*, a 2D educational adventure game set in ancient Roman times in Germany (see Viccari et al., 2024, for a description of the game development). The initial idea for the control group was to read a simple PDF version of the game´s story. However, it quickly became apparent that the limitations of this format did not allow a valid comparison with the video game. Also, key behavioural measurements that can be accessed during the gameplay of *Limes* cannot be equally measured with a standard PDF file. For example, crucial points for our research include tracking and measuring the selection of optional Codex entries, exploratory decisions—specifically, the accomplishment of the secondary missions—and a five-star rating system for level accomplishment, which are central to the *Limes* gameplay experience.

In response to these issues, we developed a structured, interactive text-based application built in Unity that replicates the game's narrative structure, meant to track and measure the key game mechanics mentioned above. This Text-app represents a novel approach to control group design in video game-based learning research, one that ensures a functional comparison between a text and a video game, allowing researchers to hold specific key mechanisms constant across the two formats.

This design paper presents the process and the decision-making behind the development of the *Limes* Text-app and proposes a framework for converting educational video games into interactive text-based counterparts. By addressing the limitations of passive text control conditions, this paper offers a methodological contribution to the field of experimental educational research. Through this framework, we aim to provide a foundation for more valid and controlled comparisons between video games and text-based learning formats, ensuring that differences in outcomes can be more confidently attributed to format effects.

2. How to Convert a Video Game into Text

2.1 The Game

Limes[1] is a 2D educational video game developed in Unity and designed for 5th and 6th-grade students in Germany, focusing on Roman history. The video game story is set in third-century southern Germany; the game follows the journey of an Alemanni child and a Roman centurion named Ariovist in a period where the tensions between the Roman Empire and the Alemanni, a prominent Germanic tribe, are rising. The narrative is structured across five levels; each level contains a main and a secondary mission that rewards players through a five-star rating system. Players can engage in varied game mechanics, including stealth, exploration, dialogue choices, horse racing, puzzle-solving, and rock-throwing.

Players can obtain a considerable amount of historical information from the dialogues presented during the main and secondary missions. However, an essential pedagogical feature is the Codex system, which allows players to access historical content embedded in the game world (Figure 1). These entries are unlocked through interaction with the Non-Playable-Characters (NPCs) (Figure 1), providing deeper context and more historical information about the Roman period. These behaviours are also trackable, providing researchers with crucial behavioural information, such as interactions with the codex entries, the accomplishment of secondary missions, and time-on-task tracking. The video game has been designed with input from history education, psychology, and game-based learning principles; *Limes* aims to foster historical knowledge, positive diversity beliefs, and motivation through a narrative-driven, interactive experience (Viccari *et al.*, 2024).

[1] The *Limes* video game can be accessed at: https://ancient-verse-research.itch.io/limes (Windows and Mac versions available).

Figure 1: (Top-left) Gameplay screenshot in *Limes* video game. (Top-right) Login screen of the *Limes* video game. (Bottom-left) An example of a Codex entry being unlocked during gameplay. (Bottom-right) The Codex menu shows unlocked entries during gameplay

2.2 Identifying Core Game Features for Adaptation

While educational video games may include various immersive and interactive elements, not all are essential—or feasible—for replication in a text-based format. Identifying the suitable mechanics in the *Limes* video game was a crucial stage in creating a comparable text-based control condition. It was decided to select features that support the intended learning outcomes and represent behavioural data relevant to the experimental study. The following elements were selected as core to the adaptation process.

Codex entries are a central mechanic in *Limes* (Figure 2), allowing players to read or hear historical information connected to in-game dialogues and explore Roman history in greater depth. The content was adapted for 5th and 6th-grade students, covering key topics from the school curriculum. These entries are optional and are unlocked through exploration or dialogue. Their inclusion is pedagogically significant, as they support factual knowledge acquisition and allow learners to engage with supplementary material at their own pace. As Mayer (2015) notes, narrative context and thematic relevance can enhance learner motivation and engagement. According to relevance-based reading models, learners are more inclined to engage with optional content if they find it meaningful (McCrudden and Schraw, 2007; McCrudden, Magliano and Schraw, 2010). For this reason, the text version needed to replicate both the availability of these entries and the ability to track interactions, specifically, how often they were accessed and how much time was spent on them.

Figure 2: Codex entry example during a gameplay in *Limes* video game

Secondary missions function as exploratory and additional side quests, allowing players to interact with additional narrative material, deepen their understanding of the game world, and access extra game mechanics, such as horse racing. These missions are optional, reflecting the player's autonomy in engaging with extended content. From a design perspective, they represent an opportunity to allow for learner agency, autonomy, and interest-driven behaviour, thus contributing to their self-determined motivation (Ryan and Deci, 2000; Dennie, 2012; Proulx, Romero and Arnab, 2017). In adapting the game into a text format, it was important to preserve this element of choice, allowing readers to decide whether to access the additional material while also enabling that choice to be tracked.

Time-on-task tracking was another essential feature that needed to be included in the text adaptation of *Limes*. In the original game, the Unity code records the amount of time spent on several sections and transfers that information to the Mongo Database —such sections are the main storyline, secondary missions, and Codex entries. Tracking time spent on different sections provides insight into learners' attention, engagement, and navigation behaviour within the *Limes* environment. Therefore, incorporating equivalent tracking in the text version was necessary to allow for behavioural comparison across conditions. This approach aligns with recent research advocating for objective behavioural tracking in digital environments, as it provides more accurate insights into user engagement than self-reported measures (Johannes, Vuorre and Przybylski, 2021).

The game's **five-star rating system** is an integrated assessment mechanism that evaluates performance based on exploration, completion of secondary missions, and Codex usage. This system is pedagogically relevant because it provides immediate, performance-based feedback, which has been shown to foster learners' satisfaction of their need for competence, and their motivation (Sailer *et al.*, 2017; Bardach and Murayama, 2025). Recreating this rating system in the Text-app was important to allow participants in both conditions to receive similar performance feedback and to maintain motivational comparability across formats.

Together, these four features—Codex interaction, secondary mission engagement, time-on-task in the different sections of the game, and the five-star feedback system—were identified as central to the pedagogical structure of *Limes* and critical for experimental comparability. Their inclusion in the text version was not an attempt to gamify the reading experience but rather to create a structurally aligned learning environment that would allow for meaningful behavioural tracking and outcome comparison in a controlled study.

2.3 Framework for Game-to-Text Adaptation

Challenges discussed earlier in the introduction highlighted the need for a control condition that goes beyond a static PDF or linear text, offering greater interactivity and measurability. Considering the experience gained while developing the *Limes* video game, we opted for a structured text application[2] using Unity. This allowed for precise segmentation of content and the implementation of custom tracking systems mirroring the logic of the game (Figure 3). The text was divided into three main types of content:

1. Main storyline,
2. Secondary missions
3. Codex entries

[2] *Limes* Text-app can be accessed at: *https://ancient-verse-research.itch.io/limes-version-2* (Windows and Mac versions available).

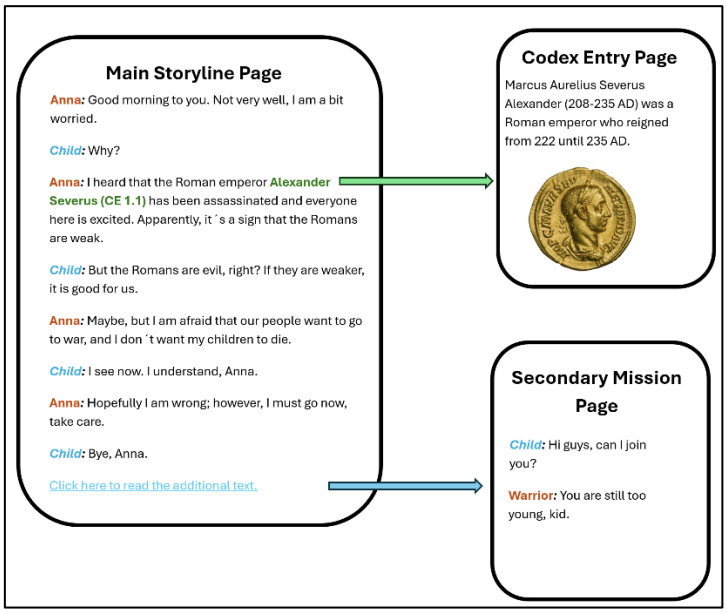

Figure 3: The diagram provides a simplified illustration of the Unity-based structure, showing how the main storyline connects to optional Codex entries and secondary missions, each displayed in separate text panels

Each section was implemented as an interactive module with automated time tracking and click logging.

The **main storyline** served as the structural backbone of the app and was set as the default view that loaded when the user launched the application. It was implemented as a scrollable text panel within Unity's system, very similar to a regular PDF document, with time tracking initiated automatically upon scene load. Since all study participants are required to read the main story, this section provided the baseline to which optional interactions, like secondary missions and Codex entries, could be added.

Secondary missions, which were optional side quests in the game, were similarly adapted as clickable links embedded in the main narrative (Figure 4). These links appeared as light blue text at relevant decision points of the story, such as "Click here to read the additional text."

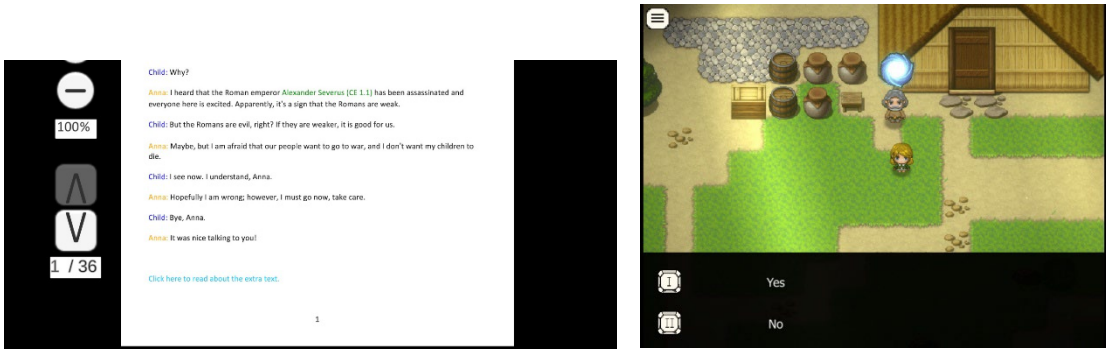

Figure 4: (Left) additional text link in the Text-app, (right) secondary mission choices during the gameplay of *Limes* video game

When the link is clicked, the app records the interaction and the time spent on the additional text page(s). This enables precise measurement of engagement with optional content—an essential feature to support autonomy and potential indicator of learners' interest.

Codex entries, another optional learning mechanic in the game, were embedded directly into the main narrative using the same green-highlighted format as in the original game (Figure 1). When clicked, each Codex entry opened in a dedicated window (Figure 5). As with the game counterpart, the system logged the time spent reading each entry and whether it had been accessed. All interaction data was stored in a Mongo Database, identical to the architecture used for logging gameplay behavioural data in *Limes*.

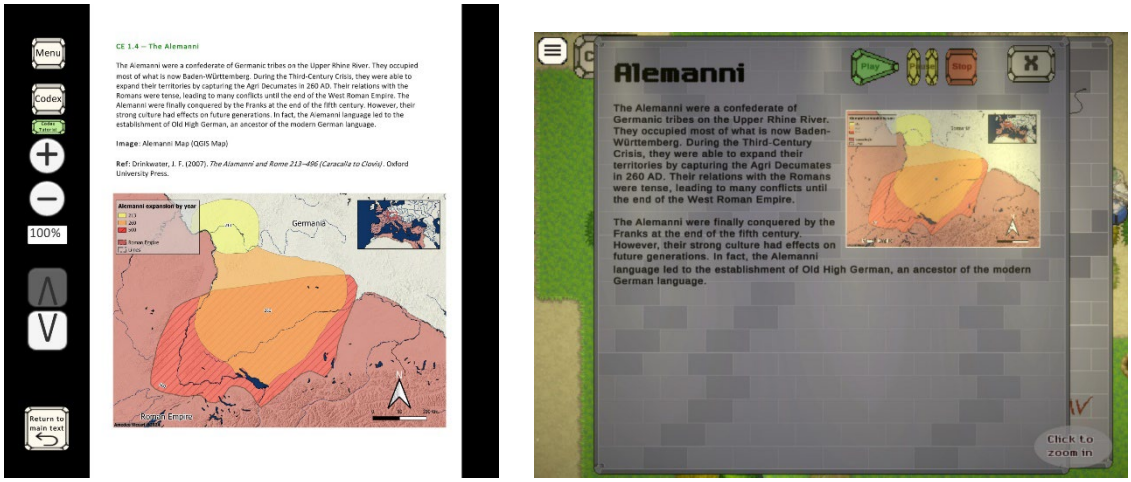

Figure 5: (Left) Codex entry example in the Text-app. (Right) Codex entry example in *Limes* video game

The five-star rating system was also implemented in the text version. This allows users to see their performance for each section of the text, equivalent to the levels in the game version. The performance is based on these actions:

- Clicking all Codex entries available in a text section.
- Access the additional text link corresponding to the secondary mission in the gameplay.

As in the game version, the Text-app requires users to complete the main storyline before receiving their star rating, which is displayed in a similar format to maintain consi stency across the two media (Figure 6).

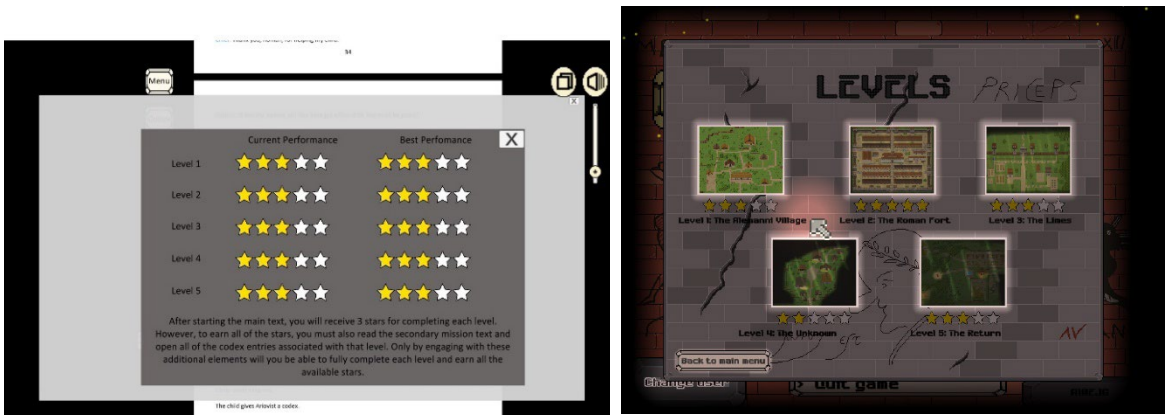

Figure 6: (Left) Five stars awarding system in the Text-app. (Right) Five stars awarding system in *Limes* video game

Another important aspect replicated in the Text-app is full access to the Codex entries once the main text has been completed. As in the game, all Codex entries become accessible at this point; however, accessing them after completing the main content does not affect the five-star rating—unless the reader revisits the corresponding text sections, just as players would need to replay levels in the game.

The Text-app preserves the same narrative and allows users to make similar decision options by clicking on additional text or the codex entries, while also enabling precise tracking of these behaviours. This approach is meant to establish a structurally aligned control condition, ensuring that any differences in learning outcomes are more likely connected to the format itself (game vs. text), rather than to variations in content structure, engagement features, or users' behaviours.

2.4 Early Testing and Feedback

As with the original *Limes* video game, the text-based application was tested with experts during development to gather formative feedback on content clarity and possible technical problems. These reviewers included educational researchers and historians familiar with the project's goals, as well as individuals experienced with digital learning tools.

Since the app was developed in both German and English, preliminary testing was conducted in both languages. However, special attention was given to the German version, as it was the version intended for use our first experiments. This included reviewing the linguistic accuracy of the texts and checking for fluency and user comfort when navigating the app's interface.

Feedback led to two main refinements. First, some dialogue passages and transitions were restructured slightly to better fit a linear reading experience, particularly in the German version. Second, the initial scroll system was unintuitive and slow, presenting several issues when combined with the navigation arrows. This resulted in delays and imprecise navigation through the text. To address this, the underlying code was adjusted to ensure smoother scrolling and to make the app interface more user-friendly. These changes significantly improved navigation fluidity across the main story, Codex entries, and secondary missions while preserving the behaviour-tracking structure required for the experiment.

A crucial aspect of the testing phase was verifying the interaction between the Text-app and the Mongo Database, where behavioural data, such as Codex clicks and time-on-section, is stored. The tests confirmed that the data was recorded accurately and reliably. While the video game and Text-app use separate MongoDB databases with different field names and structures, the underlying logic and data types are aligned. These differences are the results of the independent Unity development of the two applications. Both systems record the same core variables: time spent (in seconds), Codex interactions (number of clicks), star achievements per level, and secondary mission completion, see below:

Mongo Database – Video game	***Mongo Database – Text-app***
totalTimeLevel1: seconds	**timeSpentMainText:** seconds
totalTimeLevel2: seconds	**timeSpentCodex:** seconds
totalTimeLevel3: seconds	**timeSpentSecondaryMission:** seconds
totalTimeLevel4: seconds	**codexEntryClicks:** number of clicks
totalTimeLevel5: seconds	**totalActiveTimeMainTextSecondaryMission:** seconds
totalTimeMainSec: seconds	**level_1_stars:** number of stars
totalTimeCodexMenuOpen: seconds	**level_2_stars:** number of stars
codexButtonClicked: number of clicks	**level_3_stars:** number of stars
starsLevel1: number of stars	**level_4_stars:** number of stars
starsLevel2: number of stars	**level_5_stars:** number of stars
starsLevel3: number of stars	**level_[*level number*]_secondary_star_awarded:** Mission Achieved – true or false
starsLevel4: number of stars	
starsLevel5: number of stars	
CompletedSecondaryMissions: Object 1 (Mission Achieved)	

In the game, mission completion is logged as an object per level; in the Text-app, the same is recorded as Boolean values (true of false). Time tracking of the secondary missions is split in the Text-app for structural reasons but later merged—mirroring the unified level time in the game.

2.5 Limitations and Future Directions

While this paper does not report empirical results from experiments, its contribution lies in presenting a structured and trackable text-based format that enables more valid comparisons between video games and texts in experimental research. This constitutes, to the best of our understanding, the first attempt of its kind. Our paper provides a practical framework that other researchers can adapt or build upon when designing their own structurally aligned control conditions. While tailored to a narrative-driven history game, the framework may be transferable to other domains that rely on exploratory learning or decision-making, such as science simulations or cultural education. Its modular structure and tracking logic are adaptable to any learning context involving optional content, time-on-task, and user-driven exploration. Future work could explore how this framework performs when adapted to other domains (e.g., environmental science, language learning, or civic education), where narrative and autonomy also play key roles. Overall, our approach has the potential to inspire similar projects in other domains by showing how behavioural tracking and narrative structure can be replicated in non-

game formats. Future work will evaluate the empirical utility of this framework and examine how structural alignment, and behavioural tracking can support robust comparisons across different educational formats. In our own upcoming experimental studies comparing the *Limes* video game and the *Limes* Text-app, we aim to gain insights into the pedagogical effectiveness of such a Text-app compared to its game counterpart, particularly in terms of learning outcomes (e.g., knowledge on the Roman Empire), motivation, engagement patterns, and intercultural attitudes.

Beyond its applicability in experimental contexts, the newly developed Text-app opens up additional opportunities for future research. There is growing interest in educational and psychological research in modelling and assessing digital traces of learner characteristics and behaviours to test theories *in action* and inform practice. For example, researchers are exploring digital traces of educationally relevant personality traits and motivations, and use digital traces to predict outcome variables, such as test performance and knowledge attainment (e.g., Tlili *et al.*, 2019; Matcha *et al.*, 2020; Schumacher *et al.*, 2025). Exploring whether different learner characteristics are reflected in behavioural patterns captured by the *Limes* Text-app and the video game could yield valuable insights for research and offer practical implications for adaptive educational technologies. In addition to using the behavioural indicators described in the present design paper, researchers could also create new indicators to more comprehensively test their theoretical assumptions in future research with *Limes*. For instance, a recent study found some indications that intellectual curiosity (as a personality trait) and domain-specific interest (as a motivational construct) manifested in different information-seeking behaviours: interested learners employed a more widespread search for information, whereas curious individuals engaged more deeply with the learning content by revisiting information more frequently (Schumacher *et al.*, 2025). This distinction could be further investigated using *Limes*, for example, by analysing the revisiting of codex entries as a behavioural indicator.

3. Conclusion

This design paper introduced the development of a structured, interactive Text-app built as a control condition for experimental research comparing video game- and text-based learning formats in history education. The text application replicates the key pedagogical mechanics of the educational video game *Limes*—including time-on-task tracking, engagement with optional content, and a five-star feedback system—within a Unity-based environment that enables precise behavioural monitoring. By ensuring structural comparability and capturing interaction data across formats, the Text-app addresses a significant methodological challenge in video game-based learning research: the difficulty of creating valid text-based control conditions that allow meaningful comparisons. Even though the current project is tailored to Roman history and the *Limes* project, the framework is adaptable and could be extended to other domains and narrative-based games.

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Ethics declaration: Research on the *Limes* project has been approved by the ethics committee of the University of Giessen, Department of Psychology.

AI Declaration: AI tools were used in a supportive capacity during this project. Grammarly was used during the writing process to assist with grammar and style suggestions. GitHub Copilot was employed to support and accelerate the development of C# scripts for the interactive Text-App in Unity. All code was authored and reviewed by the first author, with Copilot assisting in suggesting possible changes. Additionally, OpenAI's ChatGPT was, in some instances, consulted during the writing process for feedback on the structure of English sentences. All content decisions and final formulations were made by the authors.

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Playful Citizen Discussion Space to Help Steer Society Towards Water Security

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Abstract: In this paper, we explore the use of a playful dilemma activity, a survey and public data analysis to spark citizen awareness and reflection on water use within the UK. Water security ensures access to fresh water for survival and society's needs. There is significant citizen agency in water security that impacts the freshwater reserves. However, in many countries, water security is under-discussed. Encouraging spaces for individuals to assess their water use, identify waste, and adopt sustainable practices is key to sustaining freshwater resources for the future. We present a case study conducted as part of the GREAT project to stimulate citizen discussion on water use and its subsequent impact on the broader water system. Through a series of activities, citizens can reflect on their water use, consider the future forecast of water security within the UK, and experience a playful dilemma to save a city from the effects of drought. In this dilemma, players are part of an organisation tackling a city's water crisis. Faced with limited water resources, players analyse data on the population's usage and suggest behaviour changes to reduce consumption. The challenge lies in balancing the need for water conservation with the risk of proposing changes that are resisted by the population. The players must convince the facilitator of both the practicality and acceptability of their plans. Success restores water security, but failure reveals the consequences of inaction. Within this playful discussion space, we create an exchange for citizens to elicit attitudes and preferences on current water use and explore how individuals might be "nudged" into less wasteful behaviour. In this paper, we describe the co-design of this qualitative approach, share findings on attitudes and preferences elicited (n = 19), and reflect on this method as a tool for fostering awareness and meaningful citizen discussions.

Keywords: Dilemma game, Playful education, Climate conversation, Water sustainability

1. Background

Water security refers to society's access to fresh water for survival and sustainable continuation. Sustaining water systems amid climate change and population growth is complex, requiring infrastructure, industries, and agriculture to consider usage (He et al., 2021). Collectively, population habits significantly affect national reserves. For instance, daily domestic use per person is 379 litres in the US versus 147 in France (BSI, 2024, pp. 31–32). Despite citizen impact, water use remains underdiscussed (BSI, 2024), creating a disconnect between water security needs and public understanding of sustainable engagement.

To educate the public on climate issues, the traditional knowledge deficit model assumes lack of understanding is a barrier to action (Simis et al., 2016). While information is crucial, this model presumes people will adjust behaviour once informed. Yet, even when content is heard, personal beliefs, values, and circumstances shape climate engagement. Two-way discussion allows citizens to interpret and integrate new knowledge through these subjective lenses (Ettinger & Painter, 2023). Dialogue fosters shared understanding, opens diverse perspectives, and supports decision-making (Pröpper, et al., 2024). In short, safe spaces for climate discussion can aid interpretation and help overcome behavioural barriers.

Educational games support learning outcomes, though a tension often exists between subject depth and engaging gameplay. Playful learning occupies a middle ground between game-based learning and gamification (Plass et al., 2020). Game-based learning presents subjects as systems of rules, choices, and consequences, inviting experiential interaction (Perrotta et al., 2013). Gameplay becomes the learning process. For example, nursing students developed procedural knowledge of intravenous injections through a digital game requiring appropriate equipment selection, turning decision-making into learning (Hwang & Chang, 2023). Gamification applies specific game features, like points or achievements, to non-entertainment activities, enhancing motivation (Deterding et al., 2011). However, the learning content remains largely unchanged. A playful

approach subtly integrates game design principles into learning activities. These activities align meaningfully with game elements, moving beyond simple gamification. However, they are not full games (Plass et al., 2020, p. 5). For example, scripted narratives support hotel room design decisions (Hamalainen, 2008) or water management case work (Hummel et al., 2011). In these examples, interaction within the game world is limited to visualising information. The game world and narrative structure support the intended learning activities and outcomes.

Social dilemmas occur when short-term self-interest conflicts with long-term collective wellbeing (Van Lange et al., 2013). In sustainability contexts, this reflects how resource overuse today may compromise future societal needs. Social dilemma games often adopt a macro perspective to simulate how decisions benefiting one group can undermine broader systems (Druen & Zawadzki, 2021). Quick game rounds allow players to observe impacts, fostering empathy and showing how sustainable cooperation benefits all (Cerutti, 2017). These games introduce core concepts, prompting choice-making and experiential learning. When framed around local issues, dilemmas may engage communities in securing sustainable resources (Meinzen-Dick et al., 2018). Reflection on personal resource use is present but may not occur during gameplay due to the game's macro lens. Instead, it surfaces between rounds or afterward, when participants' energy may be too low for meaningful sensemaking (Cerutti, 2017; Liao et al., 2023).

Social dilemmas offer a helpful framework for participatory activities promoting discussion on resource norms and fairness. The dilemma becomes a focal point where diverse perspectives converge, and discussion fosters ideation (Janssen et al., 2023). Recent work has shown discussion can be a core mechanic shaping player choice. For example, Merry et al. (2025) presented a dilemma game on a "green roofs" initiative. It enabled role-play among housing stakeholders to explore policy compromises. Through dialogue, players engaged with the dilemma and diverse perspectives, advocating fairer policy details.

To contribute to water sustainability education, we employ a co-design methodology to develop a dilemma discussion as a concise, playful activity. Building on previous dilemma games, we utilise this playful approach not to understand the socio-economic dynamics of a broader water system, but rather to reflect on and engage with sensemaking on sustainable citizen water use, something that citizens have the power to adjust in their daily lives. Drawing on principles of collaborative game design (Wang & Huang, 2021), we utilise a shared space, narrative, cooperative goals, and social dilemma framing to incentivise sustainability discussions and sense-making that elicits reflection and attitudes towards individual water use. Through playful engagement, we look to draw out what reasonable citizen water use looks like and explore the impact of this approach on individual water behaviour.

2. Playful Dilemma Design

This study presents initial work designing and implementing the "Save the City" playful dilemma. A collaboration with Waterwise (Waterwise 2025), a UK non-profit organisation that promote the "*wise*" use of water. We utilised the GREAT (Games Realising Effective and Affective Transformations) (Hollins *et al.,* 2023) co-design methodology to explore how game-based approaches can foster public discussion on reasonable citizen water use.

The GREAT methodology is an eight-step process for co-designing game-based activities that facilitate communication between citizens and policymakers. This approach facilitates a "dialogue through games" between these stakeholders, eliciting attitudes and preferences on climate issues. Steps one to three outline the policymaker's goals and explore how game-based activities can facilitate these goals. These steps culminate in the development of interactions and supporting artefacts. Step four focuses on engaging the target group with the designed approach. Steps five to eight involve evaluating the collected data with stakeholders, disseminating findings to a broader audience, and reflecting on what has been achieved and what can be improved. This paper covers the work completed in steps one to four.

In step one workshops with Waterwise, two goals summarised what this case study should achieve:

- Improve public consideration towards water use
- Discuss with the public how they would be willing to achieve water sustainability in the UK

In the second step workshops, policymakers ideated game concepts aimed at achieving the goals established in the first step. The ideas that resonated with the workshop group included:

- Narrative of water use within the broader water system
- Activities that allowed players to calculate water consumption per day
- Scenarios involving personal water use and conflicts with the broader water system

In step three, industry partner Serious Games Interactive (SGI) engaged with the learning goals and how these could be represented on their Dilemma Based Learning (DiBL) platform (DiBL, 2025). On this platform, facilitators present discussion content on screen, while "players" join via PC or mobile to form teams, discuss, vote, and comment. The platform enables different media to be delivered to individual devices than what's shown on the facilitator's screen, supporting varied perspectives. The result is a set of interactive activities and dilemma scenarios, with votes and choices recorded through the platform.

Facilitator DiBL Screen Player DiBL Screen

Figure 1: Facilitator and player screen using the DiBL platform. Players can see both the facilitator screen and their own screen. Player screen can be used for text entry, voting, and information delivery

Through a series of meetings with Waterwise, the following activities were chosen:

Activity 1: Water Use Survey: Players are surveyed on their current perception of water supply within the UK and asked questions about daily water use (Watson, 2025 S1). The result is an estimate of how much water each player uses each day. The results are private, a personal point of reflection and primer for examining water use information in the playful dilemma (Activity 3).

Activity 2: Data Exploration of Future Water Supply: Using two graphs (Watson, 2025 S2), players must view and discuss the data to create a title and tag line for a newspaper article on the outlook of water supply in the UK. This activity aims to ground players' views on water supply through data and the importance of considering water use.

Activity 3: Save the City Playful Dilemma: (See figure 2 for high-level flow) Players are informed that they are part of HYDRO, a group in charge of maintaining the water supply in the fictitious city, Belton. Belton is facing a water crisis, and HYDRO must consider the water behaviours that the population can reasonably change to halve bathroom water use. Participants collaboratively analyse citizen bathroom water use data (Watson, 2025 S4) to propose feasible behaviour-changes and supporting strategies. The shared platform and narrative provide a common space and context for discussions. The narrative is kept local to UK participants by using drought as the cause, and bathroom water use information similar to UK habits. The mission articulates the overarching goal, while the narrative structure introduces a dilemma regarding what water use should change and positions the group with a shared responsibility for resolving it. The players' actions are to deliberate and present plans to halve water use. These actions do not interact with the game world until a plan is formed. Like game-based learning, the actions of discussion and sensemaking are the required outcomes of this playful activity. Once plans have been submitted, players then vote on their preferred course of action. The facilitator evaluates the plan's impact: substantial savings result in the city's salvation, moderate success yields partial progress, and insufficient efforts lead to continued crisis. The resulting narrative is delivered to participants through the player and facilitator screens.

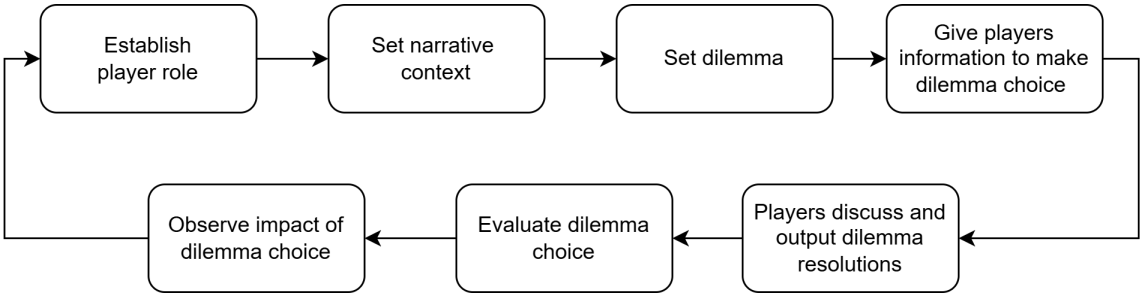

Figure 2: Save the City playful activity core progression loop

3. Pilot

A pilot was conducted using a convenience sample (n = 6) to test timings and technology. A Game Experience Questionnaire (GEQ) (IJsselsteijn et al., 2013) was administered to explore participants' perceptions of the playful dilemma experience. GEQ uses a series of 33, 5-point Likert scale questions (0 = not at all, 1 = slightly, 2 = moderately, 3 = fairly, 4 = extremely). A bug in the system interrupted the playful dilemma during this pilot, causing a period of inaction. From the GEQ (see Table 1), participants reported limited negative experiences during and after play. The positive experience was slight during play (M = 1.13, SD = 1.02), but the equivalent standard deviation suggests some variability in this. Positive experience after play was moderate. The game established a slight to moderate sense of flow and moderate immersion. Players found that the playful dilemma and supporting activities encouraged discussion on water use and enjoyed using data within the playful dilemma. Timings of all activities and worded content were adjusted based on feedback from this pilot.

Table 1: GEQ core module descriptive statistics. 0 = "not at all", 1 = "slightly", 2 = "moderately", 3 = "fairly", and 4 = "extremely"

GEQ Category	Mean	SD	SE
Competence	1.63	0.98	0.40
Immersion	2.30	0.50	0.20
Flow	1.84	0.88	0.36
Tension/Annoyance:	0.33	0.52	0.21
Challenge	1.73	0.94	0.39
Positive affect	2.53	0.75	0.30
Negative affect	0.25	0.32	0.13
Positive Experience	1.13	1.02	0.42
Negative experience	0.47	0.25	0.10
Tiredness	0.33	0.52	0.21
Returning to Reality	0.28	0.33	0.13

4. Methods

In total, 19 participants (female = 10, mean age = 46, min age = 22, max age = 71) were recruited for the main trial. A participant call was placed through the communication channels (e.g., LinkedIn, Facebook) of Waterwise. The call explained that we are exploring playful approaches to discussing water use. Through the sign-up process, participants were screened to make sure they were over 18 and living in the UK. No incentives were offered to participants in this study.

4.1 Experimental Setup

Sessions took place between March and April 2025. Each session had 3-6 participants. All session discussions took place online through Zoom calls. This platform was chosen as it has the potential for a broad reach. The DiBL platform requires an open webpage to load the player screen. The facilitator delivers their screen through an online video format. Players will then have to engage with the facilitator screen and their own screen. The player screen can be accessed on a phone, tablet, or web browser. (See figure 4).

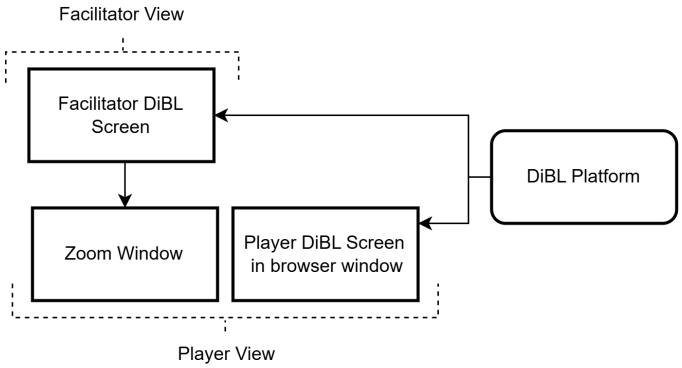

Figure 4: Participants needed to navigate between the zoom discussion and their own webpage to take part in the sessions

4.2 Procedure

Participants would arrive online to the allocated Zoom session. The information sheet was discussed, and consent to take part was gathered (10 mins). Then followed facilitated activities. Activity one (10 mins), activity two (15 mins), and activity three (15 mins). A reflective survey was then given to the participants through the DiBL platform which asked about their experience (Watson, 2025 S4). During this reflective section, the text entry of what participants enjoyed the most and least appeared on screen to engage some final thoughts on this reflection (10 mins). One week later, a follow-up survey was sent to the participants, which asked the same questions from activity one, along with additional questions inquiring about any changes in behaviour (Watson, 2025 S6).

4.3 Data capture

Video sessions and transcriptions were recorded through Zoom features. Transcriptions were checked and anonymised after sessions were completed. Transcripts were used for thematic analysis of discussions (Clarke & Braun, 2017). The themes explored were *Water Reduction Concept*s, the general areas where participants felt water savings could be made, *Water Reduction Ideas*, specific actions to reduce water use, and *Reasons Against*, which included reasons for disagreement with suggested ideas. Text entry and voting behaviour were recorded on the DiBL platform and received by the researcher after the sessions were conducted. Microsoft Forms were used for a follow-up survey and a sign-up survey. Through the sign-up survey, basic demographic data on age and gender were gathered.

5. Results

Through the follow-up survey, participants were asked if they had made any changes to their water use habits. Out of 19 participants, 16 responded. Eight stated no changes in water use. Four stated purposeful effort in turning off running taps, two stated taking shorter showers, one stated trying to generally be more water efficient, and two stated that they had made changes, but did not give details on what changes.

Participants were surveyed as part of activity one in the Zoom sessions, and one week later on their reported their water use. Although overall mean water use was reduced (756.59 L – 725.68 L), this was not significant (t(15) 0.61, p = 0.531) across the group.

Table 2: The water reductions themes and ideas generated from the Save the City playful activity

Water Reduction Concepts	Water Reduction Ideas	No. P's agree	Reasons Against
Reductions in shower time	Shower no more than 4- 5 per week	8	Vocation, family needs, skin conditions
	Reduce shower time to 4-6 mins	7	
Change in shower habits	Wash hair less	3	
Reduce Toilet flushing	If it is yellow, let it mellow (some of the time)	10	Considered unsanitary
Turn of taps	Brushing teeth	8	

Water Reduction Concepts	Water Reduction Ideas	No. P's agree	Reasons Against
Bathroom hardware	Install efficient devices	3	Expensive, should be government supported
	Maintenance and leakage	2	
	Subsidies for bathroom hardware	4	
SMART metering	Personal monitoring	5	No one should be penalised as water use is dynamic between households. Potential for state control effects
	Comparing to collective	7	
Water awareness	Promote benefits of less water use on self + collective + environment	5	
	Volume used + Water targets	8	
Dynamic Pricing	If use more water, you pay more	3	Not penalise certain family demographics and appreciate dynamic between households.
Water recycling	Rain catchers	6	
	Grey water use	1	

The follow-up survey included a 5-point Likert scale question (1 = strongly disagree, 5 = strongly agree) on whether they found themselves considering water use more, and if they had discussed water use more. The population sample was not normally distributed, so a one-sample Wilcoxon T-test was conducted on the median response against the mid-point of 3.00. A significant deviation below 3.00 would suggest a median disagreement with the statement, while a deviation above 3.00 would indicate agreement. There was a significant positive agreement that participants had been considering their water use more ($V=105.50$, $p=0.006$) with a large effect size (0.76). Discussions of water use were not significant ($V=51.00$, $p=0.685$) with a small effect size (0.13). This suggests a median neutral response.

Table 2 summarises the thematic analysis of the Save the City playful discussions. Participants commonly supported reducing shower time, toilet flushing, and turning off taps while brushing teeth. While it was considered that many could adopt these habits, barriers existed (e.g. family size, vocations, skin conditions). One participant opposed flushing reduction, citing hygiene concerns. Turning off taps was seen as easy and surprisingly impactful when they realised how much water runs through the tap each minute. Upgrading to water-efficient devices was well regarded, if subsidised. Otherwise, it was considered cost-prohibitive, despite its potential effectiveness.

When discussing supportive infrastructure for water use reduction, SMART metering was positively received for raising awareness of personal water use and leakages. However, concerns emerged around potential surveillance and micromanagement through the data generated. Participants saw value in comparing usage data with others, but only if anonymised. Identifiable data was viewed as a privacy violation. Through data, comparisons with anonymised collectives were viewed as motivating and helpful for understanding reasonable water use and a potential avenue for gamification and goal setting.

Participants welcomed information campaigns, noting the need for clearer guidance to support behavioural change. Ideas included health benefits of reduced washing, local water targets, and environmental impacts. Dynamic pricing was favourably received in one session, provided it didn't unfairly affect families or those with barriers to water efficiency. Suggestions for water recycling and greywater use emerged, although without concrete proposals. While participants believed UK rainfall could support non-drinking water reuse, practical implementation remained unclear.

Participants were asked to write one sentence on what they enjoyed the most and least. When reporting on what they enjoyed the most, eight participants mentioned group discussions and hearing others' points of view. Four specifically mentioned the Save the City exercise, one mentioned learning about their water use, one mentioned the computer game-style of the playful dilemma, and another mentioned that the activities used data. When reporting on what they enjoyed the least, two mentioned the article activity as it required creative thought, two mentioned seeing how much water they used, and one mentioned technical issues of logging in. When surveyed "How was your experience of the session (1=very negative and 5=very positive", the average response was 4.32 (SD=0.58). A Wilcoxon one-sample t-test against the middle value of 3 suggests a significant positive subjective affect in the sessions ($p= p < .001$, $v = 171$) with a large effect size (1.00).

6. Discussion

We explored the use of a playful dilemma and supporting activities to create a discussion space where citizens could reflect on and advise a path forward for reasonable water use at home.

Despite the short time given to these sessions, the playful dilemma prompted discussion on reasonable water reductions. Prior games emphasised stakeholder dynamics at a societal level, and as such, predominantly generate knowledge and concern within that framing (Cerutti, 2017; Cheng et al., 2019; Liao et al., 2023). Given the tighter focus on citizen water use, this playful dilemma was able to highlight sustainable and fair use of daily water habits. Self-washing routines became a dominant strategy due to the dilemma's focus on bathroom water use and equivalent real-world impact. Discussion shifted toward communicating these habits to Belton residents, with suggestions on promoting change through policy and infrastructure (e.g. SMART metering, dynamic pricing, informational tools). Two themes influenced the acceptance of such measures. First, participants valued insight into personal and collective water use to inform water behaviour. Second, there was concern about ensuring no demographic is unfairly penalised by rigid ideals of efficient water use.

Dilemma game studies have focused evaluations on how conceptual knowledge of a dilemma is developed through play and the ideas of awareness and concern that arise after playing the game (Cheng et al., 2019; Neset et al., 2020). Some assessment on how this experience may shape sustainable behaviour after play (Albertarelli et al., 2018). Our playful dilemma and supporting activities may aid general awareness and concern about water use, similar to full dilemma games. Participants reported they considered their water usage more. However, they were not found to discuss water behaviour more than normal, which might be expected if individuals were grappling with or more interested in the water habits. No significant reduction in overall reported water use was observed in the follow-up survey, but 8/16 participants who took part in the follow-up survey reported purposeful changes in their water use (shorter showers and turning off taps). This suggests that this approach may help nudge easily adjustable behaviours that have limited impact elsewhere in a citizen's behaviour.

GEQ scores from the pilot indicate a generally positive experience. However, flow and immersion were only moderate, suggesting that the activity functioned well as a discussion but less so as a game experience. Designed to prompt discourse and reflection on citizen water use, the narrative structure and shared goal effectively stimulated broad inquiry into responsible water practices. While the absence of game-world interactions facilitated immediate discussion, incorporating additional game elements, such as role-specific sub-goals aligned with a collective objective, could enhance engagement and foster deeper dialogue (Oksanen & Hämäläinen, 2014; Wang & Huang, 2021). Yet, introducing complex, non-discursive mechanics may shift focus toward gameplay navigation, potentially detracting from the intended sensemaking process (Liao et al., 2023).

The playful dilemma and the discussion it fostered were highlighted several times as the most enjoyable part of the session. This suggests that the format has the potential to engage a variety of perspectives in a water conversation. Slight delays in the network can foster awkward discussion moments where individuals talk over each other, and a gap in the discussion can seem more poignant than a real-world conversation. However, this did not halt discussion over the topics presented. Those who engaged with a mobile device needed to be *technologically savvy* to use both the Zoom application and DiBL player screen. However, with facilitation, the platform delivered data, surveys, game exposition, and consequences of dilemmas.

Limitations on the discussions should be noted. While the discussions drew on diverse perspectives, the group format may have subtly influenced the contributions. Social desirability bias, where responses align with perceived group norms, can distort sustainability discourse (Bergen & Labonté, 2020). We sought to mitigate this by facilitating discussions that encouraged divergent views and fostered rapport. Nonetheless, when interpreting consensus, it is essential to consider the influence of dominant narratives. Future research could strengthen findings by incorporating opportunities for anonymous reflection and individual input beyond group settings.

Limitations on how we measured behaviour change through self-reported water use are also susceptible to social desirability bias. It was impractical to gather actual water usage during the study. Improvements to this method could be made by finding independent water use observations to triangulate with self-reporting.

The participant pool must be considered. The call may have attracted citizens who are already interested in water sustainability, which could impact discussion and reported behaviour. Reproducing the approach across different demographics would help identify the type and mix of citizens this approach may or may not impact.

7. Conclusions

This study demonstrates the potential of playful dilemmas to foster meaningful reflection on sustainable water use at the household level. While participants reported increased awareness and some behavioural shifts, broader engagement with water habits remained limited. The activity functioned effectively as a discursive tool, with its narrative structure and shared goal prompting critical dialogue, although the game-like immersion was moderate. Social dynamics shaped the discourse, underscoring the need for future designs to support both individual expression and group exchange. With careful facilitation and targeted enhancements, such interventions could play a valuable role in changing low-barrier, sustainable behaviours.

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AI Declaration: AI tools were used to check grammar and help phrase some content.

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Enhancing Cybersecurity Education Through Multi-Opposing-Role Gameplay and Simulations

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Abstract: This paper presents the development, implementation, and evaluation of The XSS Game (TXG), a game-based educational tool designed to teach Cross-Site Scripting (XSS) attacks through a multi-opposing-role-playing game. Inspired by cognitive concepts like Transfer Learning, previous cybersecurity educational games have incorporated techniques such as adversarial thinking and role-switching. In many such games, the playable roles are often limited to attacker and defender. Building upon these, TXG was developed with an approach where players can take on three distinct roles: Attacker, Defender, as well as User, each providing players with a different perspective on XSS attacks. This approach aims to deepen students' understanding of XSS attacks by allowing them to experience multiple perspectives, enhancing their ability to identify, prevent, and respond to such threats. In addition, simulations are often used in cybersecurity educational games to provide learners with practical, hands-on experiences that are crucial for understanding complex cybersecurity concepts. While the main gameplay in TXG centres on role-based narratives drawn from real-life cybersecurity scenarios, requiring players to answer questions based on those narratives, the game also includes a Simulation Zone. This zone offers an immersive environment where players can perform various actions and observe their outcomes, enhancing experiential learning. Even though quiz-based and simulation-based cybersecurity educational games exist separately, the combination of the two has not been widely studied. By integrating both narrative-driven quizzes and interactive simulations, TXG aims to enhance students' learning by reinforcing theoretical knowledge with practical, hands-on experience, leading to a deeper and more applied understanding of XSS concepts. TXG was evaluated within a computer science course with 162 students through pre- and post-game surveys. Student feedback indicated that the multi-opposing-roleplaying with real-life scenarios approach had a modest but meaningful and practical impact on their learning to understand XSS attacks holistically. The Simulator Zone showed promise as an immersive and reinforcing learning tool, but low engagement limited its impact, and future improvements, such as more varied tasks, additional game elements, enhanced interactivity, and better UI/UX, are planned to boost engagement and better assess its educational value. Several players highlighted the game's effective learning format, which combines immediate in-game feedback with reflective pre- and post-game surveys, which holds promise for broader applications in cybersecurity education and beyond.

Keywords: Game-Based learning, Multi-opposing-role-playing, In-Game simulations, Cybersecurity education, Web application security, Cross-Site scripting attacks

1. Introduction

Cybersecurity is a critical concern across industries, making it essential for students, professionals, and the general public to understand its importance. However, widespread gaps in awareness persist. For instance, a multitude of firms, including media companies, retailers, and financial institutions, have been affected by cybersecurity breaches (Chen et al, 2025). These incidents highlight the severe consequences of neglecting cybersecurity, including financial loss, reputational harm, and even threats to human safety. In response, countries such as the US, Canada, EU members and several others have launched public initiatives to promote better cybersecurity practices (Van Steen et al, 2020).

1.1 Goals and Scope of the Paper

This study outlines the design, implementation, and testing of The XSS Game (TXG), a multi-opposing-role-playing game developed to teach Cross-Site Scripting (XSS) attacks to second-year computer science undergraduates. Players take on one of three roles, including opposing roles:

- Attacker: A technically skilled role focused on exploiting web application vulnerabilities.
- Defender (Developer): A technically skilled role aimed at securing web applications against attacks.
- User: A less technical role that interacts with the developed web applications.

This study aims to explore how a multi-opposing-role-playing game can teach the harmful effects of XSS attacks and provide mitigation skills to both technical and non-technical audiences. By adopting attacker and defender roles, players can learn to analyse and build more secure web applications, while the user role raises awareness about XSS threats for everyday users. Grounded in cognitive concepts like transfer learning, this approach helps students understand XSS attacks holistically through real-life scenarios from multiple

viewpoints. In addition, TXG includes a Simulation Zone where players can interactively simulate actions based on these cybersecurity roles.

Specifically, this paper explores the following research questions:

- RQ1: How can a multi-opposing-role-playing game effectively support teaching XSS topics to students?
- RQ2: What could the impact of narrative-based simulations be in helping students learn XSS topics?

The main contributions of this study include:

- TXG (The XSS Game): A web-based, multi-opposing-role-playing game designed to teach XSS attacks for all audiences.
- Analysis of results: Qualitative and quantitative insights from the first version of the game.
- An outline of a development framework: For creating educational games across various subject domains.

2. Background

2.1 Cross-Site Scripting (XSS) Attacks

Cross-Site Scripting (XSS) is an injection attack where malicious scripts are inserted into trusted websites. It occurs when a web application includes user input in its output without proper validation or encoding, allowing attackers to inject harmful code, typically JavaScript, into pages viewed by others (KirstenS, 2024). When a victim loads the compromised page, their browser executes the script, assuming it's from a trusted source. This can lead to exposure of sensitive data like cookies and session tokens, or even altered webpage content (KirstenS, 2024). Due to its severity, OWASP ranks XSS as the third highest risk in its Top 10 Web Application Security Risks list (The Open Worldwide Application Security Project, 2024).

2.2 Transfer Learning

In cognitive science and artificial intelligence research, transfer learning involves improving performance in one domain by applying knowledge from a related domain (Weiss et al, 2016). Blickensderfer et al (1998) describe a similar concept, cross-training, where training in multiple interacting roles enhances performance in each role. Similarly, Gonzalez et al (2013) mention that individuals perform better in competitive and team environments after experiencing the roles of teammates or rivals, as demonstrated in a role-switching simulation game.

2.3 Related Work

Recent studies highlight the effectiveness of game-based learning (GBL) in cybersecurity education by boosting engagement and understanding across diverse learners. For instance, Williams et al (2024) found that gamified Capture The Flag (CTF) events increased interest in cybersecurity careers among non-technical students. Similarly, Kim et al (2025) reported that gamified labs improved both learning outcomes and motivation over multiple semesters.

Moreover, existing educational games on XSS attacks have primarily focused on attacker/defender roles. Gaurav et al (2021) introduced four web-based games covering topics like SQL Injection, XSS, and more, aimed at system administrators and IT beginners. Adversarial thinking is another common element in cybersecurity games. For instance, [d0x3d!] (Gondree & Peterson, 2013) is a board game where players act as white-hat hackers combating adversarial networks. Moreover, MeetingMayhem (Huang et al, 2024) teaches asymmetric encryption by allowing players to assume adversarial roles.

In the context of role-playing and simulations, Jaffray et al (2021) introduced "SherLOCKED," a detective-themed serious game that effectively consolidated foundational security concepts among undergraduate students, highlighting the value of narrative-driven learning environments. Role-switching is also used in games like PenQuest (Luh et al, 2020), where players alternate between attacker and defender roles. Similarly, Zolotarev et al (2021) propose a game with diverse switchable roles including auditors, technicians, and managers. Bahrini et al (2020) developed a mobile game featuring opposing narratives, “Save My Home” and “Hacker War”, allowing players to act as both defender and attacker.

In summary, while there are several cybersecurity games that target XSS attacks, adversarial thinking and role-switching, there appear to be no educational games that involve multi-opposing-role gameplay, specifically

focused on XSS attacks. Moreover, many of the existing games focus on the attacker\defender dynamic and do not investigate the user role. Hence, this is the main research gap that this study aims to address.

3. Learning Outcomes

The primary intended learning outcomes of TXG are:

- Know how to identify the different types of XSS attacks from multiple perspectives
- Develop secure applications containing preventive measures to mitigate XSS attacks
- Providing an interactive and fun approach to learning cybersecurity

4. Implementation

TXG's implementation includes a frontend built with HTML, JavaScript, and CSS, and a backend using the Flask framework (Pallets Projects, 2010). For evaluation, players accessed the game via a shared application link. As shown in Figure 1, TXG follows a multi-opposing-role gameplay flow, where players take on Attacker, Defender, and User roles. Participants were also required to complete integrated pre- and post-game surveys for evaluation.

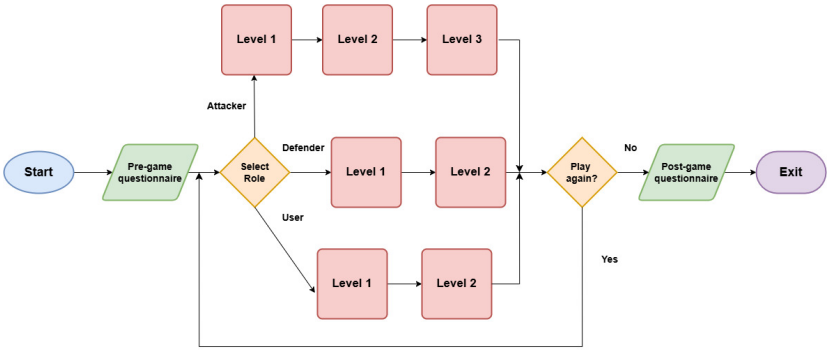

Figure 1: The XSS Game gameplay flowchart

5. Example Gameplay

TXG is a role-playing game where players assume different roles to answer questions based on specific XSS scenarios. As illustrated in Figure 2, the main gameplay involves players receiving an XSS-related question (box C), often paired with an image. To proceed, players must select answer(s) from the provided tiles (box E). In addition, box A offers access to external XSS information (KirstenS, 2024) and in-game guidance.

5.1 Simulator Zone

The Simulator Zone is a key feature of TXG, accessible through the crosshair button (Figure 2, box B) during specific questions. Within this zone (Figure 3), players can perform simulated actions such as navigating a target website, submitting test attack scripts, or defending against attacks by validating and sanitising inputs. These interactive elements aim to reinforce learning and provide a deeper understanding of XSS attacks, making TXG more than just a gamified quiz.

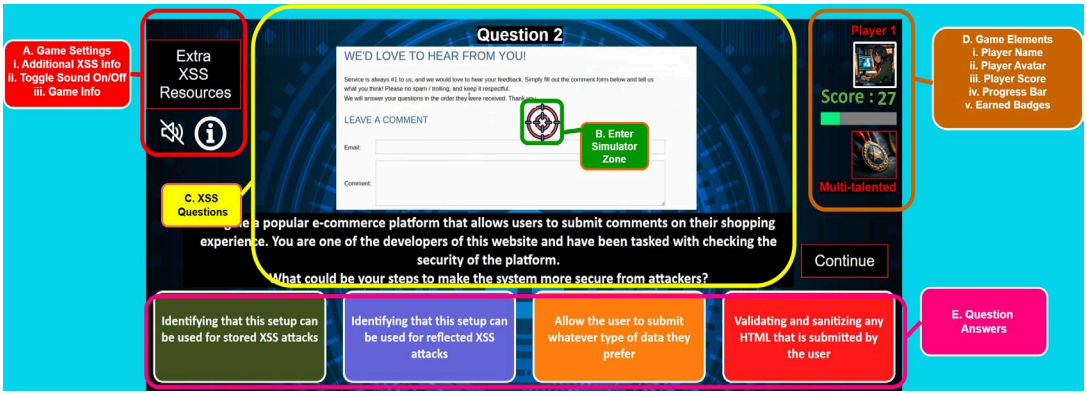

Figure 1: The XSS Game gameplay main components: A. Game Settings, B. Simulator Zone Button, C. XSS Questions, D. Game Elements, E. Question Answers

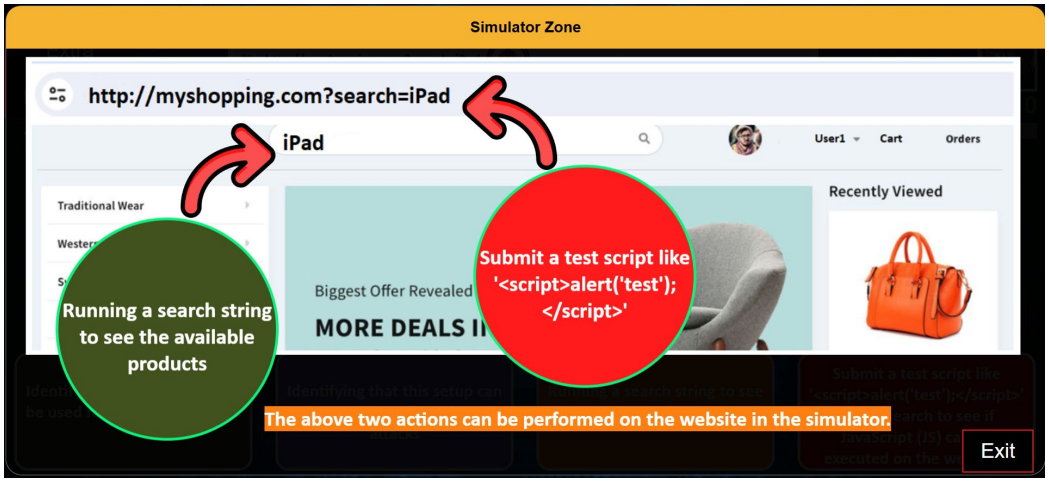

Figure 2: TXG Simulator Zone, where players can simulate actions

5.2 Game Elements

TXG contains several game elements aimed at increasing players' motivation and engagement, which can be seen in box D in Figure 2. Table 1 describes the elements in more detail.

Table 1: Game elements and description

Game element	Description
Player name	Allows players to personalise the gaming experience.
Player avatar	Allows players to personalise the gaming experience.
Player score	Rewards/penalises player actions. Players receive positive points for correct answers and negative points for incorrect answers. Adds a sense of accomplishment as well as competition.
Progress bar	Allows players to monitor game progression status.
Badges	Rewards player achievements. Players receive awards according to the number of completed roles: Expert badge for 1 completed role, Multi-talented badge for 2 completed roles, and All-rounder badge for 3 completed roles.
Leaderboard	Ranks player achievements, such as score and earned badges, to add a sense of competition and motivate players.

Moreover, interface features such as progress indicators, avatars, and badges were designed in line with Nielsen's usability heuristics (e.g., visibility of system status, user control) (Nielsen, 1994) and motivational principles from Malone and Lepper's framework, including challenge, control, and feedback (Malone & Lepper, 1987). These design choices aim to balance usability with meaningful learning engagement.

6. Data Collection

TXG was evaluated with a class of second-year undergraduate computer science students, where it was presented as an assignment in which the students would have to obtain a score of 80% or more to pass. The data for the evaluation were mainly collected from the pre-game and post-game surveys, as well as other in-game player behavioural data, such as the time spent completing the game, achieved scores and badges, and the time spent in the Simulator Zone.

Before data collection, the survey and data handling procedures were reviewed and approved by Sikt – the Norwegian Agency for Shared Services in Education and Research. The study primarily collected non-personal data, such as participants' age group, education level, cybersecurity knowledge, gaming experience, and opinions. The only personal data collected, participants' institutional email addresses, were used solely for assignment marking and were permanently deleted after grading to ensure anonymisation.

The research adhered to international standards for human-subject research, following General Data Protection Regulation (GDPR), National Committee for Research Ethics in the Social Sciences and the Humanities (NESH) guidelines, and Declaration of Helsinki. Participants were clearly informed about the study's purpose, the data collected, and their rights, including the right to withdraw at any time without

penalty. Since the study posed minimal risk and all personal data were anonymised, additional ethics committee approval was not required under national regulations.

7. Evaluation Results and Discussion

7.1 Data Overview

After initial data cleaning steps, 162 unique players were found to have participated in the evaluation. The average playtime to complete the game was 15 minutes and 47 seconds. In the pre-game survey, information such as demographic data, player familiarity with cybersecurity concepts, and previous gaming experience was also collected. This is summarised in Table 2.

Table 2: Pre-game survey data, N=162

Category	Data values
Gender	Female (F): 29.9% Male (M): 41.5% Prefer not to answer: 28.6%
Knowledge about Cybersecurity concepts (CSK)	No knowledge (NK): 3.8% Basic knowledge (e.g. regular web surfing) (BK): 62.3% Advanced knowledge (e.g. specialised cybersecurity education) (AK): 33.9%
Previous gaming experience (PGE)	No previous gaming experience (NGE): 6.2% Some gaming experience (SGE): 43.2% High level of gaming experience (HGE): 50.6%

It should be noted that the player comments that are presented in the following sections are presented as they were received to convey their original meanings and have not been edited for grammar.

The pre-game survey also obtained the players' views on gaming, which can be categorised as Positive, Neutral and Negative sentiments, as seen below.

Positive sentiments

> *"I think gaming is a fun way to spend time, as well as a good tool to learn while having fun!"*
>
> *"I like gaming and have been gaming since I can remember. It's both social and fun when shared with others."*

Neutral sentiments

> *"I am glad that gaming is an option for a hobby, however, I don't consider myself a gamer nor am I interested in working with game development in the future."*
>
> *"No opinion."*

Negative sentiments

> *"Gaming is not really that interesting to me."*
>
> *"It's boring at my age"*

Out of the 162 players, the majority of the players' game sentiments were positive (75%) followed by neutral and negative sentiments at 24% and 1% respectively. As shown in Table 2, almost all players (about 94%) have previous gaming experience. The table also shows that almost all players had some level of cybersecurity knowledge (about 96%), with a significant portion mentioning an advanced level of cybersecurity knowledge (about 34%).

7.2 UI/UX

One of the main aspects pointed out by the players was the UI/UX issues faced during gameplay. Before starting TXG, players could adjust the browser zoom to scale the game elements. However, by looking at the player comments, it seems that this approach needs to be redone, so that the game scales for all resolutions

and browsers. Moreover, some players mentioned that having sound effects for button clicks was somewhat distracting and annoying.

> *"The design of the website. I had to change the size of the browser (after adjusting it to the targets in the beginning) for every question in order to see all of the text."*
>
> *"The sound effects kinda drove me mad."*
>
> *"Only small nitpicky stuff about the visual style, the black background behind the text is a little jarring, make it a bit more opaque or something that fits the background picture better."*

7.3 RQ1: Effectiveness of Multi-Opposing-Role-Play for learning XSS topics

7.3.1 Multi-Opposing-Role-Playing

Several players commented that playing the game through multiple opposing roles was interesting and suggested adding more tasks and variety to the roles.

> *"Love these kinds of games and assignments. I really liked getting to pick an avatar, the scoreboard and getting to try out as both user, defender, and attacker."*
>
> *"More difference in the roles, maybe an input option where you can write additional scripts as an attacker, or click on a fake link as a user to show how you can be redirected to a site."*
>
> *"More questions, but let the player choose the same player role multiple times."*
>
> *"Maybe make the role of user a bit harder."*

7.3.2 Adversarial thinking

It was interesting to see that some players were actually trying to invoke XSS attacks on TXG itself, in order to find vulnerabilities. This goes to show that adversarial thinking can be a beneficial skill when it comes to cybersecurity education.

> *"<script>alert('XSS HEHEHE')</script>"*
>
> *"<script>alert('xss')</script> just had to lol."*

7.3.3 Student learning

Most of the players (about 56%) mentioned that TXG provided a good learning experience to learn complex subject matters, such as XSS.

> *"It was fun, motivating and it did not feel like a lecture, even though I learned a lot. I also liked that I got the answers to the questions right away, so that it was easy to understand where I went wrong."*
>
> *"Educational, I think the explanations are simple enough that regular people with no knowledge about cybersecurity would understand."*
>
> *"I really enjoy this way of learning and testing my understanding of the subject at hand. This shows that the lecturer takes their students enjoyment of the subject into consideration. This was fun and engaging, something that we rarely see in our everyday as university students."*

However, some players mentioned that adding more varied tasks could result in a better learning experience.

> *"More difference in the roles, maybe an input option where you can write additional scripts as an attacker, or click on a fake link as a user to show how you can be redirected to a site."*
>
> *"Maybe add some other types of tasks than just questions. For example tasks where we can test more scripts?"*

To evaluate the effectiveness of TXG in improving participants' understanding of XSS attacks, a Wilcoxon Signed-Rank Test was conducted on the total number of correct responses before and after gameplay. The hypotheses tested were: Null Hypothesis (H_o) — there is no difference in participants' XSS knowledge before and after playing TXG (median difference = 0); and Alternative Hypothesis (H_1) — there is a significant difference in participants' XSS knowledge after gameplay (median difference ≠ 0). The analysis revealed a statistically significant improvement, with a Z-score of 3.40 and a two-tailed p-value of 0.00067, indicating strong evidence against the null hypothesis. The mean difference in scores was 0.27 (SD = 1.02), suggesting a

modest gain in performance. The effect size (r = 0.52) indicates a large practical impact, and the surprisal value (S = 10.55) further emphasises the strength of the result. These findings demonstrate that TXG had a statistically significant and practical positive effect on participants' XSS knowledge, reinforcing its potential value as an effective tool for cybersecurity education through game-based learning.

7.3.4 Overall rating

The post-game survey also featured a 1–5 Likert scale where players could rate the TXG playing experience along several dimensions. This is shown in Figure 4, which illustrates that TXG has performed relatively well in the different categories. For instance, it is encouraging to see that about 52% of the players stated that they would recommend TXG to others. However, many neutral responses suggest that there is much room for improvement.

Table 3 presents the average overall ratings across the categories shown in Table 2, such as gender, previous cybersecurity knowledge, and previous gaming experience. Both females and males have rated TXG similarly across the different categories, with a difference of only 0.1 in some of the categories. The main exception is in the category, Game elements made TXG more engaging, where males have rated TXG slightly lower than females (3.0 vs 3.2, respectively).

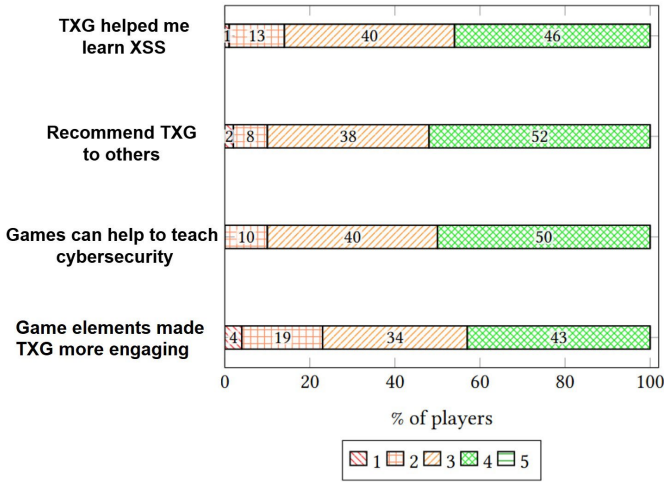

Figure 3: Survey responses represented by the Likert scale chart, where 1–5 represents strongly disagree, disagree, neutral, agree, and strongly agree, N=162

In the CSK group, players with no prior cybersecurity knowledge rated TXG more positively than those with basic or advanced knowledge in areas such as recommending the game (3.7 vs. 3.3 and 3.4), its value in teaching cybersecurity (3.8 vs. 3.4 and 3.4), and the engagement provided by game elements (3.5 vs. 3.1 and 3.2). A similar trend was seen in the PGE group, where non-gamers rated the game slightly higher in terms of recommendation and engagement. However, as these groups made up only 3.8% and 6.2% of participants respectively, firm conclusions cannot be drawn. Minimal rating differences were observed between players with some or high prior knowledge and experience, suggesting a generally consistent reception among more experienced users. Issues such as limited interactivity and UI/UX shortcomings may have influenced overall ratings.

Table 3: Average overall 1–5 Likert scale ratings analysed by the categories given in Table 2

Category	Average Overall Rating							
	Gender		CSK			PGE		
	F	M	NK	BK	AK	NGE	SGE	HGE
TXG helped me learn XSS	3.3	3.3	3.3	3.3	3.3	3.2	3.3	3.3
Recommend TXG to others	3.3	3.2	3.7	3.3	3.4	3.6	3.4	3.3
Games can help to teach cybersecurity	3.3	3.4	3.8	3.4	3.4	3.4	3.4	3.4
Game elements made TXG more engaging	3.2	3.0	3.5	3.1	3.2	3.4	3.2	3.2

Despite these limitations, TXG demonstrated its effectiveness in supporting learning outcomes and addressing RQ1. The multi-opposing-role-playing format promoted engagement, adversarial thinking, and improved understanding of XSS attacks. Players responded positively to the role diversity and suggested greater task variety, with learning outcomes showing a modest but meaningful and practical improvement. Future iterations should enhance interactivity and UI/UX design to further increase effectiveness and user satisfaction.

7.4 RQ2: Impact of Narrative-Based Simulations on XSS Concept Reinforcement

7.4.1 Simulation zone

Several players mentioned that the Simulator Zone made the game immersive and supported their learning. However, only about 22% of the players had utilised the Simulator Zone, with an average of 1 minute and 28 seconds spent within it.

> *"I like quiz type games and find them fun and interesting, and the simulator zones help with making it feel more like an immersive game."*
>
> *"I liked that it was a quiz, and with the simulation zone, it was a great idea to make the game more immersive."*
>
> *"I like the concept, the gamification makes the concepts easier and having the simulation zone helps solidify the concepts."*
>
> *"Loved being able to learn through a game, and loved the simulation area! Great that one can get more insight into a topic if needed."*
>
> *"The simulator zone was a great addition to The XSS Game, it truly makes the game feel unique and engaging. Definitely the best mechanic."*

Although there were positive comments about the Simulation Zone, several players mentioned existing weaknesses and potential improvements that can be made to it.

> *"Simplicity, easy to follow, and not a need for entering the simulation zone to complete the assignment."*
>
> *"A bit more interactive simulation zone."*
>
> *"The simulator was not very useful and often forgotten/ ignored."*

Given these findings, it is clear that while the Simulator Zone holds potential, the current version was underutilised, and its educational impact is difficult to assess reliably. Therefore, the conclusions related to RQ2 remain preliminary, with this study identifying the Simulator Zone as a promising but currently limited feature.

7.5 Educational Game Development Framework

Many of the players mentioned that this style of learning was enjoyable and effective.

> *"It is still a bare bones game but that's about it for me, so I am hopeful that with more dev time this game will become a fun tool for learning."*
>
> *"Interactivity is always fun and useful to ensure engagement. Nice to have both a pre-game and post-game questionnaire to help reflect over what was learnt throughout the game."*
>
> *"This was honestly one of the best learning experiences I've had. Incredibly fun and learning a lot along the way!"*
>
> *"I like that this game has an interactive learning approach with different scenarios that could happen in the real-world. I also like that there's somewhat an explanation of the wrong and correct answers. The visual examples are a plus too, made it more engaging."*

The educational game development framework presented in this study offers a flexible and interactive foundation for creating quiz-based learning games that incorporate multi-opposing roles, scenario-based tasks/simulations, and layered complexity. Specifically, the framework consists of a conceptual model, source code, UI designs, and evaluation data, which can be used to accelerate similar educational game development. Designed to enhance engagement and understanding, the framework allows players to take on roles such as

attacker, defender, and user, promoting critical thinking and real-world application. It also includes built-in pre- and post-game surveys to assess learning outcomes, making it suitable for researchers and educators across various disciplines. By adapting the content and roles, others can use this framework to develop educational games tailored to their specific teaching goals.

8. Limitations and Future Work

8.1 Control Group Evaluation

A key limitation of this study is the absence of a comparison with a control group. Future research plans include conducting an evaluation with one group interacting with TXG and a control group engaging in traditional learning activities, such as lectures, to compare outcomes. In addition, future studies will incorporate interviews as a data collection method, as interviews provide greater flexibility and allow for a deeper exploration of topics of interest, such as how playing different roles influenced the learning process, compared to surveys.

8.2 UI/UX Improvements

It is also planned to improve the UI/UX issues addressed by the players in the next iteration of TXG. This will focus on adding more visually appealing interfaces and options to control the sound effects. In addition, more varied tasks and XSS scenarios will be added to the different roles for a better learning experience. Specifically, it is planned to investigate why fewer players entered the Simulator Zone and whether improvements, such as increased interactivity, task variety, better game integration, multiplayer features, extra points and badges, and narrative-based simulations, along with UI/UX enhancements, would motivate players to utilise it more.

9. Conclusion

This study presents The XSS Game, a multi-opposing-role-playing game to learn XSS attacks for all audiences, which was evaluated with a group of second-year undergraduate computer science students. The initial evaluation results show that TXG was able to achieve the intended learning outcomes and is a promising tool to teach XSS attacks and other topics. Regarding RQ1, the player comments suggest that they found the multi-opposing-role-playing with real-life scenarios approach useful to their learning and proposed to have even more varied interactions, multiplayer, and replayability functionalities. Even though the study could not effectively answer RQ2, several players indicated that the TXG Simulator Zone provided an immersive experience and proposed more tasks and additions to it. UI/UX improvements, along with increased interactivity and task variety, are planned as future work to investigate RQ2 and beyond.

Many players also indicated that the TXG game format provided an effective learning experience with immediate answer feedback, while the pre- and post-game surveys helped to reflect on the lessons learned. This ultimately suggests that other game developers may consider using the TXG game format to develop educational games or even adding similar “training zones” to their games.

Acknowledgements

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Ethics Declaration: As stated in Section 6, the survey questions and data collection methods were reviewed and approved by the Sikt – the Norwegian Agency for Shared Services in Education and Research – before data gathering.

AI Declaration: Grammarly was used to check and correct the grammar of the study. This was the extent of AI use in the study.

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Enhancing Cybersecurity Learning with In-Game Feedback

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Abstract: This paper presents the development and evaluation of *The XSS Game* (TXG), an enhanced multi-opposing-role-playing educational game designed to teach Cross-Site Scripting (XSS) attacks to second-year undergraduate computer science students. TXG enables players to assume three distinct roles: Attacker, Defender (Developer), and User, each offering unique perspectives on cybersecurity challenges. Building upon feedback from the evaluation of TXG Version 1, this study focuses on incorporating various types of in-game feedback (affirming, reflective, explanatory, and personalised) and introducing a player statboard to enhance student engagement, motivation, and knowledge retention. TXG Version 2 incorporates a variety of feedback types aimed at reinforcing learning and promoting self-reflection. Confirmatory feedback helps players quickly assess the correctness of their answers, while explanatory feedback provides in-depth reasoning to enhance understanding. Affirming feedback is used to motivate players, particularly when they succeed in completing roles, and personalised feedback offers tailored guidance based on players' individual progress. The player statboard is introduced as a central feature, displaying player achievements, skills, and progression throughout the game, offering real-time feedback to sustain engagement and foster continued learning. Expert evaluations of TXG Version 2 indicated that the diverse feedback mechanisms, especially personalised feedback and the statboard, were effective in promoting learner engagement and self-reflection. However, the evaluations also identified areas for improvement, particularly regarding the clarity and readability of the feedback and statboard, while suggesting potential UI/UX enhancements. The study posits that with the suggested improvements, TXG Version 2 offers significant potential for improving cybersecurity education through a dynamic, engaging, and interactive gameplay experience. This study contributes to existing research on game-based learning by showcasing how game mechanics such as multi-opposing roles, simulations, in-game feedback and player statboards, can be integrated to enhance the learning of complex cybersecurity concepts. Furthermore, it provides a development framework for creating educational games in cybersecurity and beyond, demonstrating the effectiveness of a flexible, interactive, and immersive approach to teaching critical security concepts.

Keywords: Game-Based learning, In-Game feedback, Feedback mechanisms, Educational games, Cybersecurity education, Cross-Site scripting attacks

1. Introduction

In today's digital landscape, Cybersecurity is of utmost importance and can have ramifications across a wide range of industries and sectors. Hence, it is vital that everyone, including students, professionals, and the general public, understands its importance. Nonetheless, several examples exist that demonstrate a lack of cybersecurity awareness among these groups. For instance, a wide range of companies, such as media organisations, retail chains, and financial institutions, have been impacted by cybersecurity breaches (Chen et al, 2025). These incidents demonstrate the severe consequences that can result from failing to prioritise cybersecurity, including financial losses, reputational damage, and even risks to human life. Hence, in order to prevent/mitigate such incidents, many countries, including the US, Canada, and several members of the European Union, have launched initiatives to promote strong cybersecurity practices among the public (Van Steen et al, 2020).

1.1 Goals and Scope of the Paper

This study presents the continuation of a multi-opposing-role-playing game, named The XSS Game (TXG) (Weeratunge & Hjelsvold, 2025), to teach Cross-Site Scripting (XSS) attacks to second-year undergraduate computer science students. The players can experience the game through the eyes of three roles, where some act as opposing roles.

The roles in TXG are as follows:

- Attacker: An adversarial role with high technical expertise that tries to exploit vulnerabilities in web applications.
- Defender (Developer): An opposing role with high technical expertise that tries to develop secure web applications against adversaries.
- User: A user role with low technical expertise that utilises the developed web applications.

The primary intended learning outcomes of TXG are:

- Understand how to identify the different types of XSS attacks from multiple perspectives.
- Develop secure applications that incorporate preventive measures to mitigate XSS attacks.
- Offer an interactive and enjoyable approach to learning cybersecurity.

More information about TXG can be found in Weeratunge & Hjelsvold (2025).

TXG Version 1 was evaluated in a second-year undergraduate computer science course. The players commented that they found the multi-opposing-role-playing with real-life scenarios approach useful to their learning and proposed to have even more varied interactions, multiplayer, and replayability functionalities. In addition, several players indicated that the TXG Simulator Zone provided an immersive experience and proposed more tasks and additions to it. Moreover, many players praised the timely and clear confirmatory and explanatory feedback given in TXG, coupled with the reflective pre- and post-game surveys, as vital to the learning experience.

The main motivation of this study is to investigate how to incorporate in-game feedback within a cybersecurity educational game, namely TXG Version 2, in terms of engagement/motivation and knowledge improvement. To provide players with enhanced feedback, TXG Version 2 will feature a player statboard that displays player skills and achievements. Accordingly, a key objective of the upcoming TXG Version 2 evaluation is to examine how different types of in-game feedback (affirming, reflective, explanatory, and personalised), combined with the statboard feature, could influence learners' motivation, engagement, and overall learning within the game.

Specifically, this paper explores the following research questions:

- RQ1: How can different in-game feedback, such as affirming, reflective, explanatory, and personalised, be integrated within a cybersecurity educational game?
- RQ2: How can a player statboard be incorporated in a cybersecurity educational game to influence learner motivation, engagement, and knowledge?

The main contributions of this study include:

- A design of an enhanced web-based educational multi-opposing-role-playing game, TXG (The XSS Game), to teach XSS attacks for all audiences.
- The analysis of how to integrate in-game feedback and player statboards into an educational game.
- An enhanced development framework that can be used to create educational games for a range of subject domains.

2. Background

2.1 Cross-Site Scripting (XSS) Attacks

Cross-Site Scripting (XSS) attacks involve injecting malicious scripts into trusted websites by exploiting vulnerabilities in web applications. These attacks occur when user input is improperly validated or encoded, allowing harmful code to run in another user's browser (KirstenS, 2024).

Once the victim receives the code injected by the attacker, the victim's browser cannot detect that the script is dangerous and will execute it as if it originated from a trusted source. Consequently, the malicious script can access sensitive data, including cookies and session tokens stored in the browser. It can even alter the content displayed on the webpage (KirstenS, 2024). OWASP (Open Worldwide Application Security Project) ranks XSS as number three on its Top 10 Web Application Security Risks list due to its severity (The Open Worldwide Application Security Project, 2024).

2.2 Related Work

Firstly, existing educational games on XSS attacks will be presented. Gaurav et al (2021) presents four web-based games designed to teach system administrators and entry-level IT users about web application security, namely SQL Injection, Broken Authentication, XSS, and Sensitive Data Exposure. These games were developed using Unity (Unity Technologies, 2024) and are based on the Learning Mechanics-Game Mechanics (LM-GM) framework (Lim et al, 2015) (Arnab et al, 2012). The study also conducts a limited evaluation involving eight players by collecting objective player data through Unity analytics and subjective feedback via a questionnaire. The games featured in Google (n.d.) and Hussain (n.d.) also provide educational methods for teaching XSS

attacks to college and industry audiences. These games present various scenarios where individuals might encounter XSS attacks.

In-game feedback has been featured in several educational games. Burgers et al (2015) presents a brain-training game that utilises a range of feedback, including evaluative, comparative, positive and negative. The study states that positive feedback enhances intrinsic motivation through competence and autonomy needs while fostering long-term motivation and play. Similarly, Hwang & Kang (2023) mentions that the players appreciated and reported increased self-confidence after receiving positive and encouraging affirming feedback in a math game.

Moreover, several studies have investigated personalised feedback in educational games. Nelson et al (2014) incorporated visual cues into a virtual world-based assessment, highlighting the objects with which students needed to interact. This personalisation enhances the effectiveness of game content delivery by aligning with learners' preferred instructional strategies and directing their attention to relevant information during learning or assessment. Similarly, Hooshyar (2022) presents an educational game, named AutoThinking, aimed at enhancing the computational thinking of students. The game adapts to individual needs/playstyle and even provides adaptive feedback, hints, and tutorials, according to the learners' level of skills.

Several educational games have employed player statboards or an equivalent in their design. For instance, The Hechinger Report (n.d.) utilises a personal dashboard that displays earned points and badges, in addition to tracking academic behaviours, such as attendance, GPA, and engagement in school activities. Similarly, Shoelace (n.d.) presents a player activity report that tracks the number of questions each learner answers and provides accuracy statistics. Furthermore, this report acts as an effective tool for evaluating student engagement and emphasising the significance of accuracy.

Related work suggests that positive and affirming feedback mechanisms foster intrinsic motivation, self-confidence, and sustained engagement, while personalised feedback tailored to player skill levels enhances the effectiveness of learning. Furthermore, the use of clear, structured statboards to track achievements and progress supports self-assessment and reinforces goal-oriented learning behaviours. While several educational games are designed to target different in-game feedback and player statboards, there seems to be no educational games that combine these elements, particularly in the field of cybersecurity. Moreover, each one of the above aspects has its own set of merits and complications, and thus, the combined application within a cybersecurity educational game could lead to an improved learning experience. Hence, this is the main research gap this study wishes to address.

3. Implementation

The TXG implementation consists of an HTML, JavaScript, and CSS-based UI frontend, with a Flask backend (Pallets Projects, 2010). Players accessed the game via a shared application link.

As described in earlier sections, gameplay involves multiple opposing roles: Attacker, Defender, and User. To support evaluation, players completed built-in pre- and post-game surveys. More information about TXG implementation can be found in Weeratunge & Hjelsvold (2025)

3.1 Educational Game Development Framework

TXG Version 1 introduced the above implementation as a framework for developing educational games across disciplines. It allowed developers to build quiz-based games with multiple levels, opposing roles, interactive simulations, and built-in pre- and post-game surveys for evaluation. TXG Version 2 extends this framework by incorporating various forms of detailed in-game feedback, such as affirming feedback to acknowledge correct actions, reflective feedback to encourage deeper thinking, explanatory feedback to clarify concepts, and personalised feedback tailored to individual performance. In addition, TXG Version 2 introduces a player statboard that tracks and displays players' skills, achievements, and progression throughout the game, providing continuous visual feedback to motivate learners, sustain engagement, and support knowledge development over time.

3.2 Example Gameplay

TXG is a role-playing game where players assume different roles to answer scenario-based XSS questions, often supported by images. As shown in Figure 1, players select answers from tiles (box E) to progress and can access additional XSS resources (KirstenS, 2024) and gameplay details via options in box A. One of the

additions in TXG Version 2 is a mini version of the player Statboard, which players can extend to view more detailed stats (Box D).

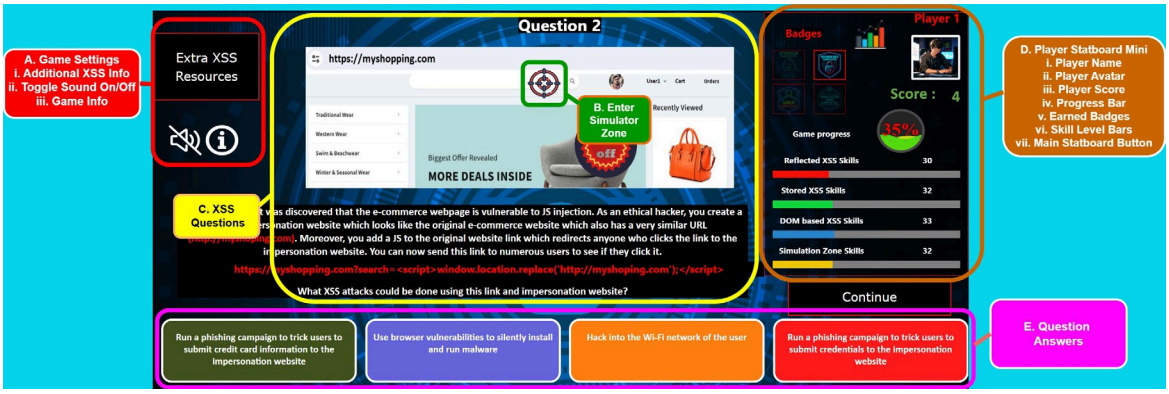

Figure 1: The revised TXG UI: A. Game Settings, B. Simulator Zone Button, C. XSS Questions, D. Player Statboard Mini, E. Question Answers

4. Design Considerations of In-Game Feedback and Player Statboard in TXG Version 2

4.1 In-Game Feedback

As mentioned in earlier sections, several types of in-game feedback are utilised in TXG Version 2. This section will describe these types in detail.

4.1.1 Confirmatory feedback

Confirmatory feedback simply states whether the answer is correct or not, without providing additional information (Wouters & Van Oostendorp, 2013). As seen in Figure 2, players receive immediate confirmatory feedback regarding their answer choices as soon as a question is answered.

4.1.2 Explanatory feedback

Conversely, explanatory feedback provides additional information about an answer, such as why it is correct or not. Several studies maintain that explanatory feedback is more effective than its counterpart (confirmatory feedback) at helping novice students learn and develop a deeper understanding (Johnson & Priest, 2014) (Mayer & Johnson, 2010). Players receive detailed, immediate explanatory feedback regarding their answer choices, as seen in Figure 2.

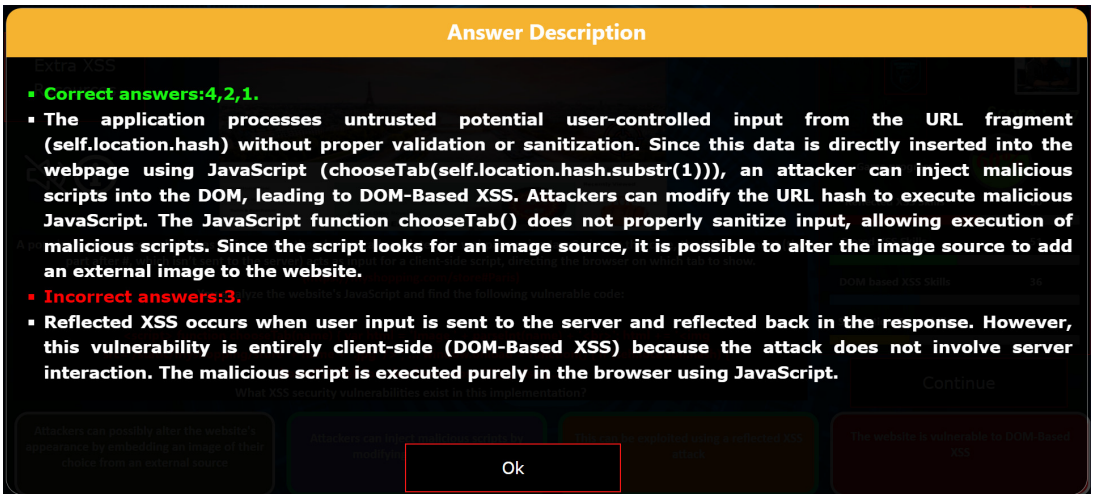

Figure 2: TXG confirmatory and explanatory feedback after the player submits answers

Cognitive Theory of Multimedia Learning (Mayer, 2005) suggests that learners benefit more when new information is immediately integrated into existing mental models, by reducing the amount of mental effort needed to track whether previous actions were correct. Moreover, immediate feedback prevents misconceptions from persisting, supporting more efficient learning (Shute, 2008). Hence, immediate feedback in TXG helps players quickly understand whether their choices are correct, reinforcing learning in real-time and

keeping the gameplay flow smooth and engaging. It reduces uncertainty, builds confidence, and supports faster error correction, which is especially important in educational games like TXG, where immediate reinforcement strengthens knowledge retention and keeps players motivated to continue.

4.1.3 Affirming feedback

Affirming feedback is used in TXG to motivate the player and increase engagement with positive feedback. This is specialised for the chosen player role and is selected from a list of pre-generated feedback. Hence, the player will be shown randomly selected feedback that is relevant for their situation and would likely see a different message each time. The goal of this approach was to make the affirming feedback seem more natural and less mechanical. This affirming feedback can be seen in box C in Figure 3. Some examples of this affirming feedback are shown below,

Attacker

> *"Attacker role accomplished. You've stepped into the adversary's mind and exposed the mechanics of XSS with skill."*
>
> *"Infiltration successful! You've completed the Attacker role and unlocked key insights into web security flaws."*

Defender

> *"Defender role complete! You've fortified the system and shown strong awareness of XSS vulnerabilities."*
>
> *"You held the line! Completing the Defender role shows your skill in identifying and neutralising web-based attacks."*

User

> *"Great job! You've learned firsthand the potential dangers of XSS and how attackers might target users like you."*
>
> *"Awesome work! You've discovered how XSS attacks can affect your experience and what to look out for as a user."*

The above affirming feedback is displayed in the player statboard as soon as a player completes a role. However, if a player decides to view the player statboard before completing a role, affirming feedback is used to encourage the user to keep playing the game to enhance their skills. These messages are given below,

Attacker

> *"Keep pushing forward! You're building valuable skills that will help you understand web vulnerabilities better."*
>
> *"You're making great progress! Each step brings you closer to becoming an expert in exploiting web vulnerabilities."*

Defender

> *"Keep up the great work! Every defensive measure you implement brings you closer to mastering web security."*
>
> *"You're doing an amazing job! Each challenge you face is a step toward becoming a skilled defender of web applications."*

User

> *"Nice job! Your efforts are building crucial awareness that will keep you safe in the digital world."*
>
> *"You're on the right track! The knowledge you're gaining now will make you more cautious and confident as a web user."*

4.1.4 Personalised feedback

TXG provides personalised feedback to the player depending on their playstyle. When a player finishes a role, feedback is presented that reflects on the player's answer choices and their implications. Moreover, TXG will

recommend the player to replay certain levels to further improve specific player skills. Hence, this personalised feedback features clear, specific goals focused on improving particular aspects of performance, combined with the reflection of player actions and their consequences. This focus on enhancing specific player skills is supported by theories of learning, such as self-regulated learning (Zimmerman, 2002) and deliberate practice (Ericsson et al, 1993). This personalised feedback can be seen in box E in Figure 3.

In TXG, affirming and personalised feedback are provided to the player after they complete a role, serving as a method of reflection. Consequently, affirming and personalised feedback in TXG are not only intended to motivate and guide players but also to act as reflective mechanisms that support deeper learning processes. This approach is based on reflective learning from experiential learning theory (Kolb, 1984), where learners, during the Reflective Observation stage of Kolb's learning cycle, critically review their actions and outcomes to gain insights that inform future behaviour. Thus, by incorporating reflective feedback into the player's post-role experience, TXG fosters a learning process whereby players can internalise their experiences, critically assess their cybersecurity skills, and refine their knowledge and strategies in subsequent plays.

4.2 Player Statboard

The player statboard, shown in Figure 3, acts as the main in-game feedback mechanism in TXG. Box A displays tabs for each player role, enabling players to switch between roles they've played. Each tab shows the corresponding skill level bars (as seen in Box B), allowing players to track their progress and assess their performance for each role individually. In addition, box C presents the affirming feedback while box E shows the personalised feedback, according to the playstyle of the player. The statboard differentiates between affirming feedback (general positive reinforcement) and personalised feedback (tailored to the player's unique playstyle). This dual-feedback approach was designed not only to reward achievement but also to facilitate improvement through customised guidance.

Box D displays core game elements, including the player's name, avatar, score, progress bar, and earned badges. These elements are prominently featured to highlight player achievements and encourage continued engagement. Badges are awarded for completing various roles and simulation zones, offering clear goals and recognising important milestones.

Lastly, the main gameplay UI shown in Figure 1 also features a compact version of the player statboard to provide more condensed feedback to the player (box D in Figure 1).

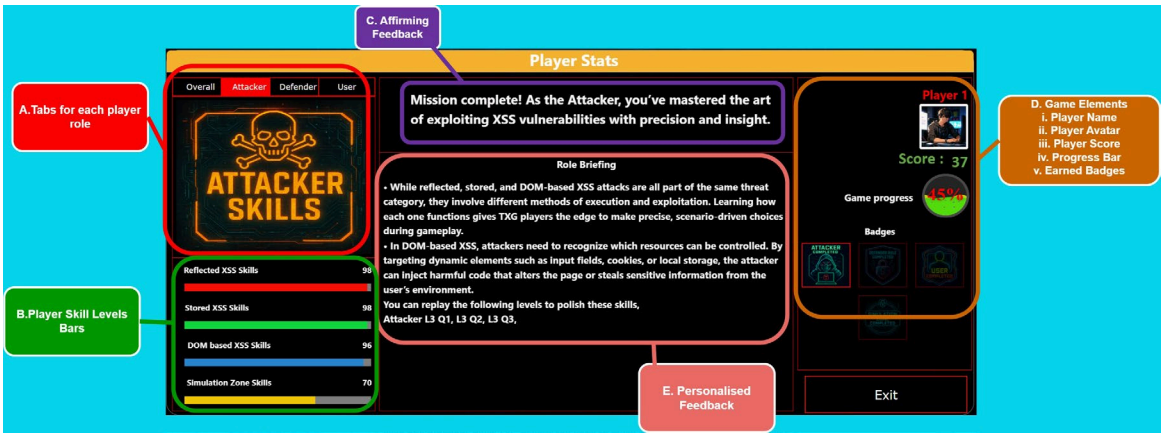

Figure 3: TXG Player Statboard with skills levels and different in-game feedback

5. Results and Discussion

5.1 Data Collection

TXG Version 2 design was evaluated by 2 experts in game-based learning. For evaluation, the experts were presented with access to the game via a shared application link along with an evaluation rubric to guide the process. The evaluation rubric focused particularly on assessing the effectiveness of in-game feedback mechanisms and the player statboard in supporting learner engagement, reflection, and skill development. In addition, the experts were encouraged to provide open-ended feedback on the gameplay experience. It is important to note that, according to Sikt – the Norwegian Agency for Shared Services in Education and Research, no approval was required since the data collection did not involve any personal data.

It should also be noted that the expert comments that are presented in the following sections are presented as they were received in order to convey their original meanings and have not been edited for grammar.

5.2 RQ1: Integrating Different In-Game Feedback Within a Cybersecurity Educational Game

Expert evaluators indicated that in-game feedback was plentiful, useful and promising.

> *"Timely feedback and it is important to provide different feedback during gameplay."*
>
> *"One thing I like about the game is that it provides ample feedback. A player would have all the feedback they need, perhaps more than what the player actually needs."*
>
> *"Useful feedback but can be overwhelming at times."*
>
> *"Yes. They do very often act as a motivator. But positive and constructive feedback during gameplay is also important."*

However, expert comments stated that the delivery of the feedback could be improved in terms of UI/UX aspects and enhanced relevance to the target player group.

> *"Feedback seems a bit much. Maybe if it has clear connections to a given course with a clear target group (students studying the topic). "*
>
> *"Need to be divided into sections and made more easily readable."*

Moreover, evaluators mentioned that the personalised feedback was useful but needs to be more specific and readable. Comments also recommended to split personalised feedback from the rest of the feedback and provide it as a summary towards the end of the game, as concluding remarks.

> *"Personalised feedback can have potential here. But still feel a bit generic."*
>
> *"It blends with the other types of feedback. Did we have a summary at the end? If not – the game should – and then the personalised feedback could be given then (splits it from the other feedback)"*
>
> *"Some feedback given as part of the end-survey of the game is needed."*
>
> *"Would have been good to receive some concluding remarks, sort of as the take-home message."*

Based on the comments, this study finds that although TXG in-game feedback shows promise in helping students learn XSS topics, there is much room for improvement in terms of UI/UX enhancements and feedback quality. Hence, improvements, such as better readability, more concise and relevant feedback, should be made before having the TXG Version 2 tested by students.

5.3 RQ2: Incorporating a Player Statboard in a Cybersecurity Educational Game

Evaluation also yielded positive comments regarding the design of the player statboard.

> *"Important feature. Most players always like to compare themselves to others, or to the max possible score."*
>
> *"Provides a variety of useful feedback for the roles."*

However, the comments indicated that improvements should be made in terms of UI/UX and better feedback quality.

> *"Ok. But feedback still hard to read and understand."*
>
> *"Role briefing is hard to read. This should be displayed more like a bullet point list. It is not clear what is general feedback and what is direct feedback to the player."*

Moreover, comments also suggested that, currently, the player statboard is geared towards skilled players and suggested utilising the player statboard in assisting less skilled players with hints and guidance.

> *"But, it acts more like (positive) feedback on progression and score. But, if my score was low – it would have the opposite effect. The design should therefore consider this – and help less skilled players with possible clues. Let them try again."*

Thus, the comments suggested that the design of the TXG Version 2 player statboard is a useful and promising feature that could be used to provide player accomplishments, assistance and guidance, especially for less

skilled players. However, improvements should be made in terms of UI/UX and enhanced feedback quality before being released for player testing.

5.4 Educational Game Development Framework

Expert evaluation also suggested that this game format could serve as a foundation for an educational game development framework.

> *"Playing the different roles gives several perspectives to increase knowledge. Can see this applied in other games."*
>
> *"The simulation zone challenge of testing my knowledge is interesting. Provides sort of a break from the gameplay. Interesting to see how this can be applied in other contexts."*
>
> *"Has potential to be used for other educational games. This current game has ONE goal in mind. What if we designed a game with two (or several) goals in mind. Would the player then be distracted enough to forget about the security issues? This can be designed with a gameplay where the player need to access different online stores to buy/collect items, adding info about themselves, etc"*

Hence, this study argues that with the suggested improvements, the TXG Version 2 game format has the potential to act as an educational game development framework in the domain of cybersecurity and beyond. TXG Version 2 extends the educational game development framework presented in Weeratunge & Hjelsvold (2025) with detailed in-game feedback and a player statboard. Researchers and developers could use this to accelerate their educational game development.

6. Limitations and Future Work

6.1 Limited Sample Size

The main limitation of the study is the limited sample size in the expert evaluation of TXG Version 2. Even though the expert evaluation provided valuable feedback and comments to improve the educational game, it would have been beneficial to have had the TXG Version 2 design evaluated by more experts. Such an evaluation could have yielded more detailed insights into how players/students perceive game features, including different in-game feedback and the player statboard, and how these can aid in player engagement, motivation and knowledge improvement. A more comprehensive evaluation is planned for Fall 2025 within a second-year undergraduate computer science course.

6.2 UI/UX Improvements

As presented in the Results and Discussion section, there are several possibilities for improvements in terms of enhanced text readability and better feedback quality. Thus, this study has identified improvements that should be made to the prototype before being tested by students.

7. Conclusion

This study presents the design of The XSS Game (TXG) Version 2, an enhanced multi-opposing-role-playing game designed to teach Cross-Site Scripting (XSS) attacks. Through the integration of multiple in-game feedback types (affirming, reflective, explanatory, and personalised) and the introduction of a player statboard, TXG Version 2 aims to improve student engagement, motivation, and knowledge retention. Expert evaluations of the first prototype of TXG Version 2 indicated that the diverse feedback mechanisms and statboard feature could be effective in supporting learners' progress and fostering self-reflection. The incorporation of various feedback types, particularly personalised feedback, aligns well with educational theories of self-regulated learning and reflective practice, further strengthening the game's role in improving cybersecurity education. While the TXG Version 2 design was seen as promising by the experts, there were several recommendations for further improvements in UI/UX design to ensure clearer presentation and enhanced readability.

The evaluation results also suggest that the TXG Version 2 game format offers the potential to serve as a robust educational game development framework for cybersecurity topics and beyond. Future work will focus on addressing the identified areas for improvement, particularly in terms of UI/UX design, as well as conducting a more comprehensive evaluation with actual players to further refine the game's features.

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Ethics Declaration: As mentioned in Section 5, the data collection did not involve any personal data and thus, according to Sikt – the Norwegian Agency for Shared Services in Education and Research guidelines, no approval was needed.

AI Declaration: Grammarly was used to check and correct the grammar of the study. This was the extent of AI use in the study.

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From Barriers to Bridges: AI-Powered Mini-Games for Accessible Game-Based Learning

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Abstract: Game-based learning (GBL) has gained considerable attention within active learning communities, yet its practical implementation remains limited in mainstream educational settings. Key barriers include the complexity of integrating games, licensing costs (often associated with serious games), and the time required for preparation. This study investigates an accessible alternative: subject-independent mini-games that require minimal setup and align with a range of learning objectives. These are supported by AI-powered bots that generate the necessary materials. Using a qualitative design, the study involved semi-structured interviews with educators from diverse fields. Participants evaluated mini-games and reflected on barriers to GBL adoption and whether these can be addressed through the integration of mini-games. Games were also compared in terms of usability, academic rigor, adaptability, and potential to boost participation. Educators further assessed AI tools (Custom GPTs) to adapt mini-games to their classrooms. These tools allowed user-friendly customization without programming or prompting skills. Findings indicate that cost, preparation effort, and lack of awareness are major barriers. Mini-games, especially when paired with AI, offer a bridge to implementing GBL. Implications and future research directions are discussed.

Keywords: Game-Based Learning, Education, Mini-Games, Barriers, Game-Based learning

1. Introduction

In recent years, educators at the college level have been confronted with a range of challenges, including increasingly diverse student populations (De Clerck et al., 2022), larger classroom sizes, and heightened competition for students' attention due to the constant availability of smartphones and laptops (Dontre, 2020). These developments have made it more difficult to maintain student engagement through traditional active learning strategies, such as group presentations, which many educators report are no longer achieving the desired increase in student motivation (Park et al., 2021).

Game-based learning (GBL), commonly defined as the use of games for educational purposes (Edwards et al., 2023), has emerged as a promising approach to address these challenges. GBL has been shown to improve learning outcomes (Clark et al., 2016) and foster higher levels of engagement and critical thinking (Mao et al., 2021). By promoting active, experiential learning, GBL offers opportunities to counteract the attention-related and motivational difficulties faced in modern classrooms.

However, the widespread adoption of GBL in higher education remains limited. In a systematic review, Lester et al. (2022) found that educators cite barriers such as a lack of time to develop new approaches, the cost of game licenses, and classroom setting issues.

One promising, yet underexplored, approach to addressing these barriers is the use of educational "mini-games." Mini-games are short (requiring less than 30 minutes of classroom time), subject-independent, and designed to operate without the need for external technical infrastructure or costly licenses. Their compact design could make them more adaptable and easier to integrate into diverse teaching settings compared to more complex gaming solutions. To date, however, little research has systematically explored the effectiveness of mini-games in overcoming the practical barriers that hinder broader GBL implementation in higher education.

We hypothesize that mini-games, particularly when supported by customized AI tools that automate the creation of educational materials without requiring advanced prompting skills, could mitigate several of the primary barriers to GBL adoption. The purpose of this paper is to identify key barriers to game-based learning, compare and evaluate a selection of AI-supported mini-games, and investigate whether this combination can reduce the challenges associated with implementing GBL across diverse higher education settings.

2. Literature Review

2.1 What is Game-Based Learning (GBL)?

We follow the definition of Edwards et al. (2023), who describe game-based learning as “the use of games in service of educational purposes” (p. 3). In GBL, learning content and objectives are embedded in playful contexts

to increase motivation, engagement, and lasting understanding. In contrast to gamification – where isolated game elements such as points, badges, or leaderboards are applied to non-game contexts (Deterding et al., 2011) – GBL involves complete games or mini-games developed or adapted with explicit educational goals in mind (Edwards et al., 2023; Al-Azawi et al., 2016).

2.2 What are the Benefits of Game-Based Learning (GBL)?

Multiple studies and meta-analyses have demonstrated that game-based learning enhances various aspects of the learning process, including learning and retention (Wouters et al. 2013), motivation, self-efficiacy and conscientiousness (Clark et al. 2016) and enjoyment leading to deeper learning (Crocco et al. 2016).

The impact of GBL on motivation has produced mixed findings. The meta-analysis by Wouters et al. (2013) found no statistically significant effect on motivational outcomes. However, more recent studies have reported increased intrinsic motivation through game-based approaches (Cerra et al., 2022; Huizenga et al., 2017; Jääskää and Rajala., 2022).

2.3 What are the Barriers to Game-Based Learning (GBL)?

Despite the demonstrated benefits of game-based learning the consistent adoption of GBL in higher education remains limited. Several reviews (e.g., Lester et al., 2022; Sousa et al., 2023; Yaman et al., 2024) have identified a range of barriers that continue to restrict the widespread implementation of GBL. These include high preparation effort, substantial classroom time requirements, perceived lack of academic rigor, technical infrastructure challenges, and limited organizational support.

Since many GBL approaches involve technological platforms such as video games, augmented reality, and online simulations (Hamari et al., 2016; Alhumairi et al., 2024), the challenges associated with GBL adoption closely mirror broader technology adoption patterns. To structure the analysis of these barriers, the present study applies the Unified Theory of Acceptance and Use of Technology (UTAUT) model, which identifies four key determinants of technology adoption: performance expectancy, effort expectancy, social influence, and facilitating conditions (Venkatesh et al., 2003; Dwivedi et al., 2019). Table 1 presents the identified barriers mapped to these UTAUT constructs, including brief definitions for each construct. Additionally, a category for personal and contextual factors is included to capture broader influences on GBL adoption. The included studies feature both higher education educators and schoolteachers as participants, as the barriers are expected to be similar and there is an insufficient number of studies focusing on college educators.

While other frameworks such as the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975) and the Theory of Planned Behavior (TPB) (Ajzen, 1991) have been used to explore educational technology adoption, these models emphasize attitudinal and intentional predictors and place less emphasis on contextual or institutional constraints. In contrast, UTAUT's inclusion of facilitating conditions allows for a more comprehensive analysis of external barriers – particularly relevant for understanding why educators may be willing, yet unable, to implement GBL in practice (Yaman et al., 2024).

Table 1: Mapping of Game-Based Learning Barriers to UTAUT Constructs with Definitions

UTAUT Construct and Definition	Barrier	Key References
Performance Expectancy: the degree to which an individual believes that using a system will help improve job performance	Belief that GBL lacks academic rigor	Ariffin 2012; Watson and Yang, 2016
	Insufficient evidence of deep learning outcomes	Ariffin 2012; Watson and Yang, 2016
	Perception that GBL promotes only superficial engagement and students get sidetracked by games	Watson and Yang, 2016
Effort Expectancy: the degree of ease associated with the use of the system	High time investment to find and select appropriate games	Dimitriadou et al., 2021; Babar, 2022
	Difficulty adapting games to specific learning goals	Dimitriadou et al., 2021
	Complexity of understanding and mastering game mechanics	Albuquerque et al., 2010; Babar, 2022; Abou Hashish et al., 2024
	Logistical challenges in classroom management when using games	Watson and Yang, 2016; Abou Hashish et al., 2024

UTAUT Construct and Definition	Barrier	Key References
Social Influence: the degree to which individuals perceive that important others believe they should use the system	Lack of peer encouragement to use GBL	Dimitriadou et al., 2021; Bourgonjon et al., 2013
	Student skepticism about the seriousness and value of GBL activities	Babar, 2022; Watson and Yang, 2016
	Limited administrative or leadership support for GBL initiatives	Dimitriadou et al., 2021; Watson and Yang, 2016
Facilitating Conditions: the degree to which individuals believe that organizational and technical infrastructure exists to support system use	Lack of institutional IT and technical support	Dimitriadou et al., 2021; Ariffin, 2012; Watson and Yang, 2016; Abou Hashish et al., 2024
	Lack of financial support for purchasing games/licenses	Ariffin, 2012; Kaimara et al., 2021; Watson and Yang, 2016; Abou Hashish et al., 2024
	Lack of professional development or training opportunities for educators	Babar, 2022; Watson and Yang, 2016; Abou Hashish et al., 2024
	Lack of knowledge about suitable games	Bourgonjon et al., 2013; Ariffin, 2012
Personal and Contextual Factors: influences related to individual teaching philosophy, role identity, or cultural norms	Traditionalist belief in superiority of lecture-based teaching	Ariffin, 2012
	Fear of losing classroom authority and control	Watson and Yang, 2016
	Cultural perceptions of games as "childish" or inappropriate for higher education	Ariffin, 2012

One potential strategy for overcoming these barriers is the use of educational mini-games – short, adaptable games designed to achieve specific learning outcomes within a limited time frame. Mini-games, by their nature, address several key adoption concerns: they typically require less preparation and classroom time than complex simulations, can be adapted across disciplines with minimal effort, and do not necessarily demand advanced technical infrastructure or costly licenses. By providing a flexible, low-barrier entry point into game-based learning, mini-games have the potential to improve performance expectancy, reduce effort expectancy, and ease facilitating condition concerns identified in the UTAUT framework. Despite their promise, mini-games remain an underexplored area in GBL research. In addition to mini-games themselves, the integration of AI-supported tools offers further potential to lower barriers to GBL adoption. Recent studies have shown that AI technologies, particularly generative AI tools like ChatGPT, are reshaping higher education by supporting content creation, personalized learning pathways, and administrative efficiency (Heredia-Carroza and Stoica, 2024; O'Donnell et al., 2024). Specifically, AI can automate the preparation of teaching materials, customize game elements to different disciplines, and simplify the design process, thereby substantially reducing the effort required from educators. By lowering effort expectancy and improving facilitating conditions, AI support could make the implementation of mini-games even more feasible for a wider range of instructors. Despite this growing interest, the specific use of AI to support the design and deployment of educational mini-games remains an underexplored area .

Based on this theoretical foundation, the study poses the following research questions (RQs):

- RQ1: How can the barriers to GBL adoption among college educators be understood through the UTAUT framework?
- RQ2: What types of educational mini-games may help address the identified barriers to GBL adoption?
- RQ3: To what extent can AI-supported tools assist in reducing preparation effort and other barriers associated with the use of mini-games in college teaching?

3. Method

Semi-structured interviews were conducted with 16 educators from a broad range of disciplines, classroom sizes, and age groups. Participants ranged in age from 28 to 65 years and represented disciplines including social sciences, engineering, computer science, and law. A purposive sampling strategy was employed to ensure

diversity across these dimensions. Both authors conducted the interviews via video calls. Participants were informed about the aim of the study and the recording of the interview and provided informed consent prior to participation.

The interviews followed a three-phase structure aligned with the study's research questions. In the first phase, participants discussed their current use of game-based learning (GBL) and perceived barriers to broader adoption, particularly in relation to the constructs identified in the Unified Theory of Acceptance and Use of Technology (UTAUT). In the second phase, participants evaluated four educational mini-games, each designed to align with specific cognitive learning objectives. Table 2 provides an overview of the mini-games and their associated teaching goals. Participants were provided with a description and sample of each game, then assessed each game regarding its perceived benefits, challenges, and suitability for their lectures. The mini-games were developed or adapted by the authors to be applicable across disciplines, require no external software licenses, be playable within a 30-minute classroom timeframe, and address a range of learning goals from basic recall to analytical reasoning.

A custom-developed chatbot, using custom GPT functionality within ChatGPT, was introduced in the third phase of the interviews. The chatbot automates the generation of mini-game content based on user-supplied topics and academic levels. The participants explored the chatbot's outputs and reflected on its potential to lower preparation effort and technical barriers to the use of GBL in their teaching.

All interviews were audio-recorded, transcribed verbatim, and analyzed using thematic analysis according to Braun and Clarke's (2006) six-phase framework. A combined deductive-inductive coding approach was employed: initial codes were derived deductively from the UTAUT framework to structure the primary analysis, while additional codes and themes were developed inductively where participant insights extended beyond the original constructs. One researcher created an initial coding framework, which was then discussed to resolve discrepancies and refine theme development. Themes were reviewed and collaboratively finalized to produce the final thematic structure.

Table 2: Mapping of Game-Based Learning Barriers to UTAUT Constructs with Definitions

Title **(Link to explanation)**	**Learning Objective** (Bloom's taxonomy) Focus of game	**Estimated Time** (E = Explanation; P = Playing)	**Short Description**
Forbidden Words **(www.inflos.de/fw)**	Remember, Understand Focus: Recall	E: 3 Min P: 10-12 Min	Students have 1 minute to explain as many scientific terms as possible. Each term includes 4 forbidden words that may not be used. Students compete in small teams (3–4 people).
Lie Detector **(www.inflos.de/ld)**	Understand, Analyze Focus: Recall	E: 4 Min P: 8 Min	Students receive application-based statements. To earn points, they must spot and correct "lies". They compete against the other team and the educator, who tries to sneak in a falsehood.
Thought Experiment Roulette **(www.inflos.de/ter)**	Analyze Focus: Discussion	E: 2 Min P: 20 Min	Students spin a wheel to select a futuristic thought experiment. In small groups, they analyze the scenario and pitch their ideas to the class. The best-rated pitch wins.
Tic-Tac-Toe **(www.inflos.de/ttt)**	Understand, Analyze, Evaluate Focus: Discussion	E: 5 Min P: 15 Min	Students play in small teams (3-4 persons) against each other. By explaining terms they can conquer squares. By evaluating complex situations they can steal already conquered squares. Whoever connects 3 neighboring squares first wins.

4. Results

4.1 Educator Attitudes Toward Game-Based Learning

In phase one of the interviews, educators discussed their current experiences with game-based learning (GBL) and the barriers they perceived in implementing it more widely. Most participants had a positive attitude towards using games in higher education. They noted that traditional active learning strategies, like group presentations, were becoming less effective due to reduced student attention spans and engagement. Several

educators acknowledged the need to adopt their teaching methods to align with students' evolving expectations and behaviors.

Participants noted that GBL positively impacts psychological safety, student motivation, and class participation aligning with previous research on educational games (Cerra et al., 2022; Huizenga et al., 2017; Jääskää and Rajala, 2022). However, only one participant used GBL regularly. The most common tools were quizzes on gamified platforms like Kahoot! and Mentimeter, which require minimal preparation and integrate easily into lectures.

4.2 Barriers to GBL Adoption Mapped to UTAUT Constructs

Figure 1 provides an overview of the thematic analysis, organized according to the UTAUT framework. While many of the barriers identified confirm earlier findings, several new insights emerged.

4.2.1 Performance expectancy

Most educators were open to the idea that games could support learning outcomes. However, a few expressed concerns about GBL's rigor and alignment with cognitive goals. Some worried that available games might not meet disciplinary standards or that students might disengage if they struggled with complex game tasks, particularly in simulations. Overall, performance expectancy was not a dominant barrier.

4.2.2 Effort expectancy

Perceived effort emerged as a key barrier. Many participants emphasized the time-intensive nature of designing, adapting, and implementing games. A novel insight was that several educators described a lack of creative capacity as an additional challenge. They reported that developing game content demanded mental focus that they could not spare during already demanding lesson preparation. Most educators in our study were not aware of games that they could implement in the lessons. This creative fatigue and the absence of readily available, discipline-specific game templates appear underrepresented in previous studies.

4.2.3 Facilitating conditions

Nearly all participants identified substantial institutional and logistical constraints. These included a lack of technical support, financial resources and access to professional development opportunities – barriers noted in prior literature (Lester et al, 2022). A major concern was the perceived cost of classroom time. Educators feared that even brief games would cut into core content delivery. Additionally, some instructors taught classes with over 1,000 students, complicating the use of interactive formats. These issues indicate that the "facilitating conditions" barrier is broader than typically portrayed.

4.2.4 Social influence

Social norms were less frequently mentioned but remained relevant. Several educators mentioned that GBL is not the norm in their discipline. This led to a lack of knowledge about appropriate games. Two educators mentioned that students might view games as "childish". Interestingly, some participants supported using games but hesitated due to concerns about students perceptions. This suggests a bidirectional social influence both among peers and from learners, which has been underexplored in previous UTAUT applications.

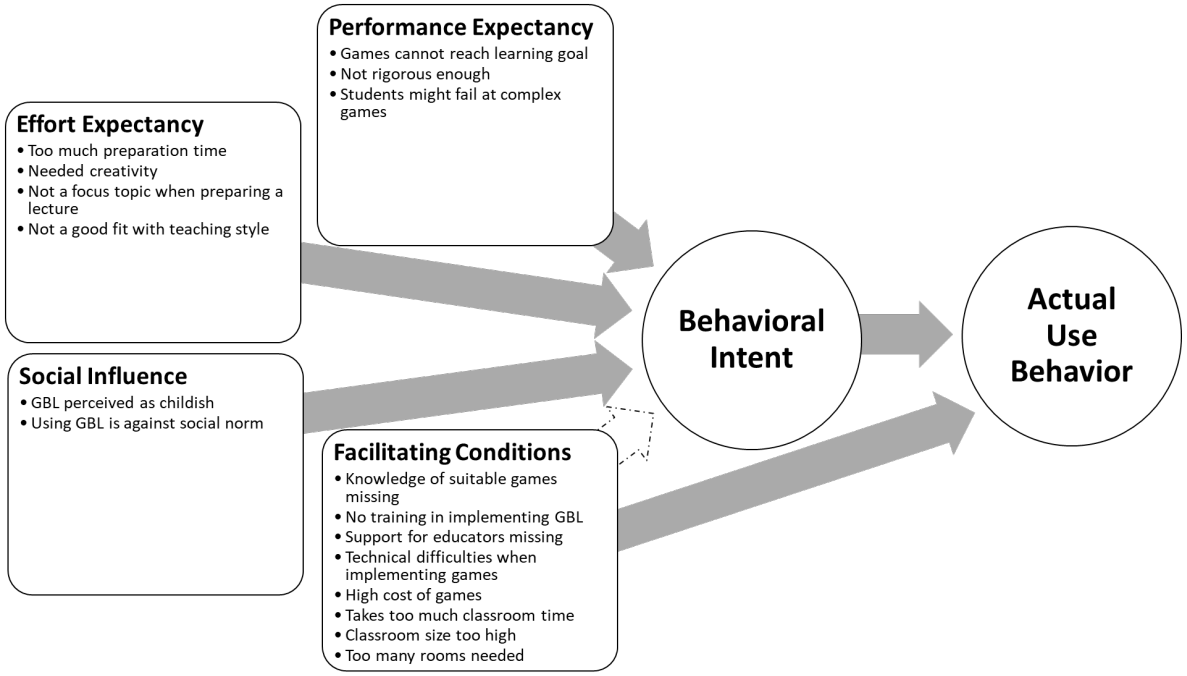

Figure 1: Findings of interviews in UTAUT model (focus on barriers; modified from Venkatesh et al., 2003)

4.3 Evaluation of Mini-Games

In the second interview phase, participants were introduced to four short-format mini-games designed by the authors. Each game was presented with a brief explanation and an example. Participants then evaluated the games with regard to suitability, benefits and challenges. Table 3 summarizes the feedback.

Table 3: Summary of Mini-Game Evaluations

Game Title (Link to explanation)	Positive Feedback	Negative Feedback
Forbidden Words (www.inflos.de/fw)	Activates recall and understanding of technical terms; effective for harmonizing vocabulary in advanced courses; easy to understand	Too basic for graduate-level instruction; seen as time-wasting if focus is on higher-order goals
Lie Detector (www.inflos.de/ld)	Can engage large classes; low setup complexity; teacher remains in control	Participation anxiety in large cohorts; relies heavily on vocal contributions
Thought Experiment Roulette (www.inflos.de/ter)	Promotes analytical thinking and perspective-taking; supports higher cognitive objectives	Not suitable for quantitative subjects; preparation and assessment perceived as effortful; game mechanics seen as less playful
Tic-Tac-Toe (www.inflos.de/ttt)	Supports differentiated learning; students engage with content at varying depths	Considered “childish” by some; rule complexity can lead to onboarding issues

Evaluations of each game varied based on participants’ teaching disciplines and class formats. All games were perceived as beneficial by some educators and critical by others, demonstrating the importance of contextual alignment. Several participants stated that simply being exposed to a list of suitable, ready-to-use games significantly changed their willingness to adopt GBL. One educator remarked: “Just seeing these options makes it feel more doable.”

4.4 Evaluation of AI Support Tool

In the final phase, participants tested an AI-supported chatbot developed using the custom GPT functionality of ChatGPT. The tool generates mini-game materials based on user-provided topics and academic levels. Across all interviews, the tool was received positively. Educators described it as a “significant support” in overcoming effort-related barriers. Most were surprised by the quality and relevance of the outputs. Several participants expressed interest in gaining immediate access to use the tool in upcoming lectures.

Participants emphasized that the tool's main value lay in reducing preparation time and mental load, especially for instructors with limited experience in designing educational games. This finding strongly supports the importance of AI-supported tools: they can significantly reduce effort expectancy and lower the barriers associated with GBL implementation. As such, AI-supported tools appear to offer a practical bridge to game-based learning for educators.

5. Discussion / Conclusion

This study explored barriers to game-based learning (GBL) in higher education and evaluated the potential of mini-games and AI-supported tools to overcome these challenges. While many of the barriers echoed prior research (e.g., Lester et al., 2022; Ariffin et al., 2014; Watson and Yang, 2016), a previously overlooked aspect was the widespread openness among educators toward using games in the classroom – despite limited current usage. In previous studies, high levels of perceived effort were considered a main obstacle. However, we identified that many educators did not only consider the implementation of our mini games to require a lot of effort instead, they were simply not aware that suitable games were available for their area of study. For many participants, GBL did not surface as a natural component of course planning. Thus, a practical application and avenue for future research would be the provision of a larger set of curated mini games to a wider range of professors to analyze implementation behavior, and not only implementation intentions. Future studies could also focus on barriers beyond the scope of this paper, such as curricular rigidity, which might be an issue in some disciplines.

The application of the UTAUT framework helped clarify the relative weight of specific barriers. While performance expectancy concerns (e.g., perceived lack of rigor) were present, they were less prominent than effort expectancy and facilitating conditions. The importance of institutional constraints – such as limited classroom time, large class sizes, and absence of technical or professional development support – was especially clear. This highlights a theoretical contribution of the study: by using UTAUT, the analysis emphasizes the role of structural and contextual barriers, which are often underrepresented in studies grounded in the Theory of Planned Behavior (TPB) or the Theory of Reasoned Action (TRA), which focus more on attitudinal factors (Fishbein & Ajzen, 1975; Ajzen, 1991). Contrary to the original UTAUT framework, facilitating conditions already impacted behavioral intent in our study, not only actual usage behavior.

Mini-games emerged as a promising tool to bridge the implementation gap. Their low time demands, absence of licensing requirements, and adaptability across disciplines directly addressed educator concerns. Notably, simply providing a curated list of ready-to-use mini-games caused many participants to reconsider their stance on GBL and begin planning for implementation. The evaluation results showed that perceived usefulness and fit varied significantly by discipline, group size, level and teaching style, reinforcing the importance of context-sensitive design.

AI-supported tools offered additional value by reducing preparation effort – a major factor in effort expectancy. Participants responded positively to the AI tool, with many expressing surprise at the quality of the outputs and a desire to integrate it into future teaching. These findings suggest that combining mini-games with low-effort AI tools may offer a scalable strategy to promote broader GBL adoption in higher education. In the study, participants only had short exposure to the different chatbots. It would be interesting in future studies to analyze the interaction between educators and the bots and the evaluation of the game experiences by students. A special focus should be placed on learning outcomes, educator satisfaction with the tools and ease of use. Practically, institutions should consider developing discipline-specific GBL repositories, providing access to generative AI tools that automate game content creation, and offering structured training on the pedagogical benefits of GBL. These interventions could accelerate cultural change by normalizing GBL and making it part of routine instructional design.

This study includes several limitations that will be addressed in future research projects. First, the perspective of students is not considered explicitly. While the authors have tested all presented games in classroom settings and have anecdotal evidence that mini-games may increase motivation and participation, these effects have not yet been evaluated scientifically. In addition, the qualitative nature of the study limits generalizability. The small sample size did not allow for full representation of all disciplines or teaching formats. Notably, several differences emerged between educators from the social sciences and those from engineering disciplines, as well as between instructors teaching small seminars versus large lectures. These variations warrant further investigation to understand how contextual factors and disciplines influence GBL adoption and perceptions of usefulness. Finally, while the AI tool was well received in interviews, its evaluation remains perceptual. Due to

social desirability bias, interviewees might have provided a too-positive evaluation of the games and tool. Future studies should explore how educators use such tools in practice and whether their reported ease of use translates into sustained adoption.

Ethics Statement: This study followed institutional ethical guidelines. Participants gave informed consent, no sensitive data were collected, and participation was voluntary. Formal ethics clearance was therefore not required.

AI Statement: Artificial intelligence tools supported several stages of this research. Two mini-games – *Lie Detector* and *Thought Experiment Roulette* – were developed with the aid of generative AI for ideation and content refinement. AI-based academic tools (Consensus, Elicit) were used to identify relevant studies and search for gaps in the literature review. Additionally, ChatGPT and DeepL enhanced the clarity and fluency of the writing, particularly for non-native English speakers. Reference formatting was also AI-assisted. All outputs generated by AI tools were reviewed and edited by the authors to ensure accuracy, relevance, and compliance with academic standards.

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Secret Hacker: A Learning-Based Cybersecurity Game for Group-Based Settings

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Abstract: Existing cyber security training methods do not deliver sufficient behaviour change to address the growing threat landscape that comes with an ever-more interconnected world. Many people of all ages struggle to effectively recognise cyber threats, and despite increasing investment in cyber security, the incidence of damaging cyber security attacks has only increased. Game-based training methods have been used successfully in a variety of fields, and many gamified and game-based cyber security training methods have been developed. Game-based training methods, as they exist, do not provide a 'silver bullet' solution for cyber security training, as a lack of commercial options, a high upfront cost to develop, and similarity with traditional training means that new game-based training methods have not had the desired impact on the cyber security landscape. This paper discusses the potential of *Learning-Based Games* - game-like training methods that are developed based on games, rather than on the training materials that educators and trainers intend to deliver. By utilising existing popular games, and introducing cyber security learning content, Learning-Based Games begin their design cycle as proven fun and engaging games, potentially reducing the developmental burden and cost. A new educational card game: *Secret Hacker* (primarily aimed at school children) is proposed, developed, and provisionally tested with a pilot group of 8 participants. It is based on a popular existing card game, and this paper justifies the design elements that make it well-suited as a game for delivering behaviour change. In particular, Secret Hacker has a focus on fun and engagement, and built-in replayability - and the game structure itself can be adapted to be suitable for more advanced learners. Methods by which this game can be used to gather assessment data are also discussed, to help educators and trainers to understand the cyber security behaviour of the users. This paper will outline the design and investigative process which may subsequently lead to the development of further such educational games, the improvement of Secret Hacker itself, and insight into the effectiveness of Learning-Based Games compared to game-based learning and traditional training.

Keywords: Game-Based learning, Cyber security, Behaviour assessment, Awareness training, Cyber games

1. Introduction

People around the world use the internet and other online systems at a rate that continues to rapidly increase. These systems are utilised by people of all ages, with over half of all 8-year-old children reportedly having their own phone or tablet (Merod, 2025), and 90% of children over 8 already using the internet (The Educator Magazine, 2024). This usage does not wane with age, as organisations and adults in general continue to use the internet and internet-connected activities for everything from online games to online banking, and web forums to storing mission-critical resources. 96% of adults use the internet (Pew Research Centre, 2024), and this rises to 98% among 18-65-year-olds. The internet is popular because it offers many positive experiences and conveniences to all types of users.

However, these benefits come at a cost. Cyber attacks have been increasing in frequency and sophistication for almost as long as the internet has been available at large and continue to do so. 72% of children have reportedly experienced at least one cyber threat (The Educator Magazine, 2024), and organisations continue to lose hundreds of billions of dollars annually (Miliefsky, 2025), to say nothing of the financial and other losses individual adults may experience in their personal lives.

Despite a clear problem, progress on combating cyber security threats is insufficient to address it (Bada, Sasse & Nurse, 2015). One of the most significant influencers of cyber security threats is the online behaviour of individuals – or human error. While the exact number is not agreed upon, most sources agree that over half of cyber security incidents are caused primarily due to human error – anywhere from 64% (Kaspersky, 2023) to 95% (World Economic Forum, 2022).

One of the main ways to improve human behaviour in cyber security scenarios is through the use of cyber security interventions – usually cyber security awareness training (Alnajim et al., 2023). This training aims to improve cyber security awareness and understanding among some group: adults in a workplace, users of a website, children of a certain age. Unfortunately, many existing training methods have been criticised as not sufficiently engaging users (Bada, Sasse & Nurse, 2015).

Game-based methods are sometimes utilised to deliver learning materials in a more engaging manner and use the well-established fun of games to improve training. In this paper I will outline a game-based training method that I have developed, *Secret Hacker*, as well as the concept of Learning-Based Games. Learning-Based

Games go further than Game-Based Learning to develop training directly from existing games and game formulae, rather than starting from the learning materials aiming to be delivered. This offers an alternative to existing methods for developing game-based cyber security interventions. I have also undertaken a practical assessment of Secret Hacker with a small focus group and used the analysis to determine improvements to the game, best practices for future game-based learning methods, and next steps.

2. Existing Work

2.1 The Effectiveness of Traditional Cyber Security Training

Traditional methods of improving cyber security behaviour have been acknowledged as ineffective in a variety of studies. Most existing cyber security awareness training programs that are utilised share a common problem: They are considered boring, overly difficult, not relevant to real world problems, they fail to engage their users, and most importantly of all – they do not sufficiently change behaviour (Bada, Sasse & Nurse, 2015; Haney & Lutters, 2018). They generally attribute this to training methods simply not considering engagement during their development.

2.2 Existing Game-Based Cyber Security Training

Game-based cyber security training methods have been considered as an alternative to traditional training. Zhang-Kennedy & Chiasson (2022) review many of these methods, finding common themes. Overall, outcomes of game-based training show promising signs, with noticeable increases in performance over traditional methods of training. However, there is significant focus on phishing which, while not unjustified (as phishing is a very prevalent threat), does risk neglecting other important areas of cyber security. Hendrix, Al-Sherbaz & Bloom (2016) also review game-based cyber security training methods, with similar results, noting that a significant proportion of the reviewed games utilise some kind of simulation of real-world environments.

2.3 The use of Card Games in Cyber Security Training

Game-based training in cyber security is a relatively small field, with adoption in the workplace being minimal, and research often limited to small games for studies, such as Anti-Phishing Phil (Sheng *et al.*, 2007) which is a well-regarded example of cyber security gamification. A large proportion of these games have been developed with the workplace in mind, as opposed to being aimed at children and younger adults. However, educational cyber security card games in particular (such as those in this section) are disproportionately targeted at children. Intuitively, this makes sense, as physical resources are often used in classrooms and a card game would be simple to implement. While technological improvements are transitioning many environments away from physical resources, there is still value to be had in the collaborative elements of in-person educational materials. Several existing educational cyber security card games were reviewed using a Google Scholar search for cyber security card games. 7 appropriate games were found in total, however 2 were discarded due to missing information.

Table 1: Card games for cyber security training

Author(s)	Game name	Gameplay	Evaluation
Aladawy, Beckers & Pape (2018)	PERSUADED	Players use special cards to carefully draw cyber attacks they can defend against and new defences	No clear evaluation of learning
Anvik, Cote & Riehl (2019)	Program Wars	Players accumulate points by attacking and defending with cards	No clear evaluation of learning
Denning *et al*. (2013)	Control-Alt-Hack	Players must carefully allocate resources to defeat cyber attacks	Users were asked to report on a number of items, including educational value, which most (11/14) found there to be.
Shah & Agarwal (2023)	Cyber Suraksha	Players match scenarios with defence mechanisms	No clear evaluation of learning
Thomas *et al*. (2019)	CySEC Crucible	Players manage hackers with differing abilities to hack other players	No clear evaluation of learning

In general, it appears that these games tend to heavily prioritise either the fun element or the learning element. Program Wars (Anvik, Cote & Reihl, 2019), Control-Alt-Hack (Denning *et al.*, 2013) and CySEC Crucible (Thomas *et al.*, 2019) focus heavily on fun, with minimal learning content – players may successfully complete the game without demonstrating much or any (substantial) knowledge of cyber security. Cyber Suraksha (Shar & Agarwal, 2023), on the other hand, very clearly requires comprehensive knowledge of the learning objectives in order to successfully complete the game, however the primary mechanic involves simple expressions of knowledge, with no gameplay skill involved (as cards simply need to be matched to each other). PERSUADED (Aladawy, Beckers & Pape, 2018) performs reasonably well on both metrics, as there is a strategic game element for fun, but players are also required to understand cyber security content in order to correctly match scenarios and defences. Unfortunately, PERSUADED is not comprehensively studied for its impact on users' behaviour, but there is certainly potential in this concept.

2.4 Summary

Cyber security training remains in clear need of improvement, and game-based training is a promising method of accomplishing an improvement in cyber security outcomes. However, cyber security game-based training methods are mostly quite small-scale and generally fail to utilise fun as effectively as existing traditional games. Card games are a common method of engaging younger audiences, but most existing games seem to lean too heavily on either learning content or fun content.

3. Game Development

Secret Hacker was developed with collaborative learning and community engagement potential in mind. The full development process is ongoing, but the initial prototype was developed over 3 weeks using basic graphical tools, basic freely available graphics (Pixabay, 2025), and literature backed cyber security scenarios. By giving players an environment in which to discuss cyber security, and the motivation to do so, the aim of the game is to encourage critical evaluation of cyber security scenarios.

In the early stages of development, this game was intended to have randomly chosen groups of "Hackers" and "Defenders" who would have security-based tasks to complete. While investigating similar games, Secret Hitler (Goat, Wolf & Cabbage, 2016) was identified as a well-established game that followed a similar gameplay loop and was therefore selected as inspiration for the game. Secret Hitler revolves around two teams - effectively a "good" team and a "bad" team - where the "bad" team (fascists in Secret Hitler) would be required to engage in social deception in order to hide their status and trick the "good" team (liberals) into enacting fascist policies, after enough of which they would win.

In Secret Hacker, Liberals and Fascists and replaced with Defenders and Hackers, who aim to place down "good cyber security behaviours" and "bad cyber security behaviours" (respectively), replacing Liberal and Fascist policy tiles. Much like in Secret Hitler, hackers have an opportunity to identify themselves to each other at the start of the game, to allow additional avenues for strategy.

3.1 Justification for the use of Learning-Based Games

Secret Hacker is a game that was developed with the concept of Learning-Based games in mind. A Learning-Based Game (LBG) is similar to Game-Based Learning and Gamification - in the sense that game elements are combined with learning elements to make training/educational content that is fun to engage with, whilst also effectively delivering the learning content. Where Learning-Based Games differ, is that they consider the "fun" element of a game as the fundamental basis to build upon, rather than the learning element. Where most existing educational/training games start with training materials and gamify them - giving users points and badges when they answer questions correctly, or complete elements (e.g. Anti-Phishing Phil; Sheng *et al.*, 2007), Learning-Based Games start with an existing game, and replace or add some elements of the game to teach and/or test cyber security knowledge and behaviours. The advantage of this method is that it results in a very high likelihood that the game will be fun and engaging – as these are games existing players have chosen to play, sometimes for considerable lengths of time.

3.2 Secret Hacker Game Content

The Secret Hacker game is a card game, and therefore it consists of several physical components. As of publication, there are a total of 71 cards, a 4-page rulebook, and an A3-size game board. The rulebook contains the game rules, instructions on how to play the game, and a comprehensive list of all 51 behaviour cards with corresponding explanations. The game is intended for 5-10 players, though could be conducted with fewer.

The game board has 13 slots for cards: 5 for each team's good/bad behaviours, one for the draw pile, one for the discard pile, and one for the active pile (that players vote on). This board is shown in figure 1.

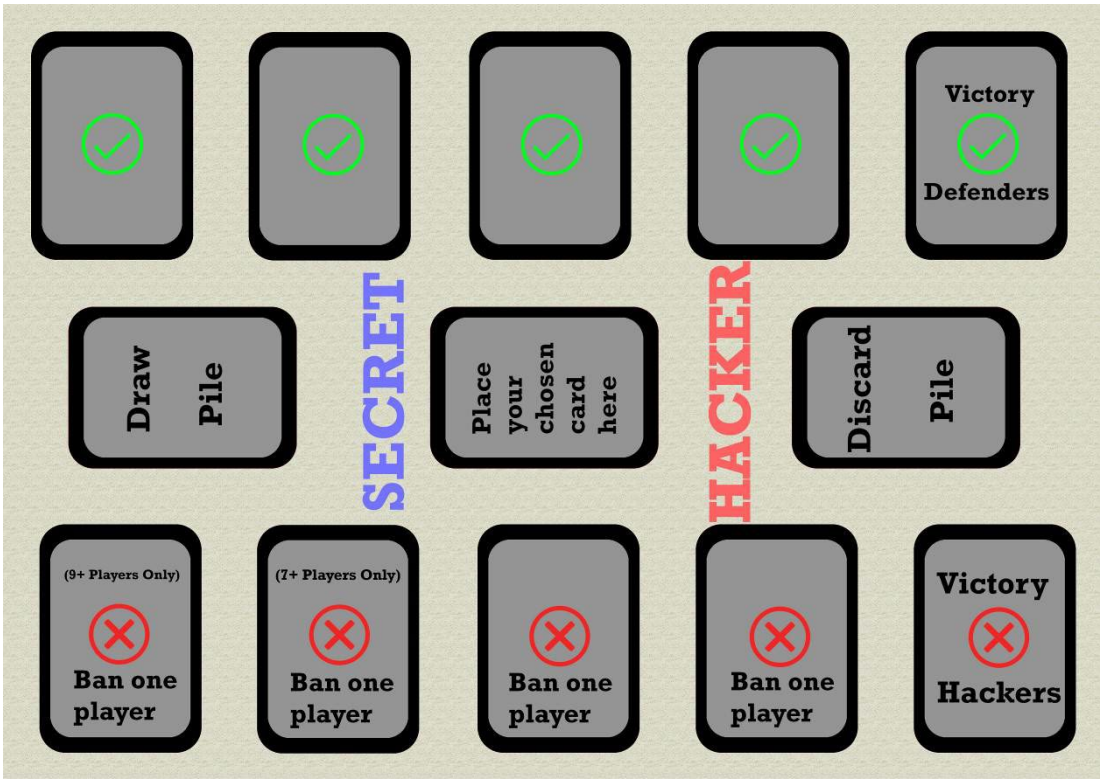

Figure 1: Secret Hacker Game Board

The 71 cards are of various types. There are 10 role cards – 6 defender and 4 hacker – to tell players which teams they are on. There are 10 yes/no double-sided voting cards – with a clear red-backed X on one side, and a green-backed tick on the other. The remaining 51 cards are all behaviour cards. In total, there are 3 sub-groups of 17 cards each, corresponding to password behaviours, phishing behaviours, and secure online behaviours, which is broadly in line with the cyber security content of existing cyber security training games. physical security, software behaviours, social media, and reporting behaviours were omitted at this stage but are intended to be added later with an additional 51 cards.

Each of these sub-groups has 7 good behaviours and 10 bad behaviours – as required for the game itself, so that an individual game on one of the cyber topic areas could be conducted, instead of the full game (in which cards come randomly from all three areas). As an example, if phishing has been identified as a particularly prevalent threat, the 17 phishing cards could be used in games, to focus on that area. These areas can then be mixed and matched as required.

A selection of these cards – each of the role cards, and a good/bad behaviour card from each of the three cyber areas is shown in figure 2. Note that the numbers in the bottom right correspond to entries in the rulebook, to ensure there is a way for players to ascertain whether the cards are good or bad behaviours.

Figure 2: 5 sample cards from the Secret Hacker pack of 71

3.3 Secret Hacker Rules

Throughout the standard gameplay loop, one player will be given three behaviours to choose from. They then have 15 seconds to choose two to pass to the player to their left, who similarly has 15 seconds to choose a card to place, face-up in the middle of the board. The entire table then has 15 seconds to either vote yes or no to this behaviour, based on their own personal strategy (generally, hackers will want bad behaviours, and defenders want good behaviours). If a majority vote no, then the card is permanently discarded. Otherwise, the card is placed on the row corresponding to whether it was a good or bad behaviour, moving towards a win for the defenders, if it was a good behaviour, or the hackers, if it was bad. After this, the players may discuss amongst themselves if they wish to question each other, and the explanation on why this behaviour was good or bad will also be read out. The rulebook contains a full list of all cards: whether they are a good or bad behaviour, and why.

The cards were designed to force players to think about whether they think that the actions being described are desirable, with the added condition of contributing towards the other team's win if they are incorrect. This is intended to motivate players to think about cyber security carefully, and to learn what makes behaviours good or bad. There are consequences for incorrectly identifying cards each way – if a card that helps the other team is voted for, their opponents progress towards victory. As there are a limited number of good and bad behaviour cards (7 good, 10 bad) and 5 are needed for a team to win, voting against cards that would help the players' team reduces their teams' chance of winning. The number of cards (7 good, 10 bad) were adjusted from traditional Secret Hitler (6 liberal, 11 fascist) to allow slightly more room for error, while discouraging reckless play in favour of carefully considering behaviours. If at any point the cards run out, the conclusion is up to the discretion of the officiator. If it is considered worthwhile the discarded cards may be reshuffled and put back into play, or the game may be called in favour of the hackers – as the defenders failed to facilitate good behaviours, and the hackers successfully disrupted service. After this, one of the teams will have won, and the group may discuss the gameplay.

As a final mechanic, after a number of bad behaviours (corresponding to the number of players) are played, the group has the option to *ban* one of their fellow players. If all of the hackers are banned, the Defenders win, and if over half of the defenders are banned, the hackers win (as they have successfully disrupted service – Availability of the CIA Triad). A full walkthrough of the rules and gameplay can be found at:

https://drive.google.com/file/d/1cv89_8Dfx9EResWaYlmzV61w5MYt3BmM/view?usp=sharing

3.4 Challenges with Learning-Based Games

While Learning-Based Games do not require the same level of challenging and often costly development for the games themselves, Learning-Based Games have their own set of challenges. One of the most significant difficulties is content generation. In total Secret Hacker has 51 distinct cyber security scenarios. A future expansion is planned which will add an additional 51 cards in 3 different cyber security areas, however each of these cyber security scenarios takes additional time on top of the basic development. Some scenarios can be developed from existing training materials; however, the fast-paced nature of many games necessitates more scenarios than traditional training. Consequently, this adds to the development burden. This may be an area where generative AI could be carefully used in the future, to develop such scenarios, but this approach is not considered in this research study.

Secret Hitler, and by extension Secret Hacker, is a social deception game. While popular, only a certain audience will enjoy the gameplay of Secret Hacker. This is the case with all games, and so in order to ensure a wide appeal, multiple different types of games would be required. While this would increase the development burden, the lack of appeal of some types of games to certain audiences is an issue that exists with standard game-based learning as well. Exploring methods of appealing to wider audiences with games is not typically explored with existing game-based learning methods and is beyond the scope of this study as well.

Among the most significant issues with Learning-Based games is the utilisation of Intellectual Property (IP). In the case of Secret Hacker, Secret Hitler is licenced under a creative commons licence, allowing non-commercialised re-distribution of modified content under certain conditions. Additionally, the principle of Fair Dealing and Fair Use may permit the use of copyrighted materials for limited research and educational purposes, but this involves legal complexities and significantly hinders commercial applications of Learning-Based Games. Successful large-scale use of Learning-Based Games would likely involve taking *inspiration* from existing games, rather than modifying existing games, unless in partnership with the original game developers.

4. Focus Group Evaluation

In order to understand the potential effectiveness of Secret Hacker as an educational game, and to improve it for more in-depth study, a small focus group study was conducted, with a total of 8 participants (2 in the first group and 6 in the second). As the first group was too small to fully play the game, the quantitative survey data has been omitted, though some of the comments and discussion from this group are still utilised.

4.1 Methodology

4.1.1 Participant recruitment

Participants were recruited primarily through convenience sampling. Posters were put out in the university building advertising the study, emails were sent around, and the study was advertised on an online forum. In the hours leading up to the study, potential participants were verbally invited. Participants were required to be 18+ but otherwise there were no restrictions on participation.

4.1.2 Study procedure

Participants in each group were asked to play the game once, for around 15-20 minutes. They were given an explanation of the rules, roughly in-line with the contents of the rulebook. They were given a sample round, in which a set of three cards were handed out as usual, but no time limit was applied and were given the opportunity to ask clarification questions throughout and after this practice round. Some guidance was given during the game segment, but this was limited, in order to not unduly influence the organic gameplay. Gameplay was terminated early, after only 4 "good" cyber security behaviours were placed down, as delays would have otherwise compromised the discussion section.

Throughout this study procedure, and the following discussion, an audio recording was taken, to capture relevant quotes and suggestions for future analysis. The participants were informed multiple times that this recording would be taken and agreed to it.

Only one playthrough (with practice round) was allowed in the study, however participants are able to access the game for future re-play if desired.

After the main gameplay, a short discussion segment was held, in which participants were asked to discuss:

- Which elements of the game they found enjoyable and not enjoyable.
- Whether they thought the game was fair and balanced, and they had broadly enough time in each segment.
- To what extent the cards could provide challenge and learning to them or others.
- What factors motivated them in the game.
- How the game could be improved, in enjoyment and learning.

After this discussion they were asked to complete a brief questionnaire that asked:

- Their cyber security knowledge from 1 to 10.
- How much they enjoyed Secret Hacker from 1 to 10.
- What they did/did not enjoy about the game.
- How much they felt they or others could've learned from Secret Hacker from 1 to 10.
- Which elements they feel did/didn't help the cyber security learning in Secret Hacker.

After these three steps were completed, participants were thanked for their time and left the study.

4.1.3 Ethical considerations

This study, of the game Secret Hacker, was granted full ethical approval by Oxford Brookes University UREC Registration No: L25372

No significant risks were identified in conducting this study, and the conditions of the approval were followed at all times.

4.2 Results

4.2.1 Headline results

Unfortunately, the first group only had 2 participants, and so the researcher needed to engage in the game in order for the study to go ahead. While the gameplay was not representative, some feedback was still gathered. The second group had 6 participants, and the game was able to progress in a much more realistic way. In total, 4 of the participants were members of staff, and 4 were university-level students. None of the participants were involved in the overall project at the time of the study, and all participants gave their consent to participate through physical consent forms before commencement of the study.

4.2.2 Full results

Due to the skewed experience of the first group (with 2 participants), only the 6 participant group is considered in these results.

Table 2: Self-report questionnaire results from the second focus group

Participant number	Cyber security knowledge	Level of enjoyment of Secret Hacker	Learning potential of Secret Hacker
1	6	8	7
2	8	10	5
3	9	8	8
4	8	9	9
5	8	8	8
6	9	10	5

Overall, on average, the participants rated themselves an 8 out of 10 in terms of cyber security knowledge – which is likely to be above the expected knowledge of a typical player of Secret Hacker (who would be expected to be an average school-aged child). In terms of "fun" content, on average participants reported 8.8 out of 10 "How much you enjoyed the game Secret Hacker". When asked how much they felt they did or could have learned from Secret Hacker, the result was 7 out of 10.

Two of the three participants that commented on the fun element of the game gave positive comments – "I genuinely had a lot of fun", "Engaging", "It's fun", but there was a significant body of constructive feedback as well. One comment asked for "room for more teamwork or us vs them elements".

4.3 Discussion

Broadly speaking, both groups found the game to be fun, and both groups felt that there was a reasonable possibility of learning from the game. In at least one instance, participants from each group incorrectly identified a card, and subsequently discussed why it was/wasn't a good behaviour, without prompting. There were some common issues – players found the game rules difficult to pick up initially, feeling that they needed more time to practice and adjust; that the strategy element may have overcomplicated matters; and that some of the cards felt more well-suited to the workplace than to school-aged children.

The level of fun participants experienced (8.8/10) is a very strong result, considering the preliminary nature of the game. These results likely stem from the *Secret Hitler* game that Secret Hacker is based on but does indicate that the "fun" of Secret Hitler was not significantly impacted by the addition of Learning Materials. The misidentification of at least one card, despite the relatively high (8/10) self-rated cyber security knowledge, indicates that there is a good amount of scope for learning content as this led to discussion in the group itself.

Participants were asked to consider the hypothetical learning, as well as their actual learning, and so it is possible the results of learning potential (7/10) were unduly skewed upwards.

The level of teamwork and competitiveness of the game may have been improved by the Hacker group being able to identify each other, as in Secret Hitler. In this instance it was not done, but in the future, it would be reasonable for the hackers to know who each other are.

While the game did run smoothly in the end, there were several comments on issues with understanding the rules – "it took a while to learn the meaning of the behaviours", "The beginning was a little confusing", "Took a

bit too long to get into it". The beginning was somewhat rushed, with participants arriving slightly late and a tight timeframe for the study, and there was only a single rulebook. The practice round did help, but it seemed to take 2-3 rounds for players to fully understand the game. One participant suggested that a "practice set of cards" could be used to not "[waste the] real cards". Additional copies of the rulebook and a more detailed explanation may help (though they would need to be modified to remove the answers), and a video explainer has also been developed. It was also suggested that the mention of strategy was confusing, and that players should simply be encouraged to vote according to their understanding of the cyber scenario and their role.

One participant said that "a discussion after each decision could be useful". This was already permitted under the rules, however this was evidently not made clear enough, and so will be clarified and encouraged in the future – as this discussion is a key aspect of the learning delivery.

The final major point that came up several times is with the suitability of the cards for the intended age group. A participant pointed out, to much agreement, that the cards are "all very work oriented". This prompted discussion around the types of threats that children face online, particularly ones that adults do not. This was reflected in the questionnaires with several comments suggesting to "add some cards [that] focus on cyber security attack[s] for children". The ability to swap out cards to address concerns for different population groups is one of the main strengths of the Secret Hacker concept, as the game structure does not rely on any particular scenario content.

4.4 Identified Game Improvements

The main points that were raised throughout this study, to improve the game experience for the target population can be summarised as follows:

- Encouraging teamwork and competitiveness by ensuring hackers identify each other at the start of the game (and where possible having odd-number groups, as the hackers struggled in an even-sized group).
- A better explanation of the rules, including more comprehensive practice rounds with special practice cards, and less focus on the strategic element of the game.
- Encouraging more discussion between rounds and explaining card results more fully (could be done by the players with their own modified rulebooks).
- Modification of some workplace-focused cards to be more appropriate to school-age children, as a separate version of the game.

5. Conclusions and Further Work

The aim of this study was to develop a game that can teach school-aged children cyber security concepts and reinforce positive cyber security behaviours. The results in this study, and of the paper more broadly, indicate a positive impact of Secret Hacker, though it is not definitely demonstrated that Secret Hacker achieves the stated purposes of this study – as this will need to be determined with further work. Participants enjoyed the game overall, maintaining the fun element of Secret Hitler, whilst providing a platform and motivation for players to engage with and discuss cyber security concepts, in such a way that helps to advance their understanding. Secret Hacker is an intact and enjoyable game, similar enough to a game that many individuals play for fun, while also delivering cyber security concepts. It is not necessarily a game that employees of a company, or students in a classroom would be required to complete once every 6, 12, or even 24 months, though it would also be possible to use it in such a way. With this in mind, it is certainly worthwhile to consider the dissemination of such games.

In a controlled environment, Secret Hacker was able to stimulate discussion of key cyber security concepts between experienced cyber security practitioners, whilst still being a fun and engaging game all around. The appeal of Secret Hacker was, if anything, more universal than expected, and certainly calls for further investigation of social-style games for cyber security education. With technology increasingly moving lifestyles online, interpersonal discussion and collaboration decreases, and games such as Secret Hacker help to reinvigorate this discussion, in a way that benefits understanding of cyber security.

Secret Hacker was, initially, intended as a game for school-age children – particularly teenagers – but the study was conducted with adults. A larger study will be required, in order to explore the impact of Secret Hacker on the cyber security behaviour of children, ideally in a classroom setting, with clear methods to measure any improvements in cyber security behaviour, and risk more widely. The results do, however, indicate that Secret Hacker could be effective among adults as well, and therefore the set of cards will need to be expanded to

include multiple versions – cards that address scenarios more typical to children, behaviours more typical to non-technical adults, and could be expanded to more technical fields as well. The Secret Hacker template appears to have been quite successful in initial testing, and with carefully chosen scenario cards could play a role in cyber security education for a wide variety of populations.

Ethics Declaration: Ethical approval was required and subsequently obtained for the study referenced in this paper, prior to the recruitment and commencement of this study, as detailed in section 4.1.3.

AI Declaration: AI was at no point used in the writing of this paper, the development or running of the study, or at any of the prior stages (e.g. ethical approval). AI was used in a limited capacity to transcribe two recordings from the study, to retrieve a small number of quotes from the text, in section 4.2.2. These quotes were, however, cross-referenced with other, non-AI sources.

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The Reach of Digital Games and Their Potential as Global Communication Tools

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Abstract: This paper examines the potential of digital games as communication tools to reach global audiences, extending beyond established cultural and geopolitical divides. It shows the empirical data gathered in our EU and UKRI-funded Games Realising Effective and Affective Transformation (GREAT) project, where we collaborated with several organizations to investigate this potential. Namely, a significant case study called Play2Act was undertaken in collaboration with the United Nations Development Programme (UNDP), which forms the focus of this paper. The aims of this study were to find out how much of the world's population could be reached via digital games and how many citizens would be willing to communicate their climate attitudes in a simple and short survey that was inserted into popular mobile games. Currently, there are 3 billion gamers in the world and the idea of reaching citizens via games to understand their opinions on critical global issues and then passing this information to policy-makers emerged. This is the main objective of our project, as to whether games can act as an effective communication channel between citizens and policy-makers, the context being the climate emergency. Governments do not typically have the opportunity to understand their citizens' needs fully. The aim of this project is to decrease the barrier and increase representation and democracy. The findings obtained from the Play2Act study suggest that games, moreover their ability to engage, and inherent social dynamics create a unique opportunity to support meaningful dialogue with a large proportion of citizens reached, engaged and completed the surveys. The study engaged with almost 1 million players from every UN recognised country, with only two exceptions, and ca. 181,000 surveys completed, confirming the global reach of games. The next steps are for UNDP to take this information to individual countries with recommendations of appropriate climate policies based on their citizens' voices, this having huge potential for digital games being policy transformational tools. This research contributes to knowledge on the intersection of technology, culture, and communication and offers valuable insights for policymakers, researchers, and stakeholder groups seeking to leverage digital games for social impact.

Keywords: Digital games, Citizen participation, Social impact

1. Introduction

Digital technologies have transformed how individuals communicate, engage with content, and participate in civic and political life. Among these technologies, digital games have emerged as a dominant global medium, not only as a source of entertainment but also as a potential vehicle for meaningful communication and social engagement. With an estimated three billion players worldwide (Costello, 2025), digital games possess unparalleled global reach, cutting across cultural, linguistic, and geopolitical boundaries. As such, they represent a promising yet underexplored channel for engaging citizens in dialogue around complex and urgent global issues, such as the climate crisis. This paper investigates the communicative potential of digital games through the lens of the Games Realising Effective and Affective Transformation (GREAT) project, funded by the European Union (EU) and UK Research and Innovation (UKRI). The study focuses on a significant case study, Play2Act, developed in collaboration with the UNDP. The initiative aimed to explore whether digital games could serve as effective conduits for citizen engagement and data collection on climate attitudes, ultimately informing policy at national and international levels.

By embedding a short climate-focused survey within popular mobile games, the Play2Act study sought to overcome traditional barriers to civic participation, particularly among demographics that may be underrepresented in conventional public consultation processes. The project reached over one million players globally—representing nearly every UN-recognized country—and generated approximately 181,000 completed surveys. These findings underscore the capacity of digital games not only to attract attention and foster engagement, but also to function as participatory platforms through which citizens can communicate their views to policymakers. In positioning games as instruments for policy-oriented dialogue, this paper contributes to

interdisciplinary research at the intersection of digital media, cultural studies, and political communication. It examines the implications of engagement strategies using digital games for enhancing democratic representation and participatory governance, especially in contexts where institutional mechanisms for citizen input are limited or inaccessible. Furthermore, it addresses the broader question of how emerging technologies can be leveraged to facilitate inclusive and scalable communication in response to global challenges.

This paper investigates the central research question – "**Can digital games function as effective communication channels between citizens and policymakers?**" By addressing this question, our research seeks to contribute to a growing body of knowledge on democratic innovation and inclusive governance. The overarching aim is to reduce barriers to participation and amplify the voices of underrepresented populations, with a particular focus on Europe while remaining attentive to broader global applications. In doing so, we position digital games as emerging tools in the effort to strengthen democratic processes, improve policy responsiveness, and promote more equitable forms of engagement in the face of complex global challenges. Our project also supports the European Democracy Shield (Bentzen, 2024). This is an initiative by the European Commission aimed at safeguarding democratic processes within the EU which focuses on enhancing media literacy and promoting citizen engagement. Our project supports this initiative by using an innovative approach to increasing citizen participation and collecting valuable data for policymakers, and our method exemplifies how digital platforms can be leveraged to foster democratic engagement and inform policy decisions.

2. Literature Review

Prior to the commencement of the GREAT project, our team (primarily PlanetPlay, previously PlayMob) launched *Mission 1.5*, an online game-based campaign designed to educate the public about climate change solutions while simultaneously gathering their opinions on the actions governments should prioritize in response to the climate crisis. This initiative formed the basis of the *People's Climate Vote*, which successfully engaged 1.2 million respondents, making it the largest survey of public opinion on climate change to date (Flynn et al, 2021). Conducted across 50 countries and covering 56% of the global population, the campaign demonstrated the potential of interactive digital platforms to combine public education with meaningful policy-oriented data collection on an international scale.

In our literature review, we identified that a range of climate-related games is expanding, with over a hundred identified across various genres and formats. However, many still prioritize educational goals over civic engagement or policy influence (Gerber et al., 2021). Despite this growth, there is limited empirical evidence on the effectiveness of climate games, especially in large-scale, cross-cultural, or policy-relevant settings. Key design features—such as credibility, social integration, and actionable feedback loops—are often applied inconsistently, and the line between serious and entertainment-oriented games remains largely unexamined (Fernández Galeote & Hamari, 2021). To our knowledge, indeed no previous study has leveraged the global reach of digital games at this scale to directly engage citizens in policy-relevant discourse across 188 countries. It represents a significant advancement in the field by demonstrating, for the first time, the feasibility of embedding large-scale attitudinal surveys within digital games to reach a truly global audience and channel civic input to policymakers. Our project pioneers a novel methodology that integrates real-time data collection into game platforms, offering an unprecedented model for participatory democracy in digital contexts, positioning it as the first of its kind in the context of global digital communication and climate policy. Our project has achieved the following milestones:

- **Global Reach**: Engaging over one million citizens from 188 countries, demonstrating unprecedented international participation.
- **Integration with Popular Mobile Games**: Embedding surveys within widely played games to seamlessly collect data on climate attitudes.
- **Direct Policy Impact**: Collaborating with the UNDP to inform national climate policies based on citizen input gathered through games.

3. Methodology and Data Sample

The Play2Act case study utilised a quantitative approach, combining in-game surveys with data collection to assess player engagement with climate-related content in digital games. The goal was to determine whether this engagement increased awareness and intent to act on environmental issues. Surveys, located here (were available in 10 languages - English, Spanish, German, Chinese, Japanese, Portuguese, French, Russian, Arabic, Italian - which was automatically translated according to the browser setting of the user's device), were embedded in widely played mobile games participating in the Playing for the Planet initiative, which integrates

sustainability themes. Game studios involved aimed to gather data to refine their approach to incorporating environmental messaging within their platforms. Surveys were integrated into the gaming ecosystem using each platform's existing communication tools, ensuring organic and non-intrusive player engagement. The Play2Act surveys engaged 933,852 players across 228 countries & territories, including 188 UN-recognised nations (exceptions being North Korea and Eritrea). The primary data collected was quantitative, focusing on demographics, climate awareness, and self-reported behavioural intentions regarding sustainability. This enabled the identification of engagement patterns, attitude shifts, and potential links between in-game climate messaging and real-world intentions. A total of 204,796 respondents answered at least one question, yielding a 90.7% response rate. Among engaged users, 77.2% completed the survey, and 181,087 players finished it, resulting in a 15.2% overall completion rate. Participants were offered a reward in the form of a discount on a PlanetPlay marketplace purchase, with a portion supporting sustainability initiatives. This case study demonstrates the potential of large-scale digital games as tools for collecting behavioural and attitudinal data. It demonstrates how digital engagement can effectively address social and environmental issues. The targeted placement strategy within mobile games such as Pokémon GO, Subway Surfers or F1 Clash, provides valuable insights for future research using high-reach platforms for data collection and assessing social impact.

4. Key Findings

The Play2Act case study examines digital gaming as both a large-scale data collection tool and an engagement mechanism in climate discourse. With 181,087 completed surveys across multiple gaming platforms (mobile games as well as gaming consoles), the study highlights gaming's potential to expand research access while revealing tensions between reach, representativeness, and engagement depth. Chi-square analysis ($X^2 = 45.62$, $p < 0.05$) confirms significant demographic differences in participation, illustrating the need for targeted strategies.

4.1 Engagement and Reach: Expanding Access or Replicating Existing Biases?

Play2Act's large-scale engagement aligns with research suggesting digital gaming can expand participation beyond traditional survey methods (Reddie et al, 2018; Pietilä et al, 2019). By reducing barriers such as literacy levels, financial constraints, and geographic isolation (Ramirez Aranda & Vezzoni, 2022; Raeburn et al, 2022), digital platforms have been identified as tools for enhancing inclusivity in climate-related research. Play2Act achieved a 77.2% completion rate among engaged users and 19.7% relative to total survey sessions. Chi-square analysis ($X^2 = 32.85$, $p < 0.05$) indicates statistically significant regional differences, with European participants more likely to complete the survey than those from Africa and Asia. Prior studies have demonstrated that factors such as survey length, display format, and recruitment strategies influence response rates (Liu & Wronski, 2018; Tangmanee & Niruttinanon, 2019). While web-based surveys often require email reminders or incentives to sustain participation (LaRose & Tsai, 2014), Play2Act embedded surveys directly within gaming environments, maintaining engagement without external prompts. However, as with other web-based research, non-response bias remains a critical limitation when assessing the survey's reach and representativeness.

Play2Act highlights the potential of digital games as both an alternative and complementary method for public opinion research, demonstrating significant geographic reach and scalability. However, chi-square analysis ($X^2 = 27.94$, $p < 0.05$) indicates participant demographics were not entirely uniform, raising questions about whether this reach extended to underrepresented groups. The study achieved a relatively balanced gender distribution, with 51.7% of respondents identifying as male, 36.1% as female, 10.1% preferring not to disclose their gender, and 2.9% identifying as non-binary. Despite this inclusivity, gender significantly influenced response rates and engagement levels, particularly in self-reported climate awareness and behavioural intent. These findings align with research indicating gendered differences in environmental engagement (Bloodhart & Swim, 2020; Zhao et al, 2021). While Play2Act's gender distribution is more representative than historical disparities in gaming participation (Leonhardt & Overå, 2021; McLaren-Gradinaru et al, 2023), it remains unclear whether these proportions reflect gaming populations or broader climate discourse participants.

Age significantly influenced engagement, with younger participants displaying higher participation levels, consistent with research indicating that digitally literate individuals are more likely to engage in game-based studies (Passmore et al, 2018; Kaye, 2018). Welch-ANOVA ($p < 0.05$) confirmed a significant relationship between age and survey completion time, with younger respondents completing surveys more quickly, raising concerns about attention span and response bias. Completion time also varied by education level, indicating differences in cognitive engagement. Welch's ANOVA (Welch's $F(6, 13{,}128.56) = 78.80$, $p < 0.001$) confirmed statistically significant differences, with post hoc Dunnett's T3 analysis showing participants with no formal education completed the survey faster than those with any level of schooling ($p = 0.001$). Completion time increased with

education level, suggesting more deliberate engagement. However, 3.8% of respondents exceeded five minutes per question, with some taking over 30 minutes, likely due to external distractions, multitasking, or disengagement rather than deeper reflection. Despite these insights, the study had limitations. While data was collected on the age at which participants left formal education, the survey did not assess income, occupation, or other socio-economic factors. As education level is often correlated with climate discourse engagement (Ballew et al, 2020), the absence of more detailed demographic data limits the ability to determine whether Play2Act reached a socio-economically diverse audience, raising concerns that digital gaming research may reinforce existing biases, engaging those already inclined toward climate action rather than expanding participation to underrepresented groups.

4.2 Measuring Depth of Engagement in Digital Research

A key concern in digital research is whether participants meaningfully engage with survey content or treat it as a secondary activity (Vecchio et al, 2020; Martins & Lavradio, 2020). Chi-square analysis identified response patterns, with 98.6% of completed sessions lasting between 10 seconds and 10 minutes, and an average dwell time of 1 minute and 43 seconds per question. Welch-ANOVA ($F = 5.63$, $p < 0.05$) confirmed significant variation in response times by education level, indicating that more highly educated participants engaged with greater deliberation. These findings underscore two key issues: the need for digital survey methodologies to distinguish between genuine engagement and passive responses through mechanisms such as attention checks and response consistency analysis, and the trade-off between maximising reach and ensuring engagement depth in game-based research. While Play2Act demonstrates the feasibility of large-scale research within gaming ecosystems, refining engagement metrics will be essential for ensuring data validity and actionable insights. Further statistical tests offer a nuanced view of demographic differences in engagement and perception. Variation in response times by education level supports environmental psychology research suggesting education fosters more reflective engagement with sustainability issues (Poškus, 2020; Sun et al, 2020), although it remains unclear whether this translates into more accurate or informed responses. Chi-square analysis ($X^2 = 38.27$, $p < 0.05$) also indicates significant gender-based differences in perceptions of climate gaming. Male and non-binary respondents were more likely to view games as active contributors to climate solutions, whereas female respondents emphasised their role in education and awareness, aligning with broader gender trends in environmental engagement, where women often prioritise community-based solutions, while men favour technological interventions (McCright, 2010; Patnaik, 2021).

4.3 Gender-Based Variations in Climate Change Emotions

Chi-square analysis identified significant variations in climate change emotions across gender identities and global regions. Males reported feeling more informed but also expressed greater scepticism, while females exhibited higher levels of hope and motivation for action. Non-binary individuals and those who did not disclose their gender were more likely to experience powerlessness and uncertainty. Females were also less likely to report unchanged climate-related emotions after engaging with Play2Act, suggesting greater responsiveness to environmental narratives in gaming. Notably, those who did not disclose their gender were most likely to believe games play no role in addressing climate change, underscoring the need for tailored engagement strategies.

4.4 Regional Disparities in Climate Policy Awareness

Chi-square analysis ($X^2 = 42.61$, $p < 0.05$) identified significant discrepancies in climate policy awareness by education level, region, and income group. While over 50% of European respondents recognised The Paris Agreement, awareness fell to 41% in Asia and 37% in Africa, highlighting regional disparities in climate literacy. Policy familiarity correlated strongly with education, reinforcing concerns that digital gaming research may primarily engage those already involved in climate discourse rather than reaching new audiences. Awareness of Nationally Determined Contributions (NDCs), the Kunming-Montreal Framework, and National Biodiversity Strategies and Action Plans (NBSAPs) remained consistently low across all regions, with over 80% of respondents unfamiliar with these mechanisms.

Europe had the highest recognition of The Paris Agreement (37%), while Oceania showed the highest unawareness (40%) and the lowest recognition of biodiversity frameworks (7%). Asia exhibited higher awareness of NDCs and NBSAPs (14%), yet also had elevated climate scepticism, reflecting a disconnect between policy knowledge and belief in climate action. Research suggests political narratives, economic priorities, and media framing influence public trust in climate governance, which may explain this trend (Stecula & Merkley, 2019). Among income groups, lower-middle-income respondents had the highest awareness of NDCs (15%) and NBSAPs (14%), possibly due to exposure to sustainability-focused development initiatives. However, high- and

low-income respondents reported the greatest unawareness (34–36%), raising concerns about the effectiveness of policy communication across socio-economic groups.

4.5 The Disconnect Between Climate Gaming and Policy Literacy

Play2Act highlights a critical gap between general environmental engagement and knowledge of climate policies. Despite strong engagement with climate-themed gaming content, significant associations ($p < 0.05$) between education and policy awareness suggest while games introduce environmental themes, they do not provide the policy literacy needed for systemic action. Without an understanding of frameworks such as The Paris Agreement or NDCs, players may struggle to translate awareness into advocacy. Many digital interventions focus on awareness or individual behaviour change but neglect policy comprehension, limiting their impact. Embedding policy education more explicitly into gameplay could address this gap, equipping players with the knowledge to advocate for structural change. While digital games can introduce players to environmental themes, they must go further in fostering meaningful policy engagement. Many interventions focus on raising awareness but fail to provide the necessary policy comprehension. Research is needed to test approaches that integrate policy literacy into games, ensuring that they move beyond informing players toward actively equipping them with the tools to advocate for systemic change.

4.6 Gaming and Climate Action: Potential and Limitations

Across all regions, video games are widely viewed as tools for climate advocacy. Most respondents (77.6%) believe games raise climate awareness, with significant regional differences ($\chi^2 = 559.001$, $df = 4$, $p < 0.001$), though weak correlation (-0.023) suggests minimal impact on overall belief patterns. Similarly, 77% agreed games can educate players on environmental actions ($\chi^2 = 1450.321$, $df = 4$, $p < 0.001$), but correlation remained negligible (0.003). Support for using games to fund green projects was also high (75.7%), with significant regional variation ($\chi^2 = 1671.279$, $df = 4$, $p < 0.001$) but weak correlation (0.016), indicating broad consensus. However, 27.9% rejected gaming's role in climate action, a belief with the strongest regional correlation (0.094), suggesting scepticism varies more by region. Post-hoc analysis showed Oceania and Asia were the most optimistic, while Africa and the Americas were more sceptical ($p < 0.05$).

The link between gaming engagement and climate risk exposure is complex. A one-way ANOVA found significant differences in green gaming engagement based on climate-related fatality rates ($F = 42.698$, $p < 0.001$), though the effect size was minimal ($\eta^2 = 0.001$). Players in high-risk regions engaged less with green games (mean difference = -3.311, $p < 0.05$). A similar pattern emerged for financial losses due to climate change ($F = 76.327$, $p < 0.001$, $\eta^2 = 0.004$). Players from regions with higher losses were more motivated by contributing to environmental causes (mean difference = 2.002, $p < 0.001$), whereas those in lower-risk regions engaged for educational reasons, reflecting different drivers of participation.

Economic context shaped climate engagement patterns. Respondents from lower-income regions were the most purpose-driven, with 40% playing beyond entertainment and 18% citing environmental learning. However, they also exhibited higher scepticism (23%) and uncertainty (24%), supporting theories that financial constraints foster eco-conscious attitudes without necessarily enabling action (Moser & Kleinhückelkotten, 2018; Petev & Coulangeon, 2021). Participants from upper-middle-income regions reported the highest behavioural changes (38%), altered consumption patterns (28%), and the lowest powerlessness (3%), suggesting they may be the most receptive audience for climate interventions, combining awareness, financial flexibility, and willingness to act. However, the long-term sustainability of these changes remains uncertain. Chi-square analysis revealed a significant gender-based difference in behaviour change. Females were more likely to adopt sustainable consumption habits, while males more often expressed general concern without specifying actions, aligning with research indicating sustainable behaviours are more likely to be adopted when they integrate seamlessly into daily routines (White et al, 2019; MacInnes et al, 2022).

Preliminary analysis suggests genre conventions and gameplay mechanics may shape how players emotionally and behaviourally respond to climate-related content. Games incorporating strategic decision-making, real-world contextualisation, or augmented reality appear to foster comparatively higher levels of climate engagement. Notably, Pokémon Go players reported the highest rates of climate optimism (31%), feeling well-informed (22%), and self-reported behavioural change (41%). These findings are consistent with prior scholarship indicating that augmented reality and place-based interaction can enhance environmental commitment (Georgiou & Kyza, 2017; Coen et al, 2019). Likewise, games such as F1 Clash, which blend real-world themes with tactical gameplay, were associated with more frequent expressions of motivation and action. Conversely, titles characterised by casual or arcade-style mechanics, such as Subway Surfers, were less

frequently linked to pro-environmental dispositions. This divergence suggests genre-specific affordances may either enable or constrain the player's sense of agency, connection to real-world issues, and perceived relevance of climate messaging.

4.7 Answering our Central Research Question "Can Digital Games Function as Effective Communication Channels Between Citizens and Policymakers?"

This case study demonstrates several methods for facilitating information exchange, notably embedding surveys within gameplay to capture real-time citizen feedback on climate issues. By using interactive, global platforms, Play2Act provides citizens a space to voice concerns and policymakers access to this data. However, the challenge remains in translating this data into actionable policy changes, as clear pathways to policy influence are not yet evident. Additionally, digital games can offer significant affordances for informing policy by engaging large, diverse audiences and enabling policymakers to access extensive citizen feedback. However, the case study reveals that while this feedback is valuable, it does not always translate into actionable policy insights. To enhance effectiveness, the methodology must be more closely integrated with existing policy frameworks, and longitudinal data tracking should be implemented to capture evolving citizen preferences over time.

5. Conclusion and Limitations

This study illustrates both the potential and limitations of integrating surveys into gaming. While response rates were high (90.7% answered the first question, 77.2% completed the survey), overall participation remained low, with only 15.2% of those who viewed the introduction completing the survey. This highlights gaming's broad reach but also the challenge of converting passive exposure into active engagement. Despite its strengths, the study had limitations. The structured survey format restricted insight into player motivations, and self-selection bias likely skewed responses toward those with existing pro-environmental attitudes. Additionally, some players may have viewed the survey as an interruption, raising concerns about data integrity. Future studies should incorporate qualitative methods to capture deeper perspectives. Findings suggest climate engagement varies by region, socioeconomic factors, and gaming context, though statistical analyses indicate weak correlations. While Africa and the Americas showed greater optimism and Asia and Oceania more scepticism, broader socio-political influences appear more significant than gaming itself. Although gaming can raise awareness, its measurable impact on behaviour remains limited. To enhance effectiveness, developers should embed climate policy education into gameplay, while policymakers should integrate digital media into broader environmental strategies. Research should prioritise longitudinal studies and cross-regional comparisons to refine gaming's role in climate advocacy. Without these targeted efforts, games will remain valuable for awareness but insufficient for driving lasting behavioural change.

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PhD Research Papers

Towards a Tasks-Interactions-Environment (TIE-SSG) Framework Guiding Integration of Serious Games in Education for Enhanced Practical, Clinical Competences

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Abstract: Clinical skills training is essential but resource-intensive for both educational programs and clinical placement settings. While simulations and serious games (SSGs) show great potential in alleviating skill-training challenges by enabling flexible, interactive, and engaging learning situations in safe environments, difficulties remain in moving beyond their basic implementation and use. The aim of this study is to explore and conceptualize the key elements that form the basis for the proposed Tasks-Interactions-Environment of Simulations and Serious Games (TIE-SSG) Framework. This work aims to initiate discussions and generate ideas that can inform future efforts in developing and refining the proposed framework. The TIE-SSG framework is grounded in instructional scaffolding, and through consideration of these theories and an examination of previous literature, the fidelity (i.e., how closely a scenario or tool mirrors real-world conditions) of the SSGs was chosen as the key factor for the framework. The fidelity term is examined and redefined specifically for introducing SSGs in the context of teaching and learning, and is broken down into three dimensions: tasks, interactions, and environment. The paper illustrates the benefits of examining the fidelity of these dimensions separately, to help place SSGs within the students' learning pathway in a progressive manner. This approach enhances the understanding of how fidelity impacts learning outcomes and provides valuable insights for designing practical learning tools. Future research will further explore how this framework can be applied across diverse educational contexts.

Keywords: Education, Practice-Based training, Simulations, Serious games, Clinical skills and procedures, Learning pathway, Instructional scaffolding, Framework, Fidelity

1. Introduction

Simulations and serious games (SSGs) have shown great promise to support practice-based training (e.g., Mann et al., 2021). SSGs provide learning experiences that are interactive, flexible, varied, and can adapt to the different students' abilities (Ye et al., 2019). It is already demonstrated that SSGs can provide safe training opportunities for providing care to unique-needs patients and contexts (e.g., Scalese et al., 2008). Learning through failing is also a powerful mechanism, made possible through the use of SSGs (Nome, 2022).

Integrating clinical skills training on campus and supervised practice-based training into the learning design of healthcare education is vital, although it is both resource- and time-intensive. Today's education faces challenges in providing sufficient training opportunities due to limited access to real-world settings, time constraints, lack of teaching resources, and restricted availability of equipment. Hence, increasing supervised clinical placements or expanding skills training on campus is not a feasible or sustainable solution. While several educational courses and modules focus on hands-on experience, particularly for learning clinical procedures, these are often challenging to integrate into a traditional curriculum (Mann et al., 2021. As more training would not only enhance the physical and coordinated movements required to perform the task (fine motor skills) but also build confidence, consistency, and adherence to best practices (Arslan et al., 2018), it is important to investigate potential technological solutions to the challenge. Present day SSGs promise to provide high (believable) user experiences and support learning of clinical procedures using a range of technologies, from specialized advanced tools to more widely available devices. There is a wide variety of SSGs, often comprising a range of tools and technologies, making it challenging to decide which one(s) to use, and how to use them, as well as other factors such as considering continuous maintenance for it (e.g., Frøland et al., 2020), application availability, development costs, and creative design (Wang et al., 2014), cognition and presence (Wijkmark et al., 2021), as well as learning goals, content, and societal aspects (Mann et al., 2021).

The aim of this paper is to explore and conceptualize key elements that could form the basis for developing a user-friendly framework that could assist teachers in selecting and implementing SSGs in teaching and learning. The proposed framework also seeks to consider key issues for the further development of suitable applications and provides an overview of essential characteristics of SSGs. The envisioned framework, named Tasks-

Interactions-Environment for Simulation and Serious Games (TIE-SSG), is based on existing frameworks and learning models from current literature utilizing SSGs in education. The methodology considers these frameworks by applying an analytical lens focusing on fidelity for learning and experiences. The usefulness of the framework in education is demonstrated through an example of selecting and utilizing SSGs for practical blood sampling training (Frøland et al., 2025).

2. Background

2.1 Instructional Scaffolding in Skills Training

Instructional scaffolding is a learning theory that concerns assisted guidance of learners, aiming to continuously provide them with tasks that are challenging but doable in order to foster development (Belland and Belland, 2017). The teacher plays an active role in the learning process of the student through means such as providing instructions, hints, and demonstrations. As the student progresses and can do more on their own, the guidance and support from the teacher can be gradually reduced, with the intention of keeping them in an ideal range of challenge. The latter has been coined the Zone of Proximal Development (ZPD) by Lev Vygotsky and is a key influence for instructional scaffolding (Masava et al., 2023). The idea of the ZPD is that the learner is faced with obstacles that are difficult, but achievable, and that the difficulty is gradually adjusted with the help of a teacher or technology. Learners can initially be presented with a situation of limited complexity and then have progressively more complex situations added. Figure 1 shows how the student utilizes various learning resources, including lectures, books, skills training, and SSGs, as part of a learning path facilitated by teachers.

Instructional scaffolding is a well-established principle demonstrated in studies on learning clinical competencies (Masava et al., 2023, Miller, 1990) and in research advocating for SSGs, such as those utilizing virtual laboratories (Ali et al., 2022). Due to the complexity of the student-centered health science education programs, it is crucial to implement varied scaffolding approaches to support learning (Masava et al., 2022). Although instructional scaffolding strategies have been widely explored in general educational contexts, there is a limited understanding of how they can be effectively applied for SSGs in health sciences education.

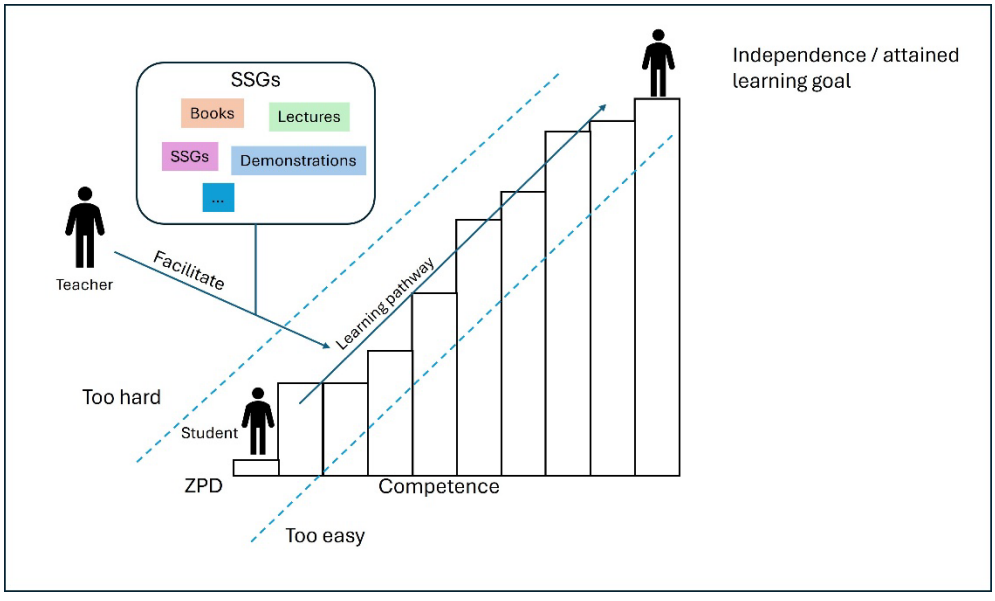

Figure 1: A model conceptualizing the learning environment

2.2 Towards a Framework for Implementing SSGs Through Instructional Scaffolding

Several studies pointed out that the implementation of purposeful use of virtual reality (VR) (e.g., Radianti et al., 2020) and SSGs (Tsekleves et al., 2016, Ravyse et al., 2017) in education is resource-demanding. If, when, and how learning technologies are implemented depends on the type of practices, organizational strategies, and actual policies (Fomin et al., 2024, Attewell, 1992, Badham, 1993). Chugh et al. developed a framework to guide teachers on implementing technology in higher education, incorporating several dimensions like type of technology, stakeholder perceptions, and academic disciplines (Chugh et al., 2023).

Table 1 summarizes the frameworks and models considered in this study.

Table 1: Frameworks and models influencing this study

Framework/Model	Year	Focus	Strengths	Limitations	Applications/Extensions
Technology Acceptance Model (TAM)	1989	Predicting and explaining user acceptance of technologies.	Widely used and adapted to various contexts, including e-learning (Ibrahim et al., 2017).	Inconsistent measurements and challenges in complex situations. Difficult to adjust to changing educational contexts.	Adapted for VR (Huang and Liaw, 2018) and serious games in education (Valencia and Duque, 2023).
Technological Pedagogical Content Knowledge (TPACK)	2005 (revised 2013)	Integration of technology into teachers' educational practices.	Conceptualizes three dimensions: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technology Knowledge (TK), along with their intersections. Helps teachers balance these dimensions for effective practice.	Lacks strategies or guidelines for selecting and using technologies.	Adapted for VR (Polikarpus et al., 2023).
Kirkpatrick's Model	N/A	Differentiates four levels of VR use for learning: user reactions (L1), learning support (L2), behavior change (L3), and societal impact (L4).	Highlights the importance of broader outcomes, from user experience to societal impact.	Connections between the levels in higher education are difficult to establish.	Applied to VR learning, originally developed in 1959 (Alsalamah and Callinan, 2022) and adopted to VR from 1994, according to our knowledge.
TPACK-G (Technological Pedagogical Content Knowledge Games)	2013	Integration of games into teachers' educational practices.	Introduces game-specific dimensions: Game Knowledge (GK), Game Pedagogical Knowledge (GPK), and Game Pedagogical Content Knowledge (GPCK). Proficiency in lower dimensions supports higher-level competence.	Does not provide specific steps on how to integrate games into education or when to use them.	Focused on serious games and educational gaming practices (Hsu et al., 2013).
CAMIL	2021	Learning in VR	Defining important cognitive aspects supporting learning	Does not directly assess games and gamification aspects and implementation for technologies.	Adapted for health and clinical education, laboratories (Makransky and Petersen, 2021)

The models and frameworks described in this paper are well known and are also customized to new technologies, in particular for VR and SSGs considered in this study. For example, TAM for VR (Huang and Liaw, 2018) and for serious games in education (Valencia and Duque, 2023), or TPACK for virtual reality (Polikarpus et al., 2023). Hsu et al. proposed the TPACK for games (TPACK-G) framework, focusing on integrating games into teachers' educational practices (Hsu et al., 2013).

2.3 The Role of Fidelity for Simulations and Serious Games

The goal of SSG-based training is to provide high-quality experiences that enable learners to achieve their learning goals. The degree to which these applications provide realistic and satisfactory experiences varies. This section will explore the role of fidelity in delivering high-quality experiences, drawing on influencing theories about fidelity (see Table 2).

Table 2: Overview of papers considering fidelity and influencing this study.

Author(s)	Year	Focus/Definition of Fidelity	Key Findings/Recommendations
Alessi	1988	Fidelity as the accuracy of a simulator replicating the real environment.	Commonly cited definition highlights the importance of realism in simulation training.
Brydges et al.	2010	Progressive increase in realism through instructional scaffolding.	Progressive realism led to superior transfer of a broad range of clinical skills in simulation-based training.
Hamstra et al.	2014	Reevaluated "fidelity" in simulation-based training.	Recommendations: (1) Abandon the term "fidelity" (due to imprecision). (2) Focus on functional task alignment over physical resemblance. (3) Enhance methods to improve learning transfer.
Tun et al.	2015	Fidelity is based on real-world cues and stimuli instead of complete realism.	Proposed three fidelity dimensions: patient, clinical scenario, and healthcare facilities. Highlighted inconsistencies in fidelity terminology and its implications for healthcare education.
Massoth et al.	2019	Comparison of low-fidelity (LF) vs. high-fidelity (HF) simulators for advanced life support.	Both LF and HF groups showed significant improvement in theoretical knowledge. No significant performance differences were observed between the groups.
Ye et al.	2020	General Conceptual Framework of Fidelity (GCFF).	Framework divides fidelity into three dimensions: sensory, conceptual, and psychological fidelity, emphasizing better clarity and assessment of fidelity in applications, especially in VR contexts.
Carey & Rossler	2023	Multi-dimensional fidelity concept, tied to realism in simulation.	Warned against the "fidelity trap," where higher fidelity is assumed to inherently provide better learning. Emphasized meaningful use of realism and the importance of refining fidelity for simulation pedagogy.
Bonfert et al.	2024	Interaction Fidelity Model (IntFi Model).	Introduced a granular definition of fidelity levels and the relationship between the user and the simulation system. Argued that deliberate reduction of fidelity could sometimes be beneficial for learning outcomes.

Alessi's definition of fidelity, which emphasizes how accurately a simulator replicates the real environment, is frequently referenced (1988). There are many investigations into the role of fidelity in training. Brydges et al. performed a study where they investigated an approach to physical simulation-based training with a progressive increase in realism based on instructional scaffolding (Brydges et al., 2010). The results showed that the progressive group had “superior transfer of a broad range of clinical skills”.

In their 2014 paper, Hamstra et al. examined existing literature and reevaluated the use of the term “fidelity” in the context of simulation-based training. They provided three recommendations:

“#1: Abandon the term fidelity”,

“#2: Shift emphasis from physical resemblance to functional task alignment”, and

“#3: Focus on methods to enhance transfer of learning.”

To effectively use SSGs as learning tools, they must align with curricular learning goals. This can occur directly, such as through a realistic simulation that allows students to practice blood sampling. However, as learning theory suggests, training situations should challenge learners by pushing them slightly beyond their current capabilities without causing cognitive overload. The concept of fidelity has been proposed as a measure of how advanced an SSG application or system is. In previous studies, fidelity is often considered as a simple binary or two-dimensional scale, ranging from low to high (Bergmann et al., 2023). While this approach may offer some utility, it oversimplifies the complexity of SSGs, which rely on diverse software and technologies. Therefore, a more nuanced framework is needed to capture the multifaceted nature of fidelity in SSG design and its impact on learning outcomes.

3. Towards Developing a Framework Considering Fidelity by a Student-Centered Approach

The potential for integration of learning theories to guide the placement of SSGs and related technologies within students' learning pathways highlights the need for a structured framework. Such a framework should support a student-centered approach with the overall focus upon the student's progression toward achieving learning goals (Figure 1). Grounding a framework in instructional scaffolding ensures its practical utility in effectively incorporating SSGs into learning environments. While fidelity has been addressed in previous efforts, it is often ambiguously defined or disconnected from its application to learning. For fidelity to hold meaning, it must be clearly defined and aligned with the tool or context in which it is applied.

We propose redefining fidelity in this context as follows: "*Fidelity is the degree to which the SSG application and tool mimics aspects relevant to achieving the learning goal."* This definition emphasizes a student-centered and learning-goal-oriented approach.

The proposed definition of fidelity represents a shift from traditional definitions, which often focus on the degree of realism or physical resemblance to real-world environments. This redefinition aligns fidelity with instructional scaffolding. Increased fidelity corresponds to the academically relevant complexity while maintaining a focus on enhancing the student's learning experience. This learner-centered definition of fidelity provides a foundation for a framework that relies on learning theories, ensuring alignment between learning goals and a progressive, scaffolded approach to skill acquisition.

4. The Task-Interaction-Environment (TIE-SSG) Framework

The Task-Interaction-Environment (TIE-SSG) Framework is structured around three dimensions: (i) Tasks, (ii) Interactions, and (iii) Environment. Recognizing the significance of each dimension, we propose examining them separately (see sections 4.1-4.2) to evaluate their suitability for achieving the learning goals within a curriculum. Focusing on the dimensions of tasks, interaction, and environment (TIE) is essential, as an SSGs levels of fidelity can vary across each dimension which impacts its potential use. The dimensions of the framework are relative to the identified learning goals. This distinction sets the framework apart from previous Figure .

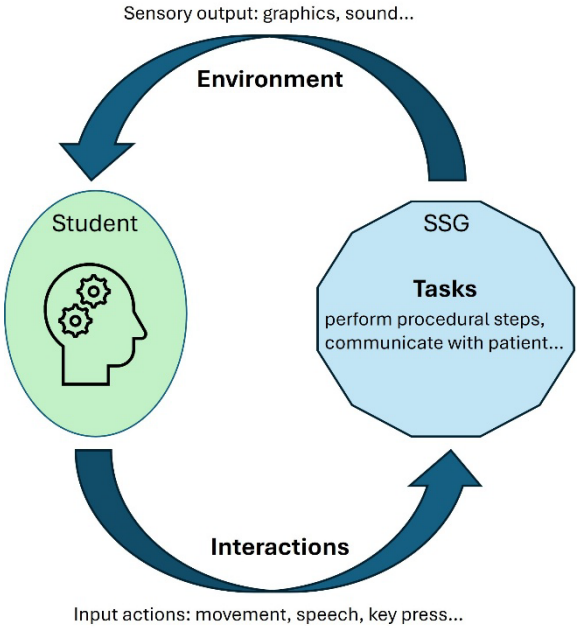

Figure 2: Model depicting the connections between the student and the SSG

4.1 Tasks – and Fidelity

Tasks can be divided into (i) user tasks (actions the learner performs during SSG use) and (ii) SSG-Generated Tasks (tasks designed by the SSG to guide learning) - to fulfil the objective.

User tasks in SSGs involve the specific actions learners perform to engage with the learning environment and achieve objectives. These tasks include executing predefined actions, applying skills in realistic scenarios, solving

problems, making decisions, assessing feedback, and role-playing to simulate professional responsibilities. Collaborative tasks are emphasized when the SSG involves teamwork to complete the objective. Assessing feedback is a critical user task in SSGs, requiring learners to actively process and reflect on the information provided by the system, involving understanding successes, identifying errors, and applying necessary corrections to refine performance. By engaging in feedback assessment, learners develop critical thinking skills as they analyze the feedback and make informed decisions to improve their actions, aligning this process with problem-solving and decision-making tasks. Furthermore, assessing feedback fosters the development of metacognitive skills, such as self-awareness and self-regulation, which are essential for mastering complex skills and improving overall learning outcomes. In the context of SSGs, feedback can be assessed in two primary ways: (1) Real-Time Feedback: Learners evaluate immediate feedback, such as performance scores or warning signals during gameplay, and adjust their actions dynamically. (2) Post-Task Feedback: After completing a task or scenario, learners review detailed feedback to reflect on their performance and plan improvements for future attempts. Assessing feedback serves as a crucial bridge between action and learning in SSGs, fostering iterative improvement.

SSG-generated tasks are algorithmically designed activities integrated into SSGs to guide learners through structured learning pathways (Makransky and Petersen, 2021, Mann et al., 2021). These tasks leverage system-driven mechanisms to deliver predefined objectives, adaptive challenges, and scenario-based assignments which can be dynamically tailored to user performance. Key features include progressive difficulty scaling, real-time feedback loops, and achievement tracking through milestone systems. By incorporating guided problem-solving algorithms and role-specific simulations, SSG-generated tasks enable personalized and data-driven instructional experiences

Fidelity in user and SSG-generated tasks: Fidelity is crucial for both user tasks and SSG-generated tasks. For user tasks, such as decision-making, problem-solving, and assessing feedback, high fidelity ensures realistic actions, accurate feedback, and authentic collaboration, fostering critical thinking, metacognitive skills, and practical application — all of which adhere strongly to the learning objectives. In SSG-generated tasks, fidelity focuses on adaptive challenges, realistic scenarios, and system-driven feedback that align with learning goals. By aligning fidelity in both user tasks and SSG-generated tasks, SSGs create immersive and compelling learning environments.

Table 3: Overview of the fidelity focus for each TIE-SSG dimension

Dimensions	Fidelity focus	Examples
Tasks (User)	The tasks performed by the user should mimic the cognitive and physical demands of real-world tasks, striking a balance between complexity and achievability. Task fidelity refers to the degree to which a user's actions align with real-world tasks.	A simulation that requires users to practice drawing blood requires high fidelity for both the physical and cognitive components of the task.
Tasks (SSG)	The tasks embedded in the SSG should align with real-world objectives, while allowing for functional fidelity, focusing on achieving learning goals without replicating every detail of the real world.	An SSG that gradually introduces more complex phlebotomy scenarios may not replicate every detail of an actual phlebotomy, but ensures learners understand the steps and logic needed to respond efficiently.
Interaction	Realistic user actions and feedback loops.	Phlebotomy simulations with realistic tool handling and feedback
Environment	Replicate the physical, visual, and auditory aspects of the real-world setting as closely as necessary for the learning objective.	An SSG for trauma alert at the hospital includes patient beds, medical equipment, and blood collection tools, as well as dynamic and high-pressure scenarios, time constraints, and teamwork and communication, in order to obtain the learning objectives.

4.2 Interaction and Environment – and Fidelity

Interaction

Interaction refers to the ways in which the user can decide, control, or alter the state of the game or simulation. Essentially, it represents the input options available to the user, such as selecting choices, manipulating objects, or navigating through scenarios. High fidelity in interactions means the user's actions closely mimic real-world behaviors or decision-making processes. This includes realistic feedback mechanisms, responsive controls, and intuitive interfaces.

Environment

This dimension consists of all sensory outputs provided to the user, including graphics, audio, and haptic feedback. Fidelity in an environment (environmental fidelity) refers to the degree to which it replicates the physical, visual, and auditory aspects of the real-world setting as closely as necessary to achieve the learning objective. While it could be beneficial to keep the fidelity in this dimension low at earlier stages, in order to reduce cognitive load and to utilize engaging game mechanics, it is crucial to provide high fidelity at the final stages of training to create an immersive and contextually relevant experience. Additionally, ensuring contextual relevance is important; the environment should gradually match the real-world application and align with specific learning goals. For example, replicating a hospital trauma ward for trauma alert training enhances both the authenticity and practicality of the learning experience, ensuring that learners develop the skills needed to meet their educational objectives.

5. Discussion, Current Limitations, and Future Works

The aim of this paper was to introduce the Tasks-Interactions-Environment of Simulations and Serious Games (TIE-SSG) framework. It builds upon key lessons from selected previous frameworks, introducing several novel aspects that make it both practical and learning-focused. First, the framework redefines fidelity by shifting the emphasis toward learning goals, diverging from traditional definitions such as Alessi's (1988). Unlike conventional approaches, the TIE-SSG framework places learning at the centre of fidelity, inspired by works such as Tun et al. (2015), who re-examined fidelity in the context of healthcare education. The framework goes further by explicitly addressing learning goals and aligning fidelity with them. Additionally, it builds on insights from Brydges et al. (2010) by supporting progressive learning but with a more refined focus on its dimensions, allowing for deeper analysis of how SSGs can be effectively utilized.

The TIE-SSG framework is designed to help teachers integrate SSGs into their teaching by providing a structured approach to analysing and reasoning about these tools. By doing so, it supports teachers in gaining deeper insights into SSGs and improving their TPACK level (Ye et al., 2019). A key challenge lies in the time investment required to evaluate SSGs. While this time investment can be justified as necessary for the effective use of any learning tool, it remains a practical consideration that must be taken into account.

Despite its promise, the framework has several limitations. Currently, the TIE-SSG framework primarily focuses on the simulated elements of SSGs and does not explicitly account for game elements. Expanding the framework to include game-specific elements and genres could offer additional value. For instance, varying the types of games suggested to students could provide diverse learning approaches and cater to different student preferences. Offering alternative games for specific steps within the learning pathway could also increase accessibility and engagement.

A systematic literature review of existing frameworks for selecting and using technologies would be valuable for further refining the proposed TIE-SSG framework. While there are reviews in this area, the integration of SSGs into education goes beyond technology acceptance and implementation. Additionally, while some learning goals can be measured objectively, others depend on subjective evaluations. Sharing assessments and feedback with others can help refine and improve these measures, enhancing the framework's utility.

Achieving the right balance of fidelity or aligning user tasks with learning goals cannot be resolved quickly and requires sustained evaluation and adjustment, as supported by Wand et al. (2014) which points out that difficulties are solved by observation over the long term. Moreover, achieving a balance between immersive user experiences and task-specific learning goals is a deliberate design choice. In the near future, the framework will be tested by teachers in ongoing courses and by closer collaboration between teachers and developers to explore how additional features, such as game elements for simulating target procedures, can be effectively integrated. Practical testing of the framework is expected to reveal new insights and areas for refinement, further enhancing its relevance and applicability to real-world teaching scenarios.

6. Conclusions

This paper introduces the initial steps toward developing the Task-Interaction-Environment for Simulation and Serious Games (TIE-SSG) framework, designed to help teachers evaluate and integrate SSGs into education. Rooted in instructional scaffolding as a learning theory, the framework emphasizes fidelity as a key factor, breaking it into its subdimensions focusing on tasks, interaction, and environment (TIE) to support a learner-centered approach. The TIE-SSG framework aims to align SSG usage with learning goals, support instructional

scaffolding, and enhance the teaching and learning of clinical skills and procedures while informing further application development.

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Tasks-Interactions-Environment for Simulations and Serious Games (TIE-SSG) Framework: Exploring Practical Applications

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Abstract: Simulations and Serious Games (SSGs) are increasingly recognized as effective and flexible tools for supporting education. Despite their potential, selecting and appropriately using SSGs within learning pathways remains a significant challenge. To address this, the Task-Interaction-Environment for Simulations and Serious Games (TIE-SSG) framework was developed. This framework is designed to evaluate and integrate SSGs based on their fidelity levels, while adhering to instructional scaffolding principles to achieve specific learning goals (Frøland et al., 2025). This paper introduces strategies for utilizing the TIE-SSG framework to evaluate and seamlessly integrate SSGs into educational curricula, particularly for healthcare education. It outlines a step-by-step guideline that emphasizes three key phases: (1) prerequisites, (2) assessment, and (3) integration. Supporting tools and templates are provided to standardize evaluations and facilitate the alignment of SSGs with learning objectives. The practical application of the TIE-SSG framework is demonstrated through a case study on teaching phlebotomy. The case study illustrates how the framework supports the systematic integration of SSGs into educational curricula. Specifically, the approach enables the comparison, selection, and alignment of SSGs with student learning objectives, ensuring their effective use in achieving desired educational outcomes. By providing a structured approach to evaluating and integrating SSGs, the TIE-SSG framework facilitates evidence-based decision-making in educational contexts. This systematic method helps educators align SSGs with learning goals, enhancing the overall effectiveness of their use in curricula. The framework offers a robust tool for addressing the challenges of incorporating SSGs into diverse learning pathways.

Keywords: TIE-SSG, Conceptual framework, Simulations and serious games, Instructional scaffolding, Learning goals, Phlebotomy

1. Introduction

Simulations and Serious Games (SSGs) have gained recognition as effective tools for supporting teaching and learning by creating engaging, interactive, and flexible educational environments (e.g., Backlund, Engström et al. 2017, Allcoat and von Mühlenen 2018, Radianti, Majchrzak et al. 2020). They are used in many educational domains, and since healthcare education faces a number of challenges their potential is widely investigated in the field, from nursing, medical education, to pharmacology, and patient care (Graafland, Schraagen et al. 2012, Sharifzadeh, Kharrazi et al. 2020, Fens, Hope et al. 2021, Xu, Lau et al. 2021). SSGs are addressing challenges in clinical skills training, which is resource-intensive and constrained by limited access to real-world settings, time, and equipment. They promise flexible, interactive, and engaging learning experiences in safe environments, allowing students to practice critical procedures, such as blood sampling, without compromising patient safety (Froland, Elsvær et al. 2019). These tools support learning through failure, confidence building, and enhancement of fine motor skills by utilizing accessible technologies such as mobile phones, computers, and VR headsets (Vlachopoulos and Makri, 2017). However, the wide variety of SSGs and their differing levels of fidelity make it challenging for educators to select and implement the most suitable tools (Rooney, 2012). Fidelity in SSGs has long been hypothesised to have an impact on learners, dependent on their proficiency level (Alessi, 1988). Many educators are not interested in exploring technological challenges and updates, though they would like to use SSGs and other technologies to make learning goals more engaging, with increased user experiences and involvement (Dimitriadou et al., 2021). A structured framework to guide the integration of SSGs into curricula is essential to ensure alignment with learning goals, optimize their use, and address practical constraints, such as development costs and maintenance.

A previous work (Frøland et al., 2025) introduced the Task-Interaction-Environment for Simulations and Serious Games (TIE-SSG) framework, a conceptual tool designed to help educators choose and integrate SSGs into structured learning pathways. The learning pathway is the process of educational activities that support students in achieving learning goals within a curriculum. The framework is built on considering fidelity as a compound of three subdimensions: Tasks, Interactions, and Environment, aimed at evaluating the usefulness of SSGs for supporting learning activities by using instructional scaffolding principles to support progressive student

development. Realistic depiction (high fidelity) often suggests easier and more intuitive usage to end-users and customers, although it can be challenging to ascertain the added value of technologies that allow higher fidelity.

The aim of this paper is to explore use of the TIE-SSG framework in practice; to assess, compare, and incorporate SSGs into teaching scenarios. By presenting step-by-step guidelines and giving illustrative examples, we aim to provide actionable insights for teachers and institutions seeking to maximize the potential of SSGs in education. The TIE-SSG framework is applied to a practical case study, identifying the main issues influencing the use of possible SSGs and integrating them into the teaching of the phlebotomy procedure, a standard procedure in many healthcare education programs. Through this example, we evaluate how the framework supports teaching practices by aligning SSG features with learning goals and facilitating collaboration through shared assessments.

The paper is organized as follows: Section 2 provides argumentations for studying the phlebotomy procedure, together with a review of relevant background literature, and includes a brief introduction to specific SSGs used as examples to demonstrate the application of the framework. In Section 3, we introduce the TIE-SSG framework, including descriptions of auxiliary tools and their usage, as well as an outline of a step-by-step guideline for assessing available or chosen SSGs. This Section also includes a proposal of methods for integrating these assessments into teaching practices. Section 4 presents a discussion of the material, and Section 5 concludes the paper.

2. Background

2.1 The phlebotomy Procedure: Aligning the Level of Fidelity to Learning Goals

To address the theory-practice gap in healthcare education and provide more suitable practice-based training (Dudley and Matheson, 2024), it is crucial to develop and evaluate strategies that better prepare graduates for professional roles. Practical learning is a crucial component in many educational programs, such as biomedical science (BMS) and other healthcare-related fields. Placing a student in a realistic environment where they must accurately perform all steps and demonstrate motor skills risks can already overwhelm them. To address issues difficult to practice in real-life contexts, it is essential to explore innovative approaches and tools that allow students to practice their procedural and technical skills. These tools are often computer-based simulation and serious games-based tools, with various degrees of fidelity (the accuracy at which reality is simulated) utilizing instructional scaffolding (Masava, Nyoni and Botma, 2022) where one can increase the complexity of the simulated environment and tasks and the level of fidelity, for increasingly advanced learning goals (Ali, Ullah and Khan, 2022; Frøland *et al.*, 2025), ensuring they are well-prepared for real-world scenarios.

SSG is one solution often used to address the barriers described for the theory-practice gap within biomedical science (Dudley and Matheson, 2024). SSGs are valuable tools for enriching the teaching and learning of topics with both low complexity (such as one clinical procedures) and high complexity (the clinical procedure in a clinical environment with several factors present). SSGs can contribute to varying the learning situations by providing engaging and interactive experiences in a wide range of forms. Virtual Reality (VR) can be used for highly immersive experiences where the student can gain a sense of being present in the virtual learning environment (Makransky *et al.*, 2020), SSGs on mobile phones are available at practically any moment, and games for PCs can be interactive and engaging (Frøland *et al.*, 2020).

While there are many potential benefits to employing SSGs into a teaching practice, it is not straightforward how and when to utilize a specific SSG for effective learning, nor how to best introduce multiple SSGs throughout a course. Likewise, when developing new SSGs, it can be challenging to identify what the gap is for the currently available ones. This paper focuses on SSGs for learning clinical procedures for phlebotomy, though many aspects of this procedure could likely be generalized to choosing and using SSGs in many other educational areas. In the current iteration, the simulation elements (depicting tasks, interactions and environmental contexts to real situations) of SSGs are in focus. Figure 1 illustrates the challenge for the teacher to help facilitate the use of SSGs in order to construct a learning pathway that keeps the student in the Zone of Proximal Development (ZPD), where the student is continually challenged according to their current level of competence.

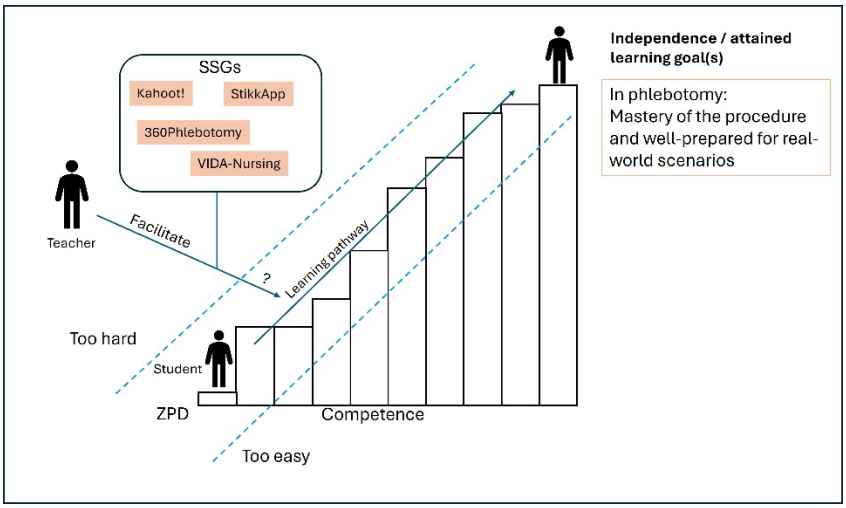

Figure 1: Illustration of the process of integrating SSGs into the student learning pathway towards phlebotomy mastery. Adapted from Frøland et al. 2025

2.2 Examples Demonstrating the Applicability of the TIE-SSG Framework

Kahoot is a widely used digital learning platform that supports active participation and interaction in classrooms, making learning more engaging and flexible. A meta-analysis of 43 experimental studies (Özdemir, 2025) shows that Kahoot has a moderate positive effect on academic achievement (effect size: 0.772) and a large positive effect on retention (effect size: 1.492) and motivation (effect size: 0.960). It also moderately reduces anxiety (effect size: −0.338) and improves attitudes toward learning (effect size: 0.678). These findings suggest that Kahoot can enhance student performance, foster engagement, and create a more supportive learning environment. Educators are encouraged to integrate Kahoot into their teaching strategies, particularly for improving retention and motivation. Regular use of Kahoot, alongside teacher training, can maximize its positive impact and support improved educational outcomes (Özdemir, 2025).

StikkApp is a Digital Game-Based Learning (DGBL) application (Frøland, Heldal, Braseth, *et al.*, 2022) designed to teach and support students in mastering the phlebotomy procedure (venous blood sampling). It provides an interactive platform for students to practice procedural steps, gain familiarity with equipment, and build confidence in performing the procedure. StikkApp also offers opportunities for repeated training and self-assessment, helping students reinforce their skills in a low-stress, simulated environment. By incorporating elements of serious games, StikkApp aims to enhance both learning outcomes and student motivation.

VIDA-Nursing v1.0 is an immersive virtual reality (VR) simulator for teaching vacuum blood collection in adult patients (Souza-Junior *et al.*, 2020). The simulator was designed to replicate 14 procedural steps. Assessments of VIDA focused on realism, interactivity, movement simulation, teaching potential, and user-friendliness (Souza-Junior *et al.*, 2020). The validation findings suggest that VIDA-Nursing v1.0 is a promising tool for enhancing phlebotomy education by integrating VR technology into the teaching of phlebotomy techniques (Souza-Junior *et al.*, 2020).

360Phlebotomy is a serious game in immersive virtual reality (VR) designed to help students become familiar with real workplaces while learning work tasks, particularly in biomedical laboratory science (BLS) education (Frøland, Heldal, Sjøholt, *et al.*, 2022). By combining virtual tasks with 360° images and videos of real laboratories, the game provides high-fidelity environments that replicate future work placements, reducing cognitive load and supporting task-focused learning. The phlebotomy process serves as the main case, with modular scene creation enabling the addition of new environments to prepare students for diverse placements. Insights from testing the prototype with five BLS teachers and six BLS students highlight the importance of realistic context in training and learning.

3. The TIE-SSG Framework

In this section, we present basic elements of the TIE-SSG framework necessary to understand its use in practical situations. The goal of the framework is to support the comparison and evaluation of SSGs for educational purposes.

The framework process is divided into three phases: Prerequisite, Assessment, and Integration. Figure 2 illustrates these phases along with their respective steps. First, *the prerequisite phase* involves steps that are performed as preparation for assessing SSGs. This means identifying learning goals through instructional scaffolding while being mindful of the fidelity dimensions for tasks, interactions, and environments, as outlined in the TIE dimensions (see Table 1). Afterwards, the teacher needs to fill out a table where they have to describe the most important aspects of each dimension that are relevant to the learning goals (see auxiliary tools, Table 2). The final step of this initial phase involves identifying potentially relevant SSGs, which can be achieved through existing knowledge, tips from other colleagues, internet searches, or other appropriate ways.

Second, *the assessment phase* begins. This is the phase where each of the identified SSGs are assessed with the identified learning goals in mind. The first step in this second phase starts with the teacher filling out a table for the SSG (see auxiliary tools, Table 2), where the relation to each dimension is described, along with a description of the envisioned activity and a description of the SSG. The next step is to compare the SSG table with the table from the prerequisite phase to determine the fidelity levels of each dimension. The TIE diagram (see auxiliary tools, Figure 3) is then filled out to visualize all the dimensions for the SSG.

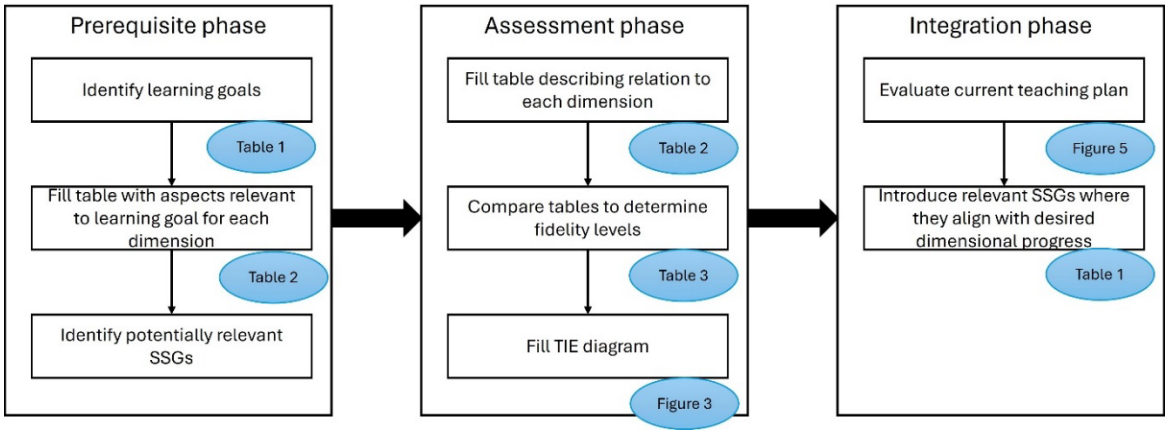

Figure 2: The three phases of the TIE-SSG framework, along with their respective steps. The figure also highlights auxiliary tools by referencing Tables 1–3 and Figures 3–5

Finally, the integration phase can begin. The first step of this final phase is to evaluate the current teaching plan, identifying the different scaffolding phases and their focus, in order to determine when it is best to introduce the specific SSGs. Finally, the SSGs are incorporated into the teaching plan to support learning goals.

Assessing SSGs to determine when to introduce them into the students' learning pathway involves several steps. A part of this decision can be supported by examining the different combinations of fidelity levels an SSG has, and how that informs us about what it could be suitable for in terms of learning. In Table 1 we provide an overview of how combinations of dimension levels can be judged in relation to their potential learning outcomes when looking at the extreme ends of the TIE dimensions. Although there are variations in these categories, they represent the major classifications that SSGs can be categorized into according to their TIE dimensions.

Table 1: Description of what can be learned from an SSG when at extreme ends.

Tasks	Interactions	Environment	Description
Low	Low	Low	Knowledge
Low	Low	High	Getting to know the environment and equipment
Low	High	Low	Motor skills
High	Low	Low	Procedural steps
Low	High	High	Contextual motor skills
High	Low	High	Contextual procedural steps
High	High	Low	Procedural steps and motor skills
High	High	High	Demonstrating knowledge, executing motor skills, and performing procedural steps in a realistic context

3.1 Auxiliary Tools for Assessment

In this section, we provide tools for assessing each SSG in relation to the TIE dimensions. The application of the tools is described stepwise in Section 3 and illustrated in Figure 2.

Table 2 serves as an auxiliary tool, allowing teachers to fill in and describe aspects of each dimension that are relevant to the learning goals.

Table 2: Fillable table for fidelity dimensions (for each SSG)

Dimension	A short description of the SSG	Fidelity
Tasks	An evaluation of the task fidelity in relation to the learning goals.	N/L/M/H
Interactions	An evaluation of the interaction fidelity in relation to the learning goals.	N/L/M/H
Environment	An evaluation of the task environment in relation to the learning goals.	N/L/M/H

*Abbreviations: None (N), Low (L), Medium (M), and High (H).

Table 3 serves as an auxiliary tool by providing a simple and structured guide to assess the fidelity of SSGs across the dimensions of Environment, Interactions, and Tasks. It provides clear criteria for distinguishing between high, medium, and low fidelity, enabling users to evaluate how closely an SSG aligns with real-world scenarios.

Table 3: Guide to fidelity levels

	Environment	Interactions	Tasks
High fidelity	The total sensory impression of the environment **closely** resembles that of the real environment.	The ways in which the user can interact with the SSG **closely** resemble those in a real case.	The tasks that the user can carry out in the SSG are **closely** tied to what would be done in a real case.
Medium fidelity	Several aspects resemble those of the real environment **quite well**.	The available interaction methods mimic real-life situations **quite well**.	Tasks that can be carried out relate **quite well** to real-world scenarios.
Low fidelity	**Few** aspects are experienced as in the real environment.	Interaction methods **somewhat** resemble real life.	Available tasks are similar to those in real scenarios to a **small** degree.

A TIE diagram (Figure 3) is then filled out to visualize all the dimensions for the SSG. The TIE diagram helps visualize the fidelity levels of the dimensions relative to the learning goal(s). The sector for each dimension is filled out according to the fidelity level. By filling only the outermost sub-sector, it is indicated that the dimension has a low fidelity level, adding the middle sub-sector indicates a medium fidelity level, and adding the innermost sub-sector indicates a high fidelity level. Filling none of the sub-sectors indicates that the dimension has none or very few similarities for that dimension.

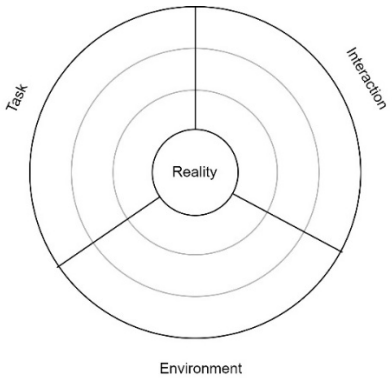

Figure 3: A model depicting the TIE dimensions

Combining all of the elements, we have a template for assessing an SSG (with an added screenshot of the SSG), as shown in Figure 4.

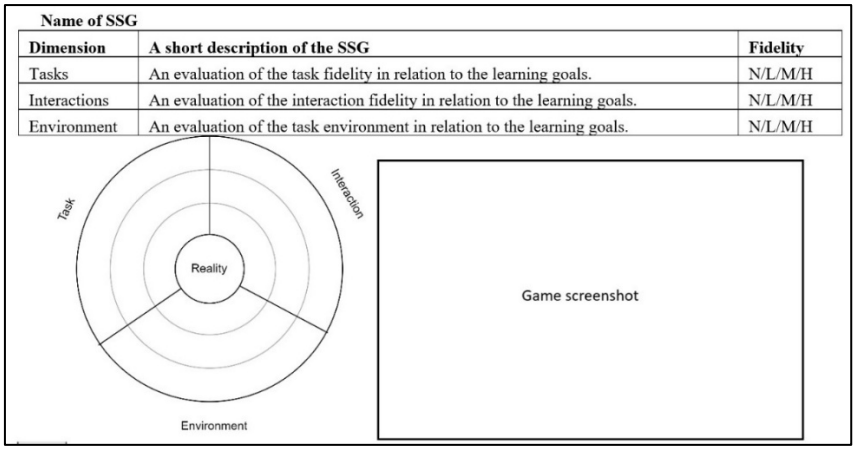

Figure 4: Template for assessing SSGs

4. Application of the TIE-SSG Framework: An Example

To illustrate how the framework can be applied, we will now provide an example of the blood sampling procedure, with each step detailed in a separate subsection.

We have chosen the phlebotomy (venous blood sampling) procedure as an example of how the TIE-SSG framework can be applied, as it is a standard procedure in many educational settings that requires hands-on training to develop the knowledge and skills necessary for practicing phlebotomy in various future contexts within their professional roles (Ialongo and Bernardini, 2016).

Phlebotomy is a key competency for various healthcare professions, but it remains a resource-intensive activity that often faces challenges in organizing sufficient training sessions. Errors in blood analysis frequently arise from pre-analytical mistakes, not only related to motoric mistakes, but also including procedural mistakes like improper handling of sample tubes, patient misidentification, and incorrect labelling of samples (Mary A *et al.*, 2023). Mastery of the procedure requires a combination of theoretical knowledge, effective communication with the patient, understanding the steps of the procedure, motor skills to physically execute it, and consideration of ethical issues.

4.1 Prerequisites

4.1.1 Instructional scaffolding and learning outcomes in phlebotomy training

Phlebotomy is a vital healthcare procedure that requires a blend of theoretical understanding, practical skills, and real-world application. Instructional scaffolding offers a structured learning process, guiding students from foundational knowledge to independent practice in clinical settings. This approach can be divided into four progressive stages for the phlebotomy (Figure 5): (i) Building theoretical knowledge, (ii) Procedural knowledge and skill application, (iii) contextual learning, and (iv) Clinical placement with authentic practice (real-world settings).

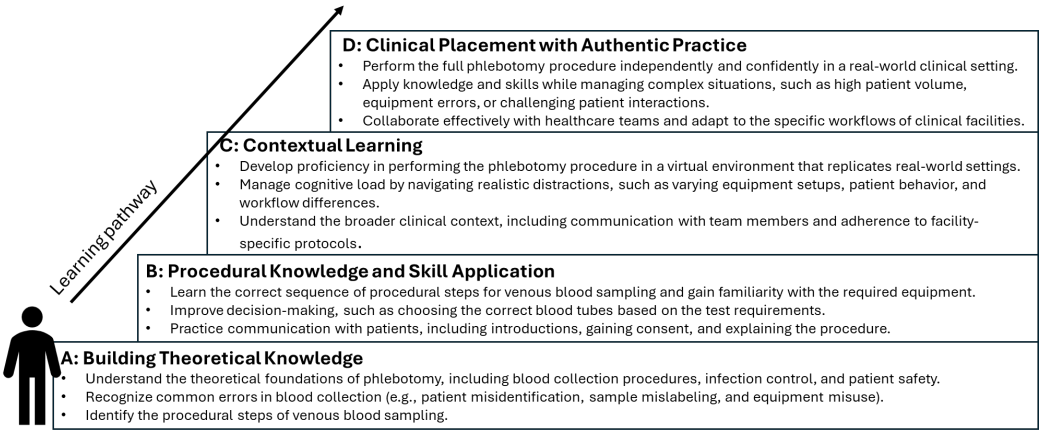

Figure 5: Learning outcome descriptions for instructional scaffolding of phlebotomy

4.1.2 Fill in the table containing the relevant aspects of each dimension

To assist in the assessment process, Table 4 (auxiliary tool, Table 2) is filled out to serve as a baseline for comparison.

Table 4: Relevant aspects of each TIE- dimension for the phlebotomy procedure

Dimension	Relevant aspects
Tasks	Carrying out a blood sampling procedure, including both knowledge and motor skill aspects. This includes communication with the patient, selecting the correct equipment, using the equipment correctly and in the correct sequence, physically inserting the cannula and drawing blood into blood tubes, labeling the samples and handling them properly, disposing of hazardous materials, and implementing safety measures.
Interactions	Relevant interactions include verbal communication and spatial interaction with the environment using hands.
Environment	A clinical setting, such as a hospital outpatient phlebotomy department or a doctor's office. All necessary equipment is available. A human patient is placed in a chair or a bed.

4.1.3 Identify potentially relevant SSGs

Through a review of relevant literature and previous experience, we have identified potentially relevant SSGs. These are described in section 2.2 and include Kahoot, StikkApp, VIDA-Nursing v1.0, 360Phlebotomy (Souza-Junior et al., 2020; Frøland, Heldal, Braseth, et al., 2022; Frøland, Heldal, Sjøholt, et al., 2022; Özdemir, 2025).

4.2 Assessment of SSGs

In the following, we evaluate SSGs where we fill out the TIE table (auxiliary tool, Table 2) and TIE diagram (auxiliary tool, Figure 3).

Kahoot

Activities	Use Kahoot quizzes to assess students' procedural knowledge, such as the sequence of blood sampling steps or safety protocols. Include collaborative and competitive sessions to engage students and enhance their retention.
Description	A quiz-based multiplayer game where players are scored based on speed and correctness. A tool for reinforcing theoretical knowledge through quizzes and interactive learning sessions.
Tasks	The player must answer questions related to the learning goals in stage A (Figure 5).
Interactions	The player clicks buttons and navigates menus with a mouse or touchscreen with no direct relation to the learning goals.
Environment	The player interacts with a 2D interface with no relevance to the learning goal.

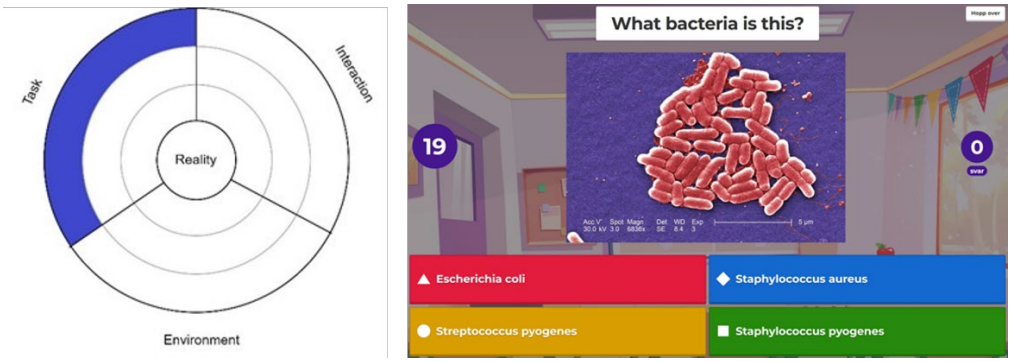

Figure 6: The TIE diagram and screenshot of Kahoot (Kahoot, 2025)

StikkApp

Activities	Use StikkApp to simulate step-by-step procedures, including vein selection, equipment handling, and patient communication. Perform self-assessment tasks in the app to evaluate procedural accuracy and identify areas for improvement.
Description	A 2D single-player game where one goes through the different parts of the blood sampling procedure. A serious game for procedural practice, focusing on task sequencing and patient interaction in a simulated environment.
Tasks	The player performs tasks, including selecting equipment, reading requisitions, and completing most, but not all, of the tasks for blood sampling, aligning well with the learning goals of Stage B (Figure 5).
Interactions	The player primarily uses a mouse or touchscreen to click on objects and navigate menus, while additional actions, such as dragging labels onto the tube and rotating the tube after sampling, add some fidelity to the interactions.
Environment	The player interacts with a 2D interface that is relevant to the learning goal, featuring images and videos of equipment and various procedure components.

Figure 7: The TIE diagram and screenshot of StikkApp (Frøland et al., 2022)

VIDA

Activities	Navigate a VR environment and practice a phlebotomy procedure from start to finish.
Description	A 3D single-player game that guides players through the various stages of the blood sampling procedure.
Tasks	Focus on learning procedural steps and executing tasks effectively.
Interactions	The player interacts with the virtual environment through motion capture of head and hands, though haptic feedback is missing.
Environment	Limited contextual realism emphasizes core procedural skills rather than complete clinical workflows.

Figure 8: The TIE diagram for VIDA (Souza-Junior et al., 2020)

360Phlebotomy

Activities	Navigate 360°-VR environments in clinical settings, practicing the full phlebotomy procedure from start to finish. Work through realistic workflows, including patient communication, navigation of work environments, and proper labeling.
Description	A VR singleplayer game based on 360°-video where the student can explore a virtual laboratory, take part in a virtual blood sampling session and carry out a blood sampling round at the local hospital.
Tasks	Many relevant tasks are included, such as navigation in a clinical environment, information gathering, and performing procedural steps.
Interactions	The player interacts with the environment through motion tracking of the head and hand controllers. Actions are taken by pointing and clicking with the hand controller.
Environment	Provides a visually immersive experience with 360° visuals of real environments and contextual workflows. Illustrates differences between university teaching laboratories and hospital environments.

Figure 9: The TIE diagram for 360Phlebotomy (Frøland et al., 2022)

Clinical Placement with Authentic Practice

Activities	Independent practice in real-world clinical settings under supervision. Students perform the complete phlebotomy procedure while managing complex scenarios, including high patient volumes, equipment malfunctions, or challenging patient interactions. They collaborate effectively with healthcare teams and adapt to the specific workflows and protocols of clinical facilities.
Description	A physical simulation setting where the students will perform the blood sampling procedure on patients under supervision.
Tasks	The tasks to be performed are the same as in a real case, according to the learning goals.
Interactions	The interactions are highly realistic.
Environment	The environment is almost indistinguishable from that of a real blood sampling situation, except for the presence of a supervisor.

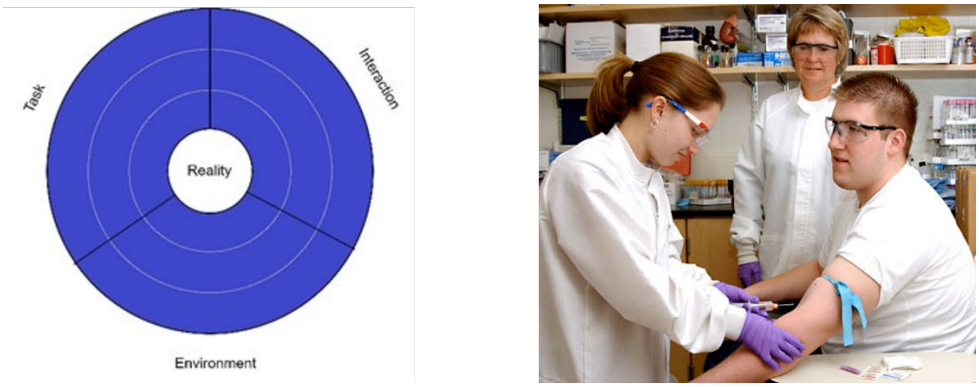

Figure 10: The TIE diagram and image of physical simulation in clinical settings (Delaware, 2005)

4.3 Integration

The TIE-SSG framework provides a structured approach to integrating SSGs into educational pathways by aligning fidelity dimensions with learning goals. By assessing the task, interaction, and environmental fidelity of each SSG, educators can strategically position these tools within a progressive learning path. Low-fidelity tools, such as knowledge-based quizzes, can support foundational learning, while moderate-fidelity tools focus on procedural knowledge, and high-fidelity simulations emphasize contextual learning and real-world application.

The framework facilitates instructional scaffolding by ensuring each SSG contributes meaningfully to the student's progression, from theoretical understanding to independent practice. Visual models and supporting tables within the framework enable educators to effectively evaluate and sequence SSGs, creating a learning pathway that balances complexity and student engagement. By using the TIE-SSG framework, educators can optimize the integration of SSGs to support student development and achieve targeted learning outcomes. Based on the assessments of the selected SSGs, a suggestion for stages where the SSGs would be valuable to introduce is presented in Figure 11.

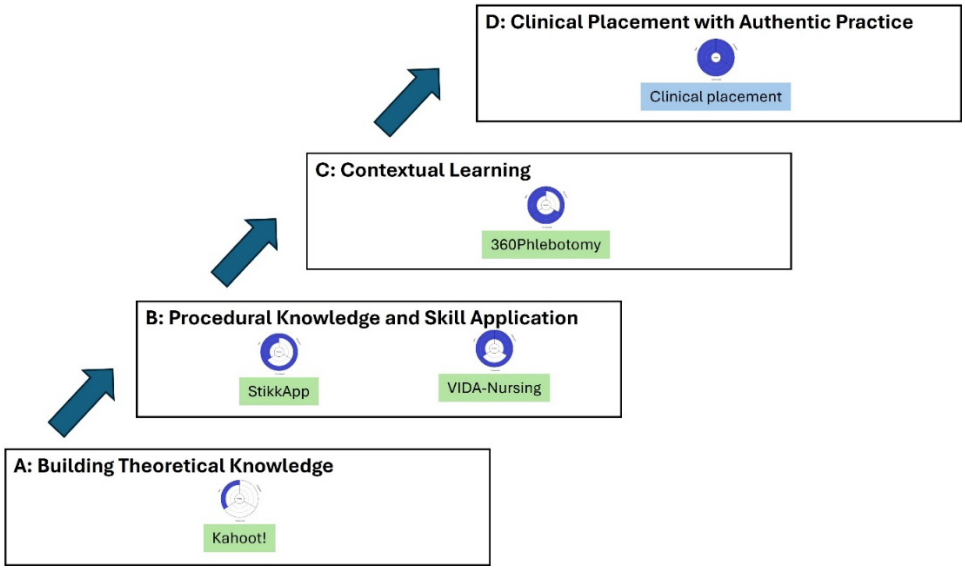

Figure 11: Placement of SSGs through the learning stages

5. Discussion

The TIE-SSG framework offers a structured approach for assessing the fidelity dimensions of SSGs across various stages of instructional scaffolding. When applied to tools like Kahoot, StikkApp, VIDA-Nursing, and 360Phlebotomy, the framework highlights their strengths and limitations in task, interaction, and environmental fidelity. For low-fidelity tools like Kahoot, the framework effectively positions them within foundational learning stages, where the development of theoretical knowledge needs to be emphasized. Moderate-fidelity tools like StikkApp and VIDA are well-suited for learning procedural skill development, where the benefits of the framework was for identifying and highlighting areas for improvement, such as enhancing contextual realism or interactivity when these are needed. High-fidelity tools like 360Phlebotomy excel in contextual learning, offering

immersive environments that prepare students for real-world clinical settings. By utilizing the TIE-SSG framework we were able to differentiate and motivate suitable SSGs for alignment with various requirements of training and learning phlebotomy.

Currently, the TIE-SSG framework is primarily focused on clinical skills and procedures. While it may have utility in other fields, adaptations may be required to ensure it fits different educational contexts. Additionally, SSGs are complex tools, and the current assessment method inevitably simplifies some aspects of their evaluation. This version of the TIE-SSG framework aims to strike a balance between including sufficient information for comparison without becoming overly detailed, while focusing predominantly on the simulated aspects of SSGs. However, certain elements, such as adaptivity, feedback, game mechanics, ethics, and communication, may warrant further consideration in future iterations. For example, game-like features may be more effective at early learning stages to enhance motivation, while higher fidelity resembling real-world scenarios becomes more crucial at advanced stages.

Despite its current limitations, the TIE-SSG framework offers valuable insights into aligning SSGs with learning goals and scaffolding stages, supporting educators in integrating these tools into progressive learning pathways. Future iterations of the framework could integrate additional dimensions, such as the role of game mechanics and learner motivation, to provide a more holistic evaluation of SSGs across diverse educational contexts.

6. Conclusions

This paper presents the TIE-SSG conceptual framework and demonstrates its application in an educational context, using the blood sampling procedure as an example. A step-by-step guide, along with tools for visualizing fidelity levels and analysing SSGs, was provided to support its implementation.

Future research should focus on testing the framework in further practical settings to evaluate its effectiveness and ensure its applicability. Expanding the framework to incorporate game mechanics and genres could enhance its utility. By refining and applying the TIE-SSG framework, teachers can more effectively integrate SSGs into their teaching practices and align them with educational goals.

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A Theoretical Model for Game Mechanics: Bridging Design Practice and Education

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Abstract: Game design decision-making involves navigating a complex space of possible mechanics, which presents a significant challenge both for professional designers and for educators seeking to teach the discipline effectively. While existing theoretical models frequently offer high-level conceptual frameworks, these often lack the granularity necessary to support the practical needs of designers who must identify, understand, and apply specific mechanics in diverse game development contexts. This research addresses that gap by outlining the utility of a structured theoretical model that compiles and organises hundreds of individual game mechanics, not only describing them but also demonstrating a practice-oriented rationale. The model has two primary aims: to assist designers in conceptualising and navigating the broad array of mechanical possibilities, thereby supporting creative ideation and analytical problem-solving; and to provide a robust and pedagogically effective foundation for game design education. A theoretical model could bridge the gap between abstract theoretical models and the practical demands of game design practice. A model such as the one described here would enable a more direct and effective translation of theory into practice, equipping designers with a more precise vocabulary and educators with a clearer pedagogical structure for explaining complex gameplay systems. By refining the connection between gameplay theory and design implementation, this research contributes to the evolving body of knowledge in game studies and design education, offering a new perspective on how mechanical complexity can be better understood, taught, and applied in creative contexts. The framework also opens new avenues for further research into game design patterns, player experience, and curriculum development, reinforcing the central role of mechanics in shaping both game systems and player engagement.

Keywords: Game design, Game mechanics, Digital games, Gameplay

1. Introduction

Digital games are complex artefacts whose development involves a range of disciplinary fields, including art, technology, and usability. Among these, game design occupies a central position. Professionals working in this area are responsible for formulating the game's overarching vision, often in close collaboration with experts from other disciplines. However, their most fundamental responsibility (and the one over which they exert the greatest control) relates to the game's rules. The quintessential act of game design is the formulation of these rules (Schell, 2011).

From an academic perspective, it is useful to conceptualise game design as comprising two interrelated subfields. The first concerns the design process itself, encompassing activities such as prototyping, playtesting, and documentation (Novak, 2011). This subfield investigates how a game concept is developed. The second relates to knowledge about the game as an object and its relationship with the player: its properties, functions, meanings, and, most importantly, the experiences it enables. Comparatively, this second domain addresses what the game is intended to become. Lankoski and Holopainen (2017) describe this distinction using the terms design praxeology (the study of design practices) and design phenomenology (the study of the experiences elicited by designed artefacts). This study aligns with the latter: it constitutes an in-depth investigation into the knowledge surrounding the experiences that emerge from player-game interaction, with the aim of informing the most iconic function of the game designer — deciding which rules, or mechanics, are to be implemented.

The term game rules applies to all types of games, such as chess or football. In traditional games, adherence to rules is typically ensured by an external agent, such as a referee or the players themselves. In digital games, however, rules are generally pre-programmed and operate akin to physical laws within the virtual environment, being enforced automatically by the system. In this context, rules are frequently referred to as mechanics, a term that highlights the intrinsic and typically immutable functioning of the system. For the purposes of this study, the definition of mechanics follows that proposed by Hunicke, LeBlanc, and Zubek: "Mechanics are the various actions, behaviors and control mechanisms afforded to the player within a game context. Together with the game's content (levels, assets and so on) the mechanics support overall gameplay dynamics." (2004, p. 3).

A central responsibility of the game designer, then, is to determine which mechanics should be implemented. Designers are presented with a vast array of options. Would a game benefit more if the protagonist could fly, or

teleport? A key challenge in game design lies in navigating this extensive design space. This challenge invites us to reflect on what game designers know to make such decisions, highlighting the importance of maps and frameworks in organising knowledge for practical application. In this sense, investigating how to structure the knowledge that game designers need and use becomes an enquiry into the epistemology of game design. According to Lankoski and Holopainen (2017),

> *The game design epistemology is concerned with what kinds of knowledge game designers have and employ in their design practice. Investigations of explicit and implicit conceptual design frameworks and studies of how designers use examples from existing games to frame design situations are part of game design epistemology.*

This research is situated within the broader challenge of organising knowledge in game design, aiming to integrate diverse perspectives. However, the knowledge that requires structuring lies at the intersection of two other dimensions of design: praxeology and phenomenology. In this regard, the study aligns with a phenomenological approach, insofar as the knowledge under examination pertains not to the design process itself (e.g., prototyping or creative workflows), but rather to the nature of the game object and its interaction with the player—in other words, the player experience.

2. Game Design Patterns and Theoretical Model Structures

One of the established strategies for categorising game mechanics involves the use of game design patterns, as outlined by Björk and Holopainen (2005). The authors define game design patterns as “semiformal interdependent descriptions of commonly reoccurring parts of the design of a game that concern gameplay” (Björk & Holopainen, 2005, p. 34). These patterns are considered "semi-formal" because they are not exhaustive; rather, they are meant to be interpreted and adapted according to specific design contexts. The authors propose that each pattern be described using the following components: (i) name, (ii) definition, (iii) general description, (iv) modes of use, (v) consequences for player experience, (vi) relationships with other patterns, and (vii) references.

Their compendium includes over 160 design patterns, grouped into categories such as: (i) game elements, (ii) resource management, (iii) information, communication, and presentation, (iv) actions and events, (v) narrative and immersion, (vi) social interaction, (vii) goals, (viii) goal structures, (ix) game sessions, (x) mastery and balance, and (xi) metagame, replayability, and learning curves. While Björk and Holopainen’s contribution is notable for its breadth, the extensive list of patterns has led subsequent studies to narrow their focus to specific contexts — such as social network games (Lewis, Wardrip-Fruin, & Whitehead, 2012), first-person shooters (Hullett & Whitehead, 2010), or the analysis of so-called “dark” patterns, where design choices may conflict with player interests (Zagal, Björk, & Lewis, 2013).

This research contributes to the theoretical landscape by proposing the need of a model that foregrounds the designer’s perspective, examining the problem through the lens of mechanics while seeking conceptual bridges to the dimension of experience, which has received more extensive attention in other frameworks. Existing methods for organising mechanics include Schell’s (2011) structural approach in his chapter on game mechanics, as well as Samarasinghe et al.’s (2021) taxonomy of board game rules. This paper contends that a robust model should articulate the relationships between digital game mechanics and types of player experience, thereby supporting designers in both professional practice and educational contexts. The central research question may be framed as follows: Can a theoretical model that integrates digital game mechanics and dimensions of player experience enhance the understanding and teaching of game design?

3. Teaching the Design of Game Mechanics

The proposal of a theoretical model necessarily invites reflection on its application and utility. The value of such a model can be considered across two key dimensions: epistemological and pedagogical.

The epistemological dimension is informed by Lankoski and Holopainen’s (2017) conceptualisation of epistemology in design, referring to the ways in which knowledge is structured and evaluated in the field. In this sense, a theoretical model that organises knowledge of game design and gameplay offers scholars a new lens through which to interpret the digital game phenomenon. From this vantage point, knowledge is not direct but mediated — filtered through theoretical constructs that inform one’s perception and analysis.

Such models are instrumental to the maturation of the discipline. For instance, they can help identify which types of mechanics have been thoroughly investigated and which remain underexplored. They function as cartographic tools, enabling researchers to navigate the intellectual terrain of the field more effectively.

The pedagogical or didactic dimension of the model lies in its potential to structure how knowledge is communicated and taught. One illustrative moment in the first author's professional trajectory exemplifies this need. Following a curriculum revision of the Game Design course at Universidade do Vale do Itajaí (Brazil), a module entitled Theory of Gameplay was introduced, specifically to address the player's experience, with an emphasis on game mechanics. This module engaged with one of the four key dimensions necessary for understanding digital games, as proposed by Zagal (2008):

> *In addition to being able to able pick out elements of a game's design, it is important to understand how the interaction between these elements helps create a certain experience for the player. Understanding a game from this perspective is akin to being able to articulate why playing a game makes the player feel a certain way. From a game designer's perspective, this sort of insight and understanding is crucial when trying to map the design goals (I want the players to have this kind of experience) with a means of achieving those goals (I will use these elements, in these ways). (…) In summary, to better understand a game it is important to understanding its components, how they interact, and how they facilitate certain experiences in players.*

Since 2020, the first author has taught the module Theory of Gameplay, and this experience has underscored the challenges involved in organising scattered knowledge for pedagogical purposes. It has become apparent that this body of knowledge constitutes an emerging disciplinary field that demands greater coherence and structure. In this light, the theoretical model proposed may function as a conceptual map, delving deeply into selected areas while also indicating directions for future inquiry. Its pedagogical potential extends beyond the first author's individual teaching practice, offering a conceptual framework that could be employed in a variety of educational settings: short courses, undergraduate and postgraduate programmes, or professional development for practitioners in the games industry.

One of the major strengths of a model that organises knowledge lies in its capacity to structure the learning process for both educators and students. Zagal (2010) highlights the difficulties associated with learning about game design patterns in a field where knowledge remains fragmented:

> *Many game designers and professionals, noting the lack of a unified vocabulary for describing existing games and thinking through the design of new ones, have called for a design language for games (...) This calls have been answered in multiple ways. For instance, many of the proposed approaches focus on offering aid to the designer, either in the form of design patterns (...), which name and describe design elements, or in the closely-related notion of design rules, which offer advice and guidelines for specific design situations (...) The ever-growing size of collections of gameplay design patterns, design rules, or terminology can be daunting to students who may easily feel overwhelmed and not know from were to start. (Zagal, 2010, pp. 90-91)*

The challenge of teaching digital games is a relatively recent development. According to a study by Carvalho (2021), based on data from the Brazilian Ministry of Education (MEC), there are 4,116 undergraduate courses in Digital Games or Game Design in Brazil, the majority of which are offered via distance learning. The study indicates that this number reflects steady annual growth since approximately 2010, a time when such courses were still rare in the country. It is therefore evident that higher education in digital games remains in its infancy when compared to more established academic fields. Within this context, it is unsurprising that the teaching of one of digital games' most distinctive areas (gameplay) remains underdeveloped. This observation reinforces the need for robust theoretical models to support and structure the teaching and learning processes within the field.

4. Previous Models of Player Experience Possibilities

Among scholars, the analysis of experiential possibilities generated by games is notably diverse. Even when proposing more systematic frameworks for conceptual organisation, academic literature often neglects the role of specific game mechanics, focusing instead on broader constructs, referred to here as dimensions of player experience.

A seminal contribution in this domain is Caillois's Man, Play and Games (2017), originally published in 1961, well before the popularisation of digital games. Caillois identifies four dimensions of experience (which can also be

interpreted as types of games): agon (competition), alea (chance), mimicry (simulation), and ilinx (vertigo), along with a duality between ludus (discipline) and paidia (spontaneity). While Caillois offers detailed discussion of these six concepts and their interrelations, their practical application is left to the discretion of readers or game designers. Where can I find a list of mechanics that will foster the experience of competition, for instance? A significant gap remains in the literature: the absence of a theoretical model that systematically integrates digital game mechanics with dimensions of gameplay experience — one that articulates how abstract principles can be operationalised in concrete design decisions.

Another influential work, particularly within the domain of digital games and learning, is the chapter by Malone and Lepper (1987). Although focused on educational games, the authors propose a taxonomy of elements that stimulate intrinsic motivation, including challenge, goals, uncertain outcomes, self-esteem, curiosity (both sensory and cognitive), control and power, agency, choice, fantasy (endogenous and exogenous), cooperation, competition, and recognition. Their work inspired further models linking game mechanics to learning outcomes, such as that of Arnab et al. (2015), who mapped game mechanics from the literature to corresponding educational objectives.

Also within psychology, though approaching from a motivational rather than pedagogical perspective, Przybylski, Rigby, and Ryan (2010) proposed a motivation model for digital games. Drawing on self-determination theory, they argue that motivation in gameplay stems from the fulfilment of three core needs: competence, autonomy, and relatedness.

An important source of knowledge in this field comes from books authored by industry professionals. Notable examples include works by Novak (2011), Rogers (2012), Schell (2011), and Schuytema (2008), as well as the work by Martinho, Santos, and Prada (2014). These texts are meant for an audience of practitioners, thus their reflections on game mechanics are typically empirical and fragmented, lacking a consistent framework to systematise knowledge. Even Koster (2013), who sought to formulate a theory of fun in games, did little to advance the organisation of concepts and mechanics into a coherent structure.

Among professional designers, Schell (2011) stands out for proposing a clearer categorisation of design elements: (i) space, (ii) objects, attributes, and states, (iii) actions, (iv) rules, (v) skill, and (vi) probability. This classification was later developed by Wang and Huang (2021) in their model for serious game design. Schell's contribution is notable for its theoretical ambition: he presents his categories not merely as pedagogical aids, but as a taxonomical model intended to organise knowledge about games. Other authors, by contrast, use similar categories simply to structure their discussions, without proposing that these could serve as a general framework for understanding gameplay across contexts. As such, their classifications often appear arbitrary or lack internal coherence.

In similar lines, Fullerton (2008) describes formal elements of games as goals, procedures, rules, resources, conflict, boundaries, and systems—a taxonomy akin to that of Crawford (2003), who categorises elements as play, challenges, conflicts, and interaction. Schuytema (2008) introduces the concept of "atoms" as essential principles common to all game genres. These include abstract concepts such as clear goals, agency, coherent interfaces, and understandable contexts. The book offers numerous examples (e.g. nested victories, rest points, comeback mechanics, varied challenges), without establishing a systematic categorisation. Brathwaite and Schreiber (2009) adopt multiple classificatory strategies, such as "atoms" (mechanics, dynamics, goals, themes), types of challenge (e.g., puzzles, lateral thinking, spatial intelligence, strategy), but again without a cohesive taxonomy of mechanics. Rogers (2012) structures his material around the "3 Cs": character (and abilities), camera (view perspective), and control (input method), adding a chapter on HUD elements. While some mechanics are described, the classification lacks systematicity. Novak (2011) is somewhat more structured, discussing player motivations (e.g., mastery, escapism, social interaction), types of interactivity, challenge formats, and aspects of game theory, but offers only limited treatment of specific mechanics.

The academic literature has also engaged with this issue. Salen and Zimmerman (2004) provide a comprehensive framework, categorising game systems into emergent, probabilistic, informational, cybernetic, and game-theoretical systems. They likewise examine five types of playful experience (pleasure, meaning, narrative, simulation, and sociability) and explore the cultural dimensions of games. Martinho, Santos, and Prada (2014) similarly compile frameworks from multiple authors.

Occasionally, efforts to link experiential concepts to concrete mechanics focus on specific gameplay dimensions. Research supervised by the first author includes: Faria and Albuquerque (2019) on the use of time-travel mechanics across genres; Urbainski and Albuquerque (2023) on mechanisms that evoke horror; and Germer and

Albuquerque (2022) on the role of puzzles in gameplay. Noteworthy here is the Playful Thinking Series (MIT Press), where Costikyan (2013) discusses uncertainty, Juul (2013) examines failure, and Isbister (2016) explores emotion in games. These works effectively translate design concepts into practical examples but do not constitute broader theoretical models.

One attempt to systematically map the factors contributing to fun in games was proposed by Albuquerque (2011) and later developed in Albuquerque and Fialho (2015). Based on a synthesis of the literature, their model proposes twelve elements of fun distributed across four quadrants, reflecting tensions between creative and destructive impulses, and between passive appreciation and active interaction. The model is operationalised via a questionnaire that maps player preferences, resulting in eight player profiles. Similarly, Lazzaro (2004) proposed four types of fun (hard fun, easy fun, altered states, and social fun) and identified seven emotional drivers (e.g., fear, pride, awe).

Typologies of player profiles have long been used to capture the diversity of gaming experiences. Bartle (1996) proposed one of the earliest, dividing players into killers, achievers, socialisers, and explorers, based on MUD players. A related framework is Brainhex (Nacke, Bateman, & Mandryk, 2014), which, while retaining some of Bartle's profiles, adds others (e.g., seeker, survivor, mastermind, daredevil), grounding its typology in neurophysiological responses to gameplay.

Although Bartle's and Brainhex's models are influential, a more recent and empirically grounded typology by Nick Yee has gained prominence. Drawing on extensive player data, Yee and Quantic Foundry (2022) propose six categories—Action, Social, Mastery, Achievement, Immersion, and Creativity—each subdivided into two dimensions. These combine to produce nine distinct player profiles, such as Acrobat, Architect, or Gladiator.

While such typologies offer valuable insight into user experience, they adopt a player-centred, rather than object-centred, perspective. Thus, in the context of game design, a crucial step is translating these insights into mechanics that elicit the desired experiences. Patzer, Chaparro, and Keebler (2020) take a step in this direction by proposing links between player types and experiential outcomes (e.g., "social connection", "creative freedom"), although they do not specify associated mechanics.

From this standpoint, the integrative model proposed here aims to fill this gap by linking gameplay principles to specific mechanics — viewing the latter as design solutions to elicit targeted experiences.

A rare example of a model focused on the mechanics themselves, rather than abstract concepts, is the study by Samarasinghe et al. (2021). Drawing on a board game database, they categorise dozens of mechanics into seven broad groups. While their methodology, based on statistical analysis, and object of study (board games) differ from those of the present research, their approach to clustering concrete mechanics serves as a valuable reference.

5. Final Considerations

This paper, as part of a doctoral research colloquium, aims to outline the gap that the thesis seeks to address. The intention here was not to elaborate on the methodological procedures behind the development of the model (something that is still in progress) but rather to clarify the nature of the work being undertaken and the direction in which it is heading. The argument presented thus focuses on justifying both the necessity and the utility — both epistemological and pedagogical — of a model such as the one proposed, while also demonstrating, through the literature, the challenges previous researchers have faced in establishing a connection between gameplay experiences and the mechanics capable of generating them.

Naturally, the proposed model cannot encompass every possible game mechanic, what would be an impossible task. Its aim is to compile and organise a sufficiently broad range of mechanics to offer a model capable of supporting the analysis and categorisation of those not explicitly included. In this way, a game designer or educator in the field, upon understanding the model, would be able (through critical reflection and practical experimentation) to infer where new or unclassified mechanics might be situated within the proposed framework.

In order to demonstrate the utility of the theoretical model, an educational card game is currently being developed alongside the model's ongoing refinement. The purpose of the card game is to create a learning experience focused on digital game mechanics, serving as an example of how a clearer structuring of knowledge in game design can operationalise teaching and learning experiences within a field whose pedagogical tradition is still relatively young. The expectation is that the model will act as a starting point for further initiatives within the discipline, both for practitioners, researchers and game design teachers.

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Have you Ever Experienced Someone Else's Breakup in First Person?

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Abstract: As video games have gradually become more immersive and impactful on players' emotions, it is quite important to know and address how players' unique experiences can influence the perception of difficult topics like heartbreak and depression. This study investigates how does closure from past relationships influence players' emotional responses while playing *Sayonara Wild Hearts*. The research employes extensive gameplay analysis including repeated playthroughs to construct interpretations of the chapters, levels and thematic contents. This was followed by examining online blogs, articles and research works regarding breakup, depression, closure, pop music, and music as a therapeutic medium to draw literature references. Additional findings were drawn from essay videos and posts from dedicated online communities. Empirical validation was obtained through conducting online survey, examining the relationship between closure and gameplay experience. The findings indicate that the participants who achieved closure from past relationships tend to experience the game as an affirmation of self-love. In contrast, players who continue to grapple with unattended emotional baggage often experience the game as a form of catharsis to confront their negative emotions.

Keywords: Sayonara Wild Hearts, Breakup, Emotional closure, Music in video games, Games as therapeutic tool, Catharsis in games, Player emotional response

1. Introduction

Love and heartbreaks are timeless in terms of the themes explored in pop music. *Sayonara Wild Hearts*, a poppy throwback arcade game, celebrates pop music by integrating these emotions into the heart of gameplay. The narrative centers on a young woman experiencing depression following a recent romantic dissolution, who catapulted into a world of vibrant colors and upbeat poppy music where personified tarot cards hinder and accompany her in her journey of self-discovery. Each chapter of the game is linked to a tarot card and its meaning, which serves as a metaphor for the main character's emotional progression through the stages of grief and self-healing. This paper examines how closure from past relationships can influence players' emotional responses to the game. Previous studies have explored how video games can engrave a deep impact on a player's emotional domain. According to (Nitsche, 2008), the events within games can be so memorable that they transcend outside of the virtual space, triggering emotional responses that can extend to real life. In such circumstances, players may seek validation of their feelings from other people who played the same game, showing how evocative narratives can create personal and memorable experiences. In *Sayonara Wild Hearts*, this concept is reflected in how several communities formed on different social media platforms to share and discuss their personal experiences with the game's meaning narrative on heartbreak and healing. These discussions on social media depict how interactive storytelling can create personal connections with players and allow them to reflect on their own personal lives. However, there is limited study of how players past experience, particularly closure from past relationships influence their experience of games designed around difficult themes like depression, heartbreak, and healing. This study aims to address this research gap.

2. Background

Heartbreak is one of the most personal and intimate crises that a person can endure. It numbs away the emotions, destroys self-esteem, and makes one question their own worthiness of love. Romantic breakups can even lead to symptoms like bereavement, such as intrusive thoughts, insomnia and health issues (Field, 2011). These can include biochemical effects like cardiac abnormality (Broken Heart Syndrome), which mimics physical heartache and immune dysfunction (Field, 2011). Emotional distress from a breakup can blur the self-concept, making it difficult to redefine identity and increasing emotional pain (Slotter, et al., 2010). In contrast, closure is a feeling of acceptance that helps individual move forward. Without it, unresolved emotions and uncertainty (Hendrickson & Štětinová, 2016) may stay, increasing distress (Koessler, et al., 2019). Achieving closure can improve mental well-being and confidence (Kansky & Allen, 2017). Given the emotional toll of breakups, our research investigates how closure influences the way people experience provocative content, particularly video games like *Sayonara Wild Hearts*.

Previous studies have explored various methods to address emotional pain from breakups. One study found propofol, an anaesthetic, may suppress traumatic memories (Vallejo, et al., 2019), but also warned of hormonal side effects and risks like memory loss. In contrast, another suggests that heartbreak songs can impose cathartic effects and reduce negative emotions, highlighting music's applicability as therapeutic tool (Tsai, et al., 2014). Since music encourages emotion addressing rather than suppressing, we prompted to ask: does closure shapes how players connect with a "pop-album" game like *Sayonara Wild Hearts*? And if so, can its musical narrative offer therapeutic experience, like commercial pop music?

For millennia, music has comforted the human soul when words fell short. For instance, *Blood on the Tracks*, often referred to as Bob Dylan's "Breakup album", has been greatly appreciated by listeners for decades for using raw and introspective lyrics (Garrigan, 2023) to express love and loss with a folk-rock sound. Each songs invites listeners to fill in the gaps with their own struggles (Jarnow, 2016). Similarly, *Sayonara Wild Hearts* explores love-sickness in a similar way, blending interaction with melody of pop soundtracks to guide players through the protagonist's transformative journey. For both of the creative works, the emotional progression is mapped through track-like stages which allow listeners to draw layered interpretation from their own perception of the experience.

There are other video games with similar emotion journeys. For example, *Florence* is an interactive puzzle novel that tells the story of a young woman's first love and its end. Each interaction is carefully designed to evoke emotions tied with the narrative, allowing players to feel her feelings. Similarly, *Celeste* tells a story about a young woman trying to conquer her anxiety and self-doubt by climbing a dangerous mountain. Each chapter she climbs reflects her internal hurdles, offering catharsis for players who have faced similar difficulties (Watanuki, 2019). *Octopus Pot*, a visual novel developed as a thesis project, explores romantic relationships and breakups. It invites the players to empathize with the characters going through phases of falling in love, growing apart, breaking up, and moving on (Cummings, 2022). Like *Sayonara Wild Hearts*, these games rely on the emotional backgrounds of players to shape their experiences.

Drawing from these examples, our study aims to answer the questions raised earlier. The findings may contribute to understanding how human emotional state can shape experiences in games in general, while also extending the domain on how digital media can serve as a tool for emotional healing after trauma.

3. Analysis

The following sections present a comprehensive analysis of the game through multiple interpretive lenses. These interpretations are derived from gameplay experience and online articles, community forum discussions and survey responses. We chose to divide the game into seven main chapters, the first chapter being *Clair De Lune* and the final chapter being *Wild Hearts Never Die*. The whole game is completely immersed in music, and each song is an integral part of the story, hence the title "pop-album video game" (Webster, 2025).

3.1 Claire De Lune

At the beginning of the game, the narrator explains that the heart of a young woman, our protagonist, is shattered into pieces, and her sorrow echoes through space and time, creating a subspace in the universe. The protagonist is then drawn into this subspace, embarking on a journey through neon-lit highways. This mirrors the denial stage from Elisabeth Kübler-Ross and David Kessler's five stages of grief (Kübler-Ross, et al., 2014), where "the world becomes meaningless and overwhelming". Here the subspace of heartbreak resembles the overwhelming nature of denial and the protagonist's non-responsiveness depicts the "numbness".

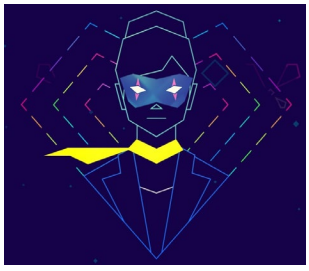

Figure 1: Claire De Lune's level selection icon, depicting The Fool

Different sources describe these events using various interpretations, but the core message remains consistent. For example, on a blogpost from *Comic Book Resources* (Nejam, 2022), the writer interprets this moment as the beginning of "The Fool's journey". Similarly, the YouTube channel Eyebrow Owl (EyebrowOwl,

2022) and the blog (Crusader, 2019) agree that the prologue symbolizes the beginning of a fool's journey, a spiritual odyssey in which a humble individual embarks on a path toward enlightenment.

From these interpretations, we can conclude that, like The Fool, the protagonist, being naive and heartbroken, answers the call of an unexpected adventure towards her self-discovery.

3.2 Dancing Devils

On her journey of self-exploration, the first figures The Fool faces are the *Dancing Devils*. The Devil tarot card shows Baphomet, or the horned goat of Mendes, symbolizes the balance between good and evil, but also sins, addiction, and desire. There are several interpretations of The Fool's interaction with the devils.

In this stage, the Fool follows the *Dancing Devils* and confronts them with the help of the tarot Wheel of Fortune, which symbolizes destiny and fate, manifested as a motorcycle.

Figure 2: The Devil tarot card

One common interpretation sees the *Dancing Devils* as representations of past relationship's residue. She recalls the pain she endured and feels *anger* (Kübler-Ross, et al., 2014) about having to go through the same process of moving on again. She has, yet again, to overpower them, and each encounter can be seen as the personal struggle and effort required to move on.

The song *Begin Again* suggests how the last relationship is nothing more than "Broken glass, smoke and ash" anymore and that it left her "Sad and scarred". Moreover, the lyrics "But I just cannot bear / One more of those calls / Where I talk and you say nothing at all" imply an abrupt closure of the past relationship, which left her saying "It's the last time" over and over again. Despite that, she is "Just happy to begin again" because she finally surrenders to the fact that there is "No need to understand" because "It's time to forget / All the pain and regrets" that those one-sided calls left her with.

Another interpretation frames (Arantt, 2020) the *Dancing Devils* in the role of peers, or rather the protagonist's anxiety caused by them, and this is supported by the way they dress and act. Each attack could represent insecurity and a perceived criticism. This feeling of being judged by the others is, in the end, overcome by The Fool when she realizes other's opinion no longer defines her.

3.3 Howling Moons

The Moon arcanum symbolizes fear and illusions (Guide, n.d.), bringing unresolved emotions into the present, causing emotional distress. Rather than confronting them, one may supress them into the subconscious. When this card appears, it reminds her to trust intuition, reject any negative self-talk, and break down emotional blockages.

Several interpretations exist for this chapter. A Reddit user (Arantt, 2020) sees the Howling Moons as symbolic of the struggle to let go fake friends amid depression and social anxiety. Another interpretation comes from a Youtuber who highlights the prominent blur hue of the level as representing sadness, phrasing, "Have you ever felt blue?". Meanwhile, Backlog Crusader (Crusader, 2019) interprets the psychedelic visuals symbolize "confusion" and "crossroads", represented in the sections where players must decide which side to take.

Figure 3: The Howling Moons

Throughout the level, The Fool confronts her inner conflict. She uses "Justice" and "Judgement" depicted as guns attached to the "Wheel of Fortune" a mystical motorcycle, first introduced in the Dancing Devil stage. Justice reflects balance, conscience, and order, while Judgement points to awakening.

In the level's soundtrack, "Dead of Night", the chorus line, "When all you cared for is the fire / You ended up blinded by the light" implies that focusing only on the negative aspects can make her blind, obscuring the positive things around her to cherish. When the chorus drops, the Howling Moons summon a three headed robotic wolf that tries to stop The Fool from following her intuition reflecting her internal resistance. By defeating them she begins to restore her emotional balance and overcome self-doubt.

3.4 Stereo Lovers

Before the *Stereo Lovers* chapter begins, the Fool must ascend a representation of the Tower tarot card, which often means destruction, chaos, and revelation (Guide, n.d.), meaning, overcoming fear of change. After overcoming various obstacles, she reaches a portal that leads to the *Stereo Lovers*. The Stereo Lovers give the tarot "Strength" to the protagonist to challenge her to a duel, symbolizing the courage needed for healing. She ultimately slashes them, revealing their duality.

The Lovers card here reflects the duality of a past relationship, either being two separate people or good and bad traits of one person. The interpretations vary depending on the player's personal experiences. For instance, a player without proper closure may see these two as opposite figures and their world transition finger snap as two different worlds with or without the lost partner. One if everything worked out perfectly and the other as the harsh reality in which the partner is no longer present, in particular a world where she is forced to move on while still being deeply connected. This duality of "what-ifs" and imaginary outcomes can be seen as *bargaining* (Kübler-Ross, et al., 2014), the third stage of grief.

Someone who had a clean closure may consider the two halves of the *Stereo Lovers* to be the good and bad traits of their former partner. The finger snaps triggering world transitions may represent the protagonist's effort to reconcile the opposing aspects of the past relationship. When she is finally does a snap herself, it resembles reclaiming control. This symbolises a moment of growth which is often reached after reflecting on what to avoid or seek in future partners.

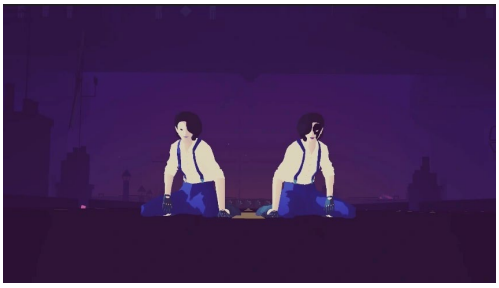

Figure 4: The Stereo Lovers

Another view, particularly for players without closure, conceptualises the two *Stereo Lovers* as symbolic of an ex-partner and a new romantic interest. The Fool is therefore caught in an emotional dilemma between fully healing from the old relationship and investing feelings and effort in a fresh start with someone new. One half of *Stereo Lovers* may represent the lingering attachment to an ex-partner, while the other half could represent a rebound. A rebound relationship is a romantic involvement usually pursued right after a breakup as a

distraction from unresolved feelings. This interpretation highlights the importance of closure before engaging emotionally in a new relationship.

The songs related to this chapter are, in order, Hearts & Swords, Parallel Universes, and Mine. While Hearts & Swords and Parallel Universes are instrumental, Mine has lyrics that can be analysed to better understand the level. The lyrics “Won't you be my lovely liar? / You're the story I desire / It doesn't matter if it's fake / I love to own for owning's sake” suggest an obsession with control over another person, even if the relationship with this person is not real or authentic. Moreover, “What isn't real could never fade / We prefer the masquerade” means that the protagonist knows exactly that the object of her obsession is a lie, yet she prefers to live with this lie rather than finding something more truthful. This theme of deception and longing allows different interpretations of these levels, making it not only about romantic conflict but also about self-deception and emotional closure.

3.5 The Hermit

The Fool reaches a stage where she faces the Hermit64. The pace is comparably slower, which offers a break from the fast action of the earlier stages. The Fool is offered a new tarot, which is called Chariot, that symbolizes control, willpower, and success (Guide, n.d.). Eventually, the Fool faces the Hermit. We also found a variety of interpretations of this stage. One interpretation suggests The Fool gradually attaches to a digital world in a form of escapism from reality. During her journey to shift herself back to face reality, she gets spirited away to Hermit's virtual world and fights her way to defeat and regain her consciousness.

Another convincing interpretation of this chapter is that Hermit's digital world represents loneliness and isolation that come from *depression* (Kübler-Ross, et al., 2014), the fourth stage of grief. In this virtual world, The Fool experiences a return to childhood and everything that gave her comfort, in this case video games. She tries to protect herself with familiar things, but in the end, she has to snap back to reality. Backlog Crusader (Crusader, 2019) states that this stage is all about self-discovery. The Hermit is the last card of the 22 major Arcana, which signals the approach to the conclusion of The Fool's journey toward complete enlightenment.

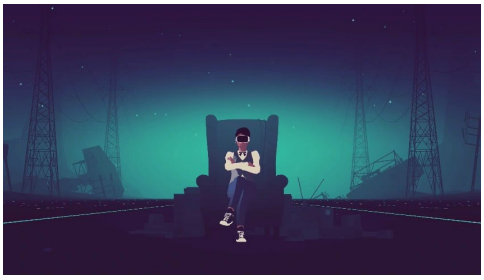

Figure 5: The Hermit

Paying attention to the soundtrack "The World We Knew", the lyrics say, "They say begin again / But I'll take any fragments I can find", which encapsulates the fatalistic and yearning thought process of anyone familiar with the darkest depths of a heartbreak. At the end of the level, the Fool literally breaks out of the through prison depicted as a VR world, resembling “withdrawal” (Kübler-Ross, et al., 2014). The Hermit arcanum represents solitude, self-discovery, and humility, which can be tied with the slow process of healing from depression caused by a heartbreak, a process that comes with time and maturity.

3.6 Little Death

The next stage begins with the Fool sailing through in the ocean, following heart-shaped figures forming a circle. Backlog Crusader (Crusader, 2019) relates the light with The Star arcanum, representing direction and renewed hope (Guide, n.d.) like the ancient navigators followed stars to find their way across seas. The battle with *Little Death* happens over several stages. At the first encounter, *Little Death* uses The Hanged Man arcanum to summon flocks of floating skulls with bat wings, while the Fool counters with Temperance arcanum, which symbolizes patience and purpose, and it turns into a shining bow.

A Reddit user (Arantt, 2020) explains that the battle represents fighting *depression* and implies the Hanged Man as a metaphor for "depression demanding sacrifice", referring to suicidal thoughts. The Fool’s use of Temperance shows her psychological growth as she is not directly fighting depression, but rather the evil winged symbolizing her internal battle. On the second stage, Little Death summons the Sun arcanum, which is about joy and playfulness. According to the same Reddit user (Arantt, 2020), the Sun, posing a hazard as death

itself, represents lifecycle, foreshadowing success and the nearing end of depression. Backlog Crusader (Crusader, 2019) suggests that, despite its negative name, the Death card reflects a profound change, a transformation, and rebirth. This is clearly portrayed in the game as Little Death goes through several "transformations" during the battle as she sheds her forms. During the last stage, her body blasts away, leaving only "The Eye of Death", a massive floating eyeball that must be defeated. When death is finally defeated by the Fool, it merges with all other boss cards to create a clone of the Fool.

Figure 6: The Little Death

Reading between the lines in the lyrics of the background song "Inside", it is quite clear that even if she wants to say something, she holds back. It may suggest that a person may be mature enough to feel that they are holding themselves back but not strong enough to let go. That is how depression holds back its victim.

3.7 Wild Hearts Never Die

After destroying the evil eye of death, the final act begins with the protagonist losing her Fool persona and returning to her original form. The most powerful event comes when all evil arcana merge to create the Fool's clone who chases the protagonist and reenacting earlier battles. However, this time instead of fighting, she responds with compassion. She kisses the Fool, embracing her fears and the pain she's carried for so long. In that moment, she stops running from heartbreak, finally *accepting* (Kübler-Ross, et al., 2014) the loss and finding the closure she had been seeking. M. Heron (Gamboa, et al., 2023) addresses this moment as cathartic, a pure self-acceptance moment. This phase completes the stages of grief, illustrating what Kübler-Ross describes as "a new norm that we must learn to live with", indicating the transformation to the new self.

Figure 7: Wild Hearts Never Die's level selection icon, showing the protagonist and all the bosses

A Reddit user (Arantt, 2020) suggests that *Sayonara Wild Hearts* shares the core message of the game that things eventually get better. A key line, "We're just changing our shape like butterflies / Cause wild hearts never die", captures the idea of growing resilience and transformation. This message is beautifully reflected in the game's final act, where the glittering dragon becomes the protagonist's heart, showing how she has become whole again throughout her journey. In the final scene, the protagonist returns to her room at home, with longer hair to indicate that time has passed. She seems to be calm, composed, and whole.

From the discussion above, we can say the soundtrack in *Sayonara Wild Hearts* complements the narrative intentions of each level. According to (Heron, 2015), game audio can serve as a form of 'developer annotation' to the ongoing narrative, often operating in a subtle and subtextual way (Heron, 2015). In *Sayonara Wild Hearts*, the soundtracks are used in a subtextual way to add more context to the audio-visual storytelling. We think this idea adds an extra layer of medium that connects players with the story it wants to tell creating a mental bridge with narrative.

4. Discussion

The analysis of *Sayonara Wild Hearts* chapters reveals that players' interpretations vary based on personal experiences. This highlights the game's ability to resonate deeply and uniquely with each player, offering reflections of their own personal struggles and growth. For the players who have reached emotional closure after a breakup, the game can serve as an affirmation of resilience. They might see the battle against the Dancing Devils or the Howling Moons, as a representation of the struggles they have already conquered in the past. The final chapter, Wild Hearts Never Die, may feel like a validation of their healing process and a reminder that pain contributes to personal growth.

On the other hand, for the players who are still attached to a past relationship and are struggling with unresolved feelings, the game may present itself as a sort of cathartic experience. The game acts as a space where they can project The Fool's journey with their own to process their unresolved feelings. The act of facing bosses could resonate with them as their effort to heal their broken heart. However, these kinds of players are still in the middle of their personal fight against unhealed wounds. That's why the final chapter, particularly the moment of acceptance of herself, could represent their final goal, a reminder that closure is attainable, even if not yet realized.

We conducted the survey using Google Forms, consisting primarily of closed-ended questions and a few short answer items. The questionnaire was anonymous, and 70 individuals from online communities participated. We have used narrative analysis to cluster the respondents, and the closed-ended format facilitated efficient analysis and enhanced the accuracy of quantitative results. Table 1 presents the distribution of the respondents and their responses in percentiles.

Table 1: Summary of the responses from participants in percentiles

	Participants with breakup history (71.4%)	**Participants without breakup history (28.6%)**
Found the game cathartic	57.1%	N/A
Connected with gameplay/music	21.4%	65%
Associated with other life events	21.5%	35%

5. Future Work

There are several aspects that we wanted to explore thoroughly but did not have enough time or resources to progress. One of the key aspects is to examine the potential of games as digital media to help individuals struggling with depression and Post-Traumatic Stress Disorder (PTSD) resulting from heartbreak or other emotional distress. We have also noticed how *Sayonara Wild Hearts* and *Florence* use simple yet symbolic mechanics that incorporate the player's mind game, and we want to explore if there are certain mechanics in games that can provide temporary relief from negative conditions like stress or anxiety.

In the future, we would like to work towards these directions, as the application of games as digital media to serve as a therapeutic medium is still unexplored. We believe video games hold the potential to help individuals struggling with mental blocks or difficulties due to trauma.

6. Conclusion

In conclusion to our paper, we showed how serious issues, such as depression and heartbreak, can impact the body and mind of people in significant ways. Then, we studied how music can help broken hearts during their healing process. After that, we compared different games with similar themes. We proceeded considering the different ways in which players' perspectives shape their emotional response while playing *Sayonara Wild Hearts*. This game's unique design and symbolism allow it to resonate with players in diverse ways, whether they are on a journey of self-discovery or searching for closure from a past relationship. By analysing different interpretations, we understood this game can be a place for emotional reflection and can serve as a cathartic experience for others.

For those who found closure, the game serves as an affirming reminder of their strength. They may interpret the battles as symbols of past struggles they have already conquered, and the final chapter, Wild Hearts Never Die, can feel like a validation of the progress they have made. On the other hand, players who are still dealing with unresolved feelings may experience the game as a cathartic space to confront their emotions. For them, engaging with The Fool's journey gives them a chance to reflect on their own situation, with each challenge

symbolizing their ongoing fight for self-healing. The conclusion of the story offers them hope, a reminder that closure is possible even if it has not yet been achieved.

When a heartbreak consumes one's life for a long period of time, it feels like an eternity of misery. But anyone who has overcome the pain can attest that it is really just a footnote on the path through life. *Sayonara Wild Hearts* reminds of the audience the single eternal truth, which is "you are worthy of love".

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Ethics declaration: Permission to record the responses from the online survey for the purpose of this research was obtained by all respondents. They were fully aware about the purposes of the research and how their responses would be used.

AI declaration: We acknowledge the use of ChatGPT and Grammarly to identify spelling mistakes and grammatical errors. The mentioned AI tools were not used to generate any kind of text or argument for this research.

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Threat Forge: Using a Narrative Game to Explore Future Societal Challenges

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Abstract: The current world is in a state of volatility, uncertainty, and complexity, characterized by the emerging challenges to democratic systems across multiple domains. Preparing to meet these complex challenges requires tools that help to build resilience and adaptability. While serious games and wargames have a long history of being applied to this goal, they often limit the player agency and creativity. This case study introduces *Threat Forge*, a narrative co-creation game designed to explore potential futures by integrating game mechanics with techniques used in future studies. It explores how the structure of this game enables players to engage in meaningful discussion of concepts as defined by frameworks like DIME and PMESII even when they have not received direct training in these frameworks. The results of a formal playtest using the CORGIS survey, as well as thematic analysis of the discussion and observation of play are presented. The results show that the type of challenges that player experiences within the game are consistent with designing a game to encourage a serious and deep reflection on complex issues. In addition, they show that the discussion was consistent with frameworks used to discuss conflict. The play-testers felt that the game was a useful method of structuring a discussion on complex issues. In conclusion, narrative co-creation games offer an important addition to the field of serious games that will need to be subjected to further study and investigation.

Keywords: Serious games, Narrative co-creation, Resilience, Wargaming, Future studies, Game Based Learning GBL

1. Introduction

Democratic societies are under an unprecedented amount of strain. Challenges to the established order threaten the coherence, functionality, and legitimacy of democratic states. The challenges exist across a wide range of domains, including the Political, Military, Economic, Social, Information, and Infrastructure (PMESII) (Kodalle and Ormrod, 2025). Addressing these threats requires governments and industries to be able to anticipate, understand, and respond to complex, contradictory, and often novel situations systematically. Among the tools best suited for addressing this, games — especially serious games and wargames — have long served as methods of building resilience, addressing social tension, and preparing for the unknown. Examples stretch back in history from the tales from Herodotus' history of the Lydians playing games to combat starvation (McGonigal, 2011) to the exaltation of games as tools for learning to deal with the unexpected in the *Book of Games* (1283) (Alphonso X *Book of Games* Home Page, no date). In more modern times, games have been used to prepare for disasters (Comfort, Boin, and Demchak, 2010), engage with business planning (Bradfield et al., 2005), and even to think the unthinkable and examine thermonuclear war (Kahn, 1984).

The vast majority of serious games have been characterized as message broadcasters (Ifenthaler, Eseryel, and Ge, 2012); that is, games in which the primary purpose is the delivery of specific information. This places the player in the role of the recipient of knowledge, either created or curtailed by the game designer, rather than in a position of collaborative co-creation and exploration of the problem space. This is readily apparent in the wargaming subset of serious games where the two most prevalent formats — rigid and freeform — despite their differences in goals, execution, and adjudication methods, both rely on prescripted scenarios that guide or, in some cases, constrain the player experience (Perla, 2023; NATO, 2023). While the focus this provides helps to maintain the clarity and manageability of the design, it also limits the agency of the player.

Agency, which can be described as "the capacity of actors to make practical and normative judgments among alternative possible trajectories of action, in response to the emerging demands, dilemmas, and ambiguities of presently evolving situations" (Emirbayer and Mische, 1998, p. 971), can be viewed as essential in producing engagement in a game system. To put it simply, if the player's choices do not have any bearing on what is happening, the player will become disinterested and disengaged.

This default assumption that serious games or wargames require a well-crafted narrative to teach (Naul and Liu, 2020) places a great deal of strain upon the game designer. It implies that the most valuable insights must be embedded in the game's construction, rather than emergent from engaging with the game.

Given these limitations, there is a need for new approaches to supplement traditional wargaming methods that retain the strategic focus of wargames while increasing player agency and the ability to co-create the scenario

space. One potential approach to explore the effects of increased agency would be the adaptation of cooperative narrative co-creation games into the field.

Narrative co-creation-based games like *Fiasco* (Morningstar, 2011), *The Quiet Year* (Alder, 2013), and *Microscope* (Robbins, 2011) stem from the exploratory game design work done at The Forge (White, 2020). They were created in response to more traditional roleplaying games, which emphasized either game balance and tactical optimization (gamerist models) or internal consistency and accuracy of simulation (simulationist). In contrast, the narrativist games sought to place participatory and collaborative gameplay at the heart of the game's structure. These games serve as scaffolds for the creation of stories and exploration of problems and decisions.

Co-creative games have gone on to be defined as having three common features: the players decide what exists and does not exist within the shared game world; the game is open enough to be adapted to the players' desires; and finally, a system of moderation exists within the game to define how content is added (Acharya and Wardrip-Fruin, 2019). These three elements dramatically increase the players' ability to make judgments and take actions within the game world.

Given their co-creative nature, such narrative games may be ideally suited to address the fundamental tension between scripted narrative and the need for agency in the creation of the scenario that is prominent in the two traditional wargame types (Perla, 2023). The construction of the narrative as a co-design process brings more voices into the discussion, allowing for better scenario creation. The narrative process can accommodate the uncertainty of wicked problems (Swain, 2007) and, in fact, provide valuable information towards defining the nature of the problem. In contrast with traditional wargaming methods, which deliver information to the participant, narrative games extract concepts from the participant.

The purpose of this study is to explore the utility of a game-based approach to conduct an analysis of potential futures. This would bridge an existing gap in traditional wargaming traditions as well as present a novel and engaging method of conducting this type of work. This study will achieve this aim by presenting a case study of the use of *Threat Forge*, a narrative co-creation game designed to explore potential futures.

The key research questions to address the aim were defined as:

- Can *Threat Forge*, a narrative-based game, facilitate structured discussion across multiple domains of conflict, represented by established analytical frameworks such as DIME and PMESII — even if the players have no formal training in these frameworks?
- How well do the challenges presented in the game mesh with the purpose that the game is designed to accomplish, measured by the CORGIS (Cognitive, Organizational, Reflective, and Game-based Interaction Survey) instrument? (Denisova et al., 2020)

2. Game Description

Threat Forge is a narrative co-creation game for 2 to 8 players developed to explore the pathways to future states. The design of *Threat Forge* drew inspiration from the mechanics of *Microscope* (Robbins, 2011) and integrated them with the process of backcasting and future studies. Backcasting is a methodological approach used by intelligence services and industry; it begins by identifying a future state and asks participants to project backwards to identify how such a future may come about (Vanatta and Johnson, 2019; Robinson, 1990). *Threat Forge* allows for a process of backcasting to take place in a game environment, complete with generating the associated flags and gates that are made in the traditional process.

Serious games are made up of two often competing goals: the ludic or player goal, and the intended learning outcome (defined by the designer) of engaging with the game. The ludic goal of *Threat Forge* is to explore the construction of a narrative with fellow players. It uses narrative and player uncertainty (Costikyan, 2013) to engage the player. The learning goal of *Threat Forge* closely aligns with the ludic goal, as through the co-construction of the narrative, players are led naturally to discuss complex multi-domain issues and explore their understanding of these challenges.

While it has been noted that "the essence of gameplay is the challenge/action relationship" (Adams and Rollings, 2010), the type of challenge that a game produces can support or inhibit the gameplay. The four types of challenge—performative, decision-making, emotional, and cognitive (Denisova et al., 2020)—have to be carefully considered in the game design. A game designed to promote serious reflective engagement with these complex issues, like *Threat Forge*, requires more cognitive and decision-making challenges to ensure that the debate is meaningful. In contrast, the more standard performative challenge found in computer games, with

their emphasis on quick responses, would not allow time for reflection and debate central to the learning goal. Another example is that the player must have some emotional space to consider the moves that are being made. The player must be emotionally invested in the discussion to increase engagement, but not so much that it will interfere with producing a coherent narrative.

During play, participants take turns creating and placing cards representing potential major events onto a timeline that initially consists of a starting point (present day) and an end point (the final future state the events culminate in). The cards are produced by the player and have a simple sentence describing the event, as well as an arrow in the top corner to denote if the event detailed increases the probability of reaching the end state or decreases it. By placing their card before or after any existing event card, players gradually construct a chain of events. They can also elaborate on how individual major events occurred: further cards can be added underneath the top-level events to explore incidents that contribute to the larger-scale event.

The most profound way in which *Threat Forge* diverges from *Microscope* is in the establishment of the scenario to be discussed. In *Microscope*, this is fully open, and the players engage in a negotiation before the start of the game to establish the narrative they wish to tell. In contrast, *Threat Forge* defines the start and end point of the timeline, as well as the setting, before play begins. The players are then allowed free rein to explore inside the defined space. This is done to help keep the discussion on point and relevant to analysis.

3. Methodology

The playtesting of a serious game, to establish its engagement and its utility as a tool, requires a mixed-methodological and pragmatic approach to be taken. The design and development decisions for Threat Forge have been outlined above. This process of design involved many iterations of informal and formal playtesting. Several of the playtest sessions included a diverse audience from security and military fields these sessions are not reported on for a mix of confidentiality and security concerns. Instead this paper describes a formal playtest using graduate students that was conducted using the game on April 8th, 2025.

3.1 Pilot Scenario

The pilot scenario assigned for the formal playtest was the lead-up to the invasion of a small Western democracy by a larger, more aggressive authoritarian state. This focus was selected due to its relevance to current political issues and its perceived ability to raise questions across multiple societal domains.

3.2 Population

The game was played by three playtesters, two male and one female. All of the play-testers were postgraduate students studying Digital Learning Games at Tallinn University. None of the participants had active military experience or had been employed by the military. The selection of non-military perspectives was intentional, as the study wished to see if the game promoted dialogue around key issues without the participants being aware of them.

3.3 Ethics

Full and informed consent was received before the game started or any data was captured. Each participant was provided with a cover letter outlining the nature of the research and the procedure for withdrawing from the research at any time.

3.4 Data collection

- **Audiovisual recording**: The playtest session was recorded using both a video and backup voice capture. This was done to allow for post-session analysis of participation and dialogue.
- **Survey Instrument:** Participants completed the CORGIS (Cognitive, Organizational, Reflective, and Game-based Interaction Survey) immediately after the session using a seven-point scale for fine-granulation of results. This 30-item Likert scale survey measures levels of challenge in four domains: cognitive, decision-making, emotional, and performative. (Denisova *et al.*, 2020)
- **Hotwash and Group Feedback**: Following the survey, a structured debriefing session was conducted based on van den Hoogen, Lo, and Meijer (2016). Participants were asked to reflect on their experiences, identify learning moments, and suggest improvements.
- **Artifact analysis**: The final state of the created timeline was photographed to ensure accurate recording of the narrative and strategic outcomes developed during the game.

3.5 Data Processing

The data from the CORGIS survey was anonymized. Patterns in high-scoring and low-scoring items were identified and highlighted in the results and discussion.

A combination of the recordings and the artifacts produced by the game were analyzed to allow for each move inside the game to be isolated.

To assess how effective the game was in eliciting structured discussion of complex societal issues, each move generated during gameplay was retroactively categorized using the DIME and PMESII. frameworks. These two frameworks were selected as they are widely used in military education in either the design of wargames (Dixson *et al.*, 2015) or as frameworks found in military doctrine (Kodalle and Ormrod, 2025). The application of these frameworks to the emergent narrative produced by *Threat Forge* allowed for judgments to be made about the quality of the discussion being produced.

4. Results and Discussion

4.1 CORGIS Results

Table 1: Combination CORGIS (Denisova *et al.*, 2020) scores and in game observations in support

Challenge Dimension	Mean score (1-7)	Game observation
Cognitive	5.16	Players paused frequently to consider plausible events.
Decision Making	4.66	Players discussed the placement and knock-on effects of proposed events.
Emotional	4.5	Players referenced real-world issues and examples in the discussion.
Performative	2.2	Players took their time and engaged with each other while making their moves.

Table 1 provides an overview of the average scores generated by CORGIS as well as observations made during play that put the numbers into context. A deeper analysis of the findings is presented in the following sections.

High Scoring Elements

Consistent with the design of the game, the most prominent type of challenge identified via CORGIS was cognitive (5.16 / 7 average) followed by decision-level challenge (4.66 / 7) and Emotional challenge (4.5 / 7).

Another important finding is that the cognitive challenge section was also the only section to score higher than 6.3/7 on individual items.

The most highly rated elements from the survey as a whole was in the cognitive elements, Item 10 "I had to think actively when playing the game" (average score 7/7). Three other items scored highly on the survey. Item 7 "I had lots of different things to think about at once in the game" (average score 6.66 /7). Item 6 "I felt challenged when playing the game," and item 9, "I had to constantly keep track of what was going on in the game," both scored 6 /7 on the CORGIS scale.

While the decision-making challenge elements scored the next highest, only 1 item scored as highly as the four taken from the cognitive challenge elements. "The game made me think hard about my decisions." Item 5 in the decision-making scale scored 6/7.

The emotional challenge had three Items scoring highly: Item 3 "I invested much thought into the game" (6.3/7); Item 5 "The game made me think about real-life issues" (6.3/7); and Item six "Playing the game was stimulating" (6/7)

All of these results paint the picture of a game that was engaging and required the player to invest cognitive resources to understand and take part in the game.

Low-scoring elements

Also consistent with the design of the game, performative challenges (2.2 / 7) were identified as being the least present in the game, with no element scoring higher than (3/7).

Of the other challenge types, certain items also scored lower than the average. In decision making, one item, "There were some decisions in the game that I regretted," scored 1.6/7. Whereas in Emotional challenge two items scored low "The things that happened in the game made me sad" (2.3 /7) "The game involved making moral choices that I didn't agree with" (2/7) the low scores from these areas suggest a game in which the player was comfortable making the moves and did not experience meaningful regrets during play.

The lowest scoring item in cognitive challenge, "I had to memorise a lot of different things when playing the game"(3/7) suggests a game that does not cognitively overload the player.

The results of the CORGIS Survey are consistent with the types of challenges the game was attempting to leverage and consistent with the intended learning goals of the game. The game was cognitively challenging, requiring careful thought and planning while not cognitively overloading the player. The players reported emotional distance in that there were no decisions regretted, and the game, although discussing difficult topics, did not have any moves that made the player sad. It also becomes clear that the game requires the player to take time and consider carefully the implications of each move. The results were supported by observations made during play, which are summarized in Table 1.

4.2 Thematic Analysis

Despite the participants not having familiarity with DIME or PMESII, the analysis showed that players produced concepts that mapped to the frameworks. This suggests that Threat Forge can act as an effective scaffold to support valuable discussions.

DIME framework

The most common move type made within the DIME framework was diplomatic (10 moves in total), which is consistent with the nature of the scenario being discussed. The types of moves made varied from an awareness of the importance of external alliances to the application of sanctions on foreign governments to apply pressure. The Economic sector was also widely discussed (5 moves in total), it was often viewed as the precursor to more heavy forms of conflict. These ranged from the discussion of changes in energy supplies to the discussion of new technologies like quantum computing and their potential influence on society. Direct military action was discussed but was placed later in the timeline, with 4 out of 5 of the moves occurring within the last three events. This showed a clear concept of events escalating up to an active military conflict.

The area least discussed in the Dime framework was information (3 moves), which dealt primarily with propaganda efforts and other informational warfare activities. The number of moves may disguise the importance of the information sphere as the very last serious move was a false flag operation that provided the justification for the invasion.

Several moves were made that did not fall within the DIME framework. Specifically, a long discussion of the internal pressures of ethnic tensions and how this could contribute to the instability leading up to an invasion was not covered by this framework. This is why the author also analyzed the moves using the PMESII Framework.

PMESII Framework

The political, military, information, and economic results have been discussed above.

The game revealed a distinct focus on social and ethnic tensions as an area in which conflict could be fomented. This falls under the social categorization of PMESII (7 moves in total). The players identified the risks associated with policing and civil rights as potential points of conflict. The largest amount of discussion within the game centred on these social issues as players negotiated where they would occur.

The final component of infrastructure was the least discussed by the player (2 moves), the discussion was about a projected cyberattack on the banking system of the smaller country and the physical moving of border markers. It is unclear if the lack of discussion of this area is due to player bias towards other areas or that the players just had not reached a full discussion yet.

All of the moves made within the game had parallels with real-world events, which were often cited by players during their discussions. This shows a willingness to engage with and bring understanding to the game.

Players, even without prior training in these frameworks, naturally considered elements from all aspects of them. This highlights that the game format is consistent with encouraging thought across multiple domains of conflict.

4.3 Observation and Hotwash

During initial rounds players, were hesitant as they began to explore the game space. This may have been due to them being aware of being recorded or uncertainty with how to begin in such an open-ended game. Once several rounds had been completed, the conversation and discussion started to come more easily. During the debrief players recognized this pattern in themselves and suggested running the game on multiple occasions to familiarize them.

Participants identified the game as a method of brainstorming that helped to construct logic chains. They agreed that the game would encourage participants to think about the world and how situations might develop into the future.

After the game had concluded, participants also spontaneously began suggesting other potential topics that they would like to explore using the game. They were particularly interested in the effect of technological changes on the world and suggested running the game again on this topic. Another suggested area was looking at projecting environmental impacts.

The game was thought-provoking enough to have participants spontaneously engage in discussion with the researcher even several days later at a social event that they were all attending.

4.4 Limitations

While the results are promising, the limited scope of the pilot in both size and audience must be recognized. Further work would be needed with larger and more diverse audiences to confirm the findings.

5. Conclusion

In a modern world that is marked by its volatility, uncertainty, and complexity, games can offer a method of building resilience and exploring problems. While traditional games have focused on explicitly defining the problems for a player, narrative co-creation games like Threat Forge allow for a more open scenario. This helps to facilitate deeper engagement and discussion of the key issues.

The results of the formal playtest above also show that the discussion generated was consistent with the PMESII and Dime frameworks. Showing that a wide range of topics can be elicited from the game and that the game produces focused and meaningful responses from the player, even in the absence of formal instruction in the frameworks.

The limitations of this study - its small size and narrow audience- suggest the need for broader testing and validation. Further studies could explore the use of the method to explore different scenarios, such as the impact of technological changes, climate change, or disaster preparation. Further work with different populations may help to extract underlying assumptions in the population or highlight different priorities in focus. Finally, longitudinal studies could reveal the impact of playing games of this sort on planning and preparation.

In conclusion, Threat Forge demonstrates that narrative, co-creative games can serve as a useful addition to both traditional wargames and those engaging in future studies, by offering a method that is both engaging and productive in the discussion that it produces.

Ethics declaration: No ethical clearance was required for this study and the study conformed to the ethical guidelines of Tallinn University.

AI declaration: Ai tools, including Grammarly and ChatGPT4, were used to check the spelling, grammar and phrasing of the above work.

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With or Without You: A Comparison of Single and Multi-Player Game-Related Assessments

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Abstract: As gamification transforms recruitment processes, understanding how different types of *game-related assessments* (GRAs) affect candidate experience becomes crucial. This study investigates candidate responses to two distinct GRA formats implemented in a large-scale, real-world recruitment process for international interns in the food and agriculture sector. The first tool, ClusterMind, is a fully automated game-based assessment requiring individual gameplay. The second, The Collectors, is a collaborative game embedded in an online assessment centre format with real-time interaction among candidates and human assessors observing the gameplay. Data were collected from 434 participants across three consecutive years, including survey responses and open-ended feedback. Results reveal that both assessments were rated favourably, with The Collectors receiving significantly higher ratings (M = 8.91, on a scale 1-10) compared to ClusterMind (M = 7.52), despite being perceived as slightly more difficult. Qualitative analysis confirmed that candidates valued the opportunity for social interaction, teamwork, and self-expression. These aspects appeared to mitigate the perceived pressure of being assessed, fostering a more enjoyable and authentic experience. Additionally, comparison with traditional assessment centre organised in the same recruitment project in previous years illustrates the operational benefits of GRA. Fewer organizational resources are needed, less work time, and greater scalability is available. The number of assessors employed in the process dropped from 90 to 32 in the first year of gamification implementation and 27 in each of the following two years. This research expands the literature on GRAs by evaluating not only different game formats but also the broader recruitment experience. It provides practical implications for organisations and game developers. It supports the notion that different GRA types serve different purposes and that the social context of assessment plays a vital role in candidate engagement. More immersive, automated GBA offer greater scalability and cost-effectiveness, while assessment centres with games as assessment tasks may result in even better candidate experience. Findings encourage the use of blended GRA formats that balance automation with human interaction.

Keywords: Game-Related assessment, Game-Based assessment, Human interaction, Gamification, Assessment centre

1. Introduction

The *Assessment Centre* (AC) has been used in personnel selection since at least the 1950s and remains a widely adopted method for evaluating candidates' potential for managerial and developmental roles. Its validity has been well-documented, with early meta-analyses confirming its effectiveness in predicting job performance (Gaugler et al., 1987).

However, traditional ACs are resource-intensive and logistically complex. A typical session requires a dedicated team of trained assessors, carefully designed assessment materials, and infrastructure such as observation rooms and breakout spaces. These sessions are usually conducted in person and often last several hours or even days, leading to additional costs associated with travel and accommodation. As a result, many organisations have sought more efficient, scalable solutions that retain the diagnostic depth of ACs while reducing time and cost burdens.

One such approach is the use of *game-related assessments* (GRAs), which incorporate elements of gamification into selection procedures. There are numerous published examples of psychometrically valid game-related assessments. GRAs are designed to improve candidate experience (Georgiou & Nikolaou, 2020) reduce faking (Landers & Collmus, 2022) and increase scalability through digital formats and automation (Marengo & Pagano, 2020). The method is used by public and private organizations, and even US Air Force (Wiernik et al., 2022).

GRAs vary in their level of playfulness. The simplest, *soft-gamified assessments* are traditional methods, such as questionnaires, surveys, and situational judgement tests with added game mechanics. *Hard-gamified assessments* (also referred to as *gamefully designed assessments*) have game elements embedded within them in such a way that they cannot be removed without rendering the tool unusable. The most elaborate tools are *game-based assessments* (GBAs). These may incorporate elements of traditional assessments, but the gameplay effectively conceals the assessment aspect, offering a level of immersion comparable to that of commercial entertainment games (Ramos-Villagrasa & Fernández-del-Río, 2023).

Despite the growing interest in GRAs, most research has focused on relatively simple, early-stage digital assessments rather than more complex or socially interactive formats. Furthermore, little is known about how

candidates experience different types of GRAs, particularly those that differ in the degree of automation and human involvement. This is a timely issue, as many organisations are increasingly introducing AI-supported assessments and replacing human evaluators with algorithmic decision-making. Emerging research suggests that these shifts may have unintended consequences for candidate perceptions.

Studies indicate that applicants tend to view human-based or hybrid selection procedures more favourably than those where assessment is based solely on algorithms. AI-driven interviews, for example, have been found to reduce successful applicants' self-efficacy and increase concerns about procedural fairness (Cui et al., 2025), and reduce procedural fairness scores when rejections are issued by an algorithm (Bedemariam & Wessel, 2023).

Köchling et al. (2022) found that AI-supported interviews increased feelings of "emotional creepiness" and reduced perceptions of opportunity to perform, both of which mediated the negative effects of AI on organisational attractiveness. The effect was observed in later stages of the selection process, but not on the earlier stages such as preselection. Similarly, Gonzalez et al. (2021) showed that participants reacted more positively to augmented (human-AI hybrid) and fully human approaches, particularly when they had low familiarity with AI. Attributions of organisational intent is supposed to play a key role in shaping reactions: algorithmic decisions were associated with cost-cutting and exploitation, whereas human decisions signalled commitment to applicant well-being and quality enhancement (Koch-Bayram & Kaibel, 2024).

These findings suggest that not all digital or gamified assessments are perceived equally. Even within GRAs, the degree of human interaction may significantly affect candidate experience. This study examines such differences in a real-life selection context, where two game-related assessments were used as part of an early career recruitment programme. The first tool, ClusterMind, was an individual, automated video game administered online without direct human involvement. The second, The Collectors, was a group task involving live collaboration among candidates and observation by trained assessors in a virtual setting.

The study had two main goals. First, to compare the efficiency and scalability of these tools against a traditional AC format previously used by the same organisation. Second, to explore candidate reactions to both GRA tools, using both quantitative feedback (ratings and difficulty scores) and qualitative feedback (open-ended responses). By examining differences in perception and engagement, this study contributes to the growing literature on GRAs and offers practical implications for organisations seeking to modernise their selection procedures without sacrificing candidate experience.

2. Method

2.1 Recruitment Process

This study examines an annual international recruitment process for an internship programme abroad, co-financed by the European Union. Its primary aim is to facilitate connections between students and organisations in the food and agriculture sector.

The programme is open to students, doctoral candidates, and recent graduates from 25 countries across Southern, Central, and Eastern Europe. Data from selected applicants are shared with the organiser's partners—such as corporations, start-ups, and research institutions based in the EU, who then select future interns from this pre-screened talent pool. Data is reported on the recruitment processes as conducted annually from 2022 to 2024.

The recruitment process is designed to identify promising candidates with limited professional experience. In such cases, CV reviews alone are inadequate for assessing potential. Although a traditional assessment centre was previously employed to evaluate several soft skills, it was considered time-consuming and not engaging. Gamification was proposed to address these limitations.

Two different GRAs were implemented to evaluate candidates' competencies. One was a single-player, online video game, which automatically measures soft skills, ClusterMind. The second, The Collectors, was an online group task delivered via Zoom, facilitated by a gamemaster and including human assessors using traditional assessment centre methodology. The process lasted two weeks and included developmental feedback for candidates. The tools are described in detail below (Table 1), offering insights for researchers, recruiters, and GRA developers.

The process began with a kick-off meeting during which participants were introduced to the assessments, informed of deadlines and technical requirements, and given the opportunity to ask questions. They selected a preferred date for the group task and received a registration link for the individual task.

Prior to the recruitment period, train-the-trainer session was held to prepare assessors, align expectations, and build a shared understanding of the targeted competencies. Assessors also participated in The Collectors to experience the challenges that candidates would later face.

2.2 Individual Task

The first assessment, ClusterMind, is a browser-based video game in which players are immersed in a futuristic science laboratory. They take on rotating roles (e.g., consultant, engineer), each with unique responsibilities. The gameplay is a mix of arcade and real-time strategy mechanics, requiring keyboard and mouse coordination. The core challenge involves managing customer flow and balancing individual tasks with helping team members.

The game was distributed following the kick-off meeting. Participants received individual registration links via email. After completing a demographic survey, they could access the browser-based game, which required no installation. The game began with a mandatory tutorial explaining the plot and mechanics. It could be played multiple times, depending on candidate's needs. The main game is automatically saved, but the participants were encouraged to complete it in a single session (approximately 90 minutes). Personalized feedback report was delivered immediately after completion.

ClusterMind assesses five soft skills grouped into two areas: accountability (self-reliance, initiative, decision-making) and teamwork (goal alignment, inviting collaboration, offering support). Skills are inferred from in-game behaviours and decisions.

Figure 1: Screenshot from ClusterMind

2.3 Group Task

The Collectors, originally developed as a training game, served as the group assessment. Its storyline involves auctioning lost luggage at major international airports. Participants form teams to create and adjust strategies in response to evolving market rules. The game requires strategic collaboration, adaptability, and effective communication.

The game was conducted via Zoom and facilitated by a game master, who introduced the mechanics and the plot. Groups were created, each of approximately eight participants, and up to ten groups running concurrently. After an initial ice-breaker and a test round, participants engaged in three rounds of gameplay, each representing a different airport with a unique scoring system. Teams had 15 minutes to prepare a shared strategy before returning to the main room to bid individually in the auction. A leaderboard was shown after each round.

Trained assessors observed behaviours linked to communication, leadership, and problem-solving. These behaviours were discussed and evaluated on a 3-point scale after the game. Competency definitions and assessment criteria were provided to assessors beforehand.

2.4 Game-related Assessments Comparison

Although both tools are GRAs, they differ significantly. Most notably in the presence of human interaction. The table below summarises key features of each tool.

Table 1: Characteristics of *ClusterMind* and *The Collectors* according to Bedwell et al.'s (2012) taxonomy

Category	ClusterMind	The Collectors
Action language	Player controls a character using keyboard and mouse.	Players vote during auctions and discuss strategy with teammates.
Assessment	Data collected on decisions, actions, and in-game survey responses.	Human assessors evaluate observable behaviours using a structured document.
Conflict / Challenge	Serving customers across four areas, prioritisation, and working under time pressure.	Creating and adjusting group strategy in a dynamic environment.
Control	Players take on four different roles, each round controlling a different role. Actions are specific to each role and include manual and automated customer service, restoring energy, and generating customers.	Players use a website to select auction options. Their individual choices affect the scores of the whole team.
Environment	A futuristic research lab, where students, businesspeople and astronauts are served by a group of characters with complementary skillsets.	Each round takes place on a different airport. Players become teams of traders looking to maximize their profit during lost luggage auctions.
Game fiction	The game plot is abstract. Prior knowledge doesn't provide an advantage. The core challenge is workflow management, as several roles possess unique features and must cooperate.	The plot is similar to some TV shows, but this kind of work remains abstract for ordinary people. Prior knowledge doesn't help, as the auction rules are specific to the game.
Human interaction	Single-player mode. Other characters appear as potential playable roles but are controlled by AI.	Game is played in groups, during a ZOOM meeting. All the players are real people, other candidates. Participants cooperate with their teammates and compete with other teams.
Rules / Goals	The goal is to serve all the incoming customers while maximizing profit. The player is made aware of the rules through a tutorial and a test game before starting the main part.	The goal is to maximize the profit from all three auctions and outrun other teams. The players are made aware of the rules through a tutorial and a test game before starting the main part.

3. Results

3.1 Comparison with Traditional Assessment

Before gamification was introduced, traditional assessment methods were used for two years. In total, 434 candidates participated in these assessments. In 2020, 15 assessment sessions were held, and in 2021, 12 sessions took place. Each session lasted more than three hours and involved up to 10 assessors. The total number of assessors was 106 in 2020 and 90 in 2021. Three separate kick-off meetings were conducted prior to the sessions. Additionally, analytical and mathematical tests were administered, with an average completion time of approximately 30 minutes.

The use of GRAs enabled the process to scale. The number of candidates increased, reaching 319 in 2024. At the same time, the number of assessors required decreased to 32 in the first year of implementation and 27 in each of the following two years.

The time commitment required from each candidate was also reduced. In the game-related assessment scenario, candidates participated in a two-hour kick-off meeting, the individual task ClusterMind (two hours), and the group task The Collectors (two hours). Assessors attended a two-hour 'train-the-trainer' session and subsequently participated in the assessments.

3.2 Feedback

3.2.1 Quantitative feedback

Candidate reaction surveys were gathered after the assessment sessions, with 126 responses in 2022, 112 in 2023, and 212 in 2024. The summarized data was analysed. As the data was gathered on the same sample and regarded two different elements of the same process, Wilcoxon signed-rank test was used to check if there are differences in candidates ratings of both tools and their perceived difficulty.

Candidate reaction surveys were collected following the assessment sessions, with 126 responses in 2022, 112 in 2023, and 212 in 2024. The aggregated data were analysed. The Wilcoxon signed-rank test was used to examine whether differences existed in candidate ratings of the two tools and their perceived difficulty.

Participants rated The Collectors more favourable, M = 8.91, SD = 1.46, than ClusterMind, M = 7.52, SD = 2.23. The difference was statistically significant (Z = -5.69; p < .001). There was also a difference in perceived difficulty (Z = -3.47; p <.001), with The Collectors (M = 6.79; SD = 1.73) seen as a slightly more difficult than ClusterMind (M = 6.45; SD = 2.1).

These results suggest both tools were positively received, with The Collectors rated more favourably despite its slightly higher perceived difficulty.

3.2.2 Qualitative feedback

Open-ended questions were used to gather qualitative data. Participants were asked: “Please share your thoughts on the recruitment process,” and “If you could change one thing about the Assessment Centre meeting, what would it be?”

Many respondents valued the game-based structure, noting that it helped them show teamwork, communication, and problem-solving skills. Some also reported gaining personal insights. For example, one candidate stated: *“I think this online infrastructure is great, can be considered more playful and efficient ways of getting to know the talents.”* Others expressed gratitude for the individual feedback provided after completing ClusterMind: *“I appreciate the fact that you gave us feedback after the individual task.”*

A few respondents expressed scepticism about the validity of game-related assessments*: “The ClusterMind could be a bit biased towards people who regularly play video games.”*; *“I think it depends on luck more than assessing abilities.”* The group task was mentioned more frequently, and typically in a positive context.

hen asked about potential improvements to the assessment process, a significant number of participants (over a third) expressed strong satisfaction, often stating that they would not change anything. Descriptions such as “fun”, “well-organised”, and “refreshing” were commonly used. The structure and preparation were praised, and the use of games was perceived as a fresh and enjoyable change from traditional methods. Participants appreciated the opportunity to meet other candidates, and several suggested incorporating more social interaction, such as pre-meetings with teammates, longer debriefings after sessions, or the ability to exchange contact information: *“I enjoyed it, met and exchanged contacts with great people.”*; *“I had a lot of fun and I met amazing people.”*

Some areas for improvement emerged. A few respondents suggested that the groups should be smaller and more diverse in terms of nationality and gender. Others recommended allocating more time for group discussions in *The Collectors*. For some, *ClusterMind* was confusing or not perceived as a valid assessment method. There were also concerns about whether the games might favour extraverted individuals or those who respond quickly under pressure.

Overall, the sentiment was largely positive. Critiques were constructive and often accompanied by expressions of appreciation and gratitude.

4. Discussion

This study adds to the growing body of literature on GRAs in recruitment by examining two contrasting approaches implemented in a real-life, international selection process. The findings provide insights into how applicants perceive different types of GRAs, underscoring the importance of human interaction, the format of the assessment, and the broader context in which the tool is embedded.

One of the most important findings was that although both used games were well received by the candidates, they preferred The Collectors, an online assessment centre incorporating a playful, cooperative group task,

over ClusterMind, a fully automated, immersive game-based assessment. This was true even though The Collectors was slightly more challenging, as rated by participants. Qualitative feedback highlighted the value of meeting other candidates, collaborating on tasks, and being observed by assessors, all of which contributed to a more engaging and motivating experience. These results align with previous research suggesting that human involvement and social interaction improve applicants' perceptions of recruitment processes (Köchling et al., 2022; Gonzalez et al., 2021).

The Collectors represents a relatively rare example of a GRA that does not rely on a videogame or algorithmic evaluation, but rather uses a traditional assessment centre structure, conducted online, with a game as the central task. Combined with the automated assessment represented by ClusterMind, the hybrid approach appears to successfully combine the benefits of gamification (e.g., increased engagement, immersion) with the strengths of human-led assessment (e.g., richer social cues, perceived fairness, contextual judgement). The results suggests that candidates may respond more positively when they feel they are being evaluated in a social context, even when competing for the same positions. In this case, the presence of other participants seemed to shift attention away from the evaluative nature of the process, making the experience more enjoyable and less stressful.

The comparison between The Collectors and ClusterMind illustrates a broader need to differentiate between types of GRAs. Presented study supports the view that GRA is not a single, homogenous category, but a spectrum ranging from soft-gamified questionnaires to fully immersive game-based assessments (Ramos-Villagrasa & Fernández-del-Río, 2023). Although it's not clear which type The Collectors would be classified to, but due to the traditional method of assessment it seem to lie within soft-gamification category. Each type of GRA may serve different organisational purposes and evoke different candidate experiences. Practitioners should therefore be equipped with clear, evidence-based guidelines to help select the appropriate type of GRA depending on the recruitment goal, whether that is improving engagement, increasing standardisation, reducing costs, or identifying specific skills.

While automated assessments offer scalability, efficiency, and standardisation, they may compromise candidates' satisfaction with the process in comparison with assessments involving social interaction. This echoes previous research on interviews, showing that AI-driven or algorithmic processes can lead to lowered applicant reactions, especially when perceived as overly mechanistic or impersonal (Bedemariam & Wessel, 2023; Cui et al., 2025). That being said, it is important to highlight that in the presented research both assessment tools were rated favourably.

The strength of this study lies in its ecological validity. The data were collected from a real selection process involving a large sample of international candidates over three consecutive years. Moreover, the novelty of *The Collectors* as an online, assessor-led group task adds a valuable contribution to the literature on gamified assessments, which so far has focused on tools in the form of applications.

However, the study also has limitations. First, the two games assessed different competencies, which limits the extent to which they can be directly compared in terms of predictive validity. Second, while both quantitative and qualitative feedback was gathered, the amount of structured data was limited, and reactions were not mapped onto established theoretical models such as applicant reactions model (Hausknecht et al., 2004; Bauer et al., 2001; Ryan & Ployhart, 2000) or technology acceptance model (Marangunić & Granić, 2015). Third, the candidate pool consisted primarily of young students, many of whom were in the food and agriculture sector, which may restrict the generalisability of the findings. Finally, while a previously used traditional assessment centre is referenced, limited data about it were available, and the comparison was therefore restricted to logistical and experiential aspects.

Other potential confounding factors should also be considered, such as individual personality traits. In assessment centres, assessors often record not only behavioural observations but also trait-based impressions (Lievens et al., 2001). However, findings regarding which traits are favoured remain mixed. Furnham et al. (2008) found that only openness correlated with assessment outcomes, while Spector et al. (2000) identified correlations between extraversion, openness, emotional stability, and performance in interpersonal tasks. The present study focused on the practical implementation of a mixed-method game-related assessment, and did not include personality measures. It is plausible that the methods employed produced similar levels of trait-related bias as traditional assessment centres, or potentially lower, due to the immersive and enjoyable nature of the assessment tasks.

Another concern relates to demographic variables, particularly differences in age and gaming experience. Traditional assessment methods, such as questionnaires and structured interviews, are more familiar to a wide range of candidates, particularly older or more experienced ones. By contrast, game-related assessments may disadvantage individuals with limited gaming experience. In the current study, the participants were students and recent graduates, and thus relatively homogeneous in age and digital literacy. While ClusterMind, a single-player video game, might favour candidates with prior gaming experience, this was mitigated by an interactive tutorial. The Collectors relied on verbal collaboration and was unlikely to be influenced by gaming experience. As such, the assessment process described here is likely to be less biased against non-gamers than a purely digital GBA, though possibly more so than a conventional assessment centre. Future research should examine how gaming experience and age influence performance and perceptions across various GRA formats.

This research demonstrates that candidate experience in GRA is shaped not only by the content and difficulty of the assessment, but by its format, social dynamics, and degree of human interaction. These results suggest that the social component of assessment centres, even in online formats, may significantly enhance engagement and distract from performance pressure. It allows the candidates to enjoy the process. While automated GRAs offer benefits in terms of scalability and cost-efficiency, our findings indicate that human-led, socially embedded tools may be slightly more favourably received. This effect was observed regardless of the multiplayer task being rated as more difficult. The practical implications are suggested for both assessment designers and employers seeking to optimise candidate experience in the context of fair, effective, and engaging recruitment. The presented results help practitioners to navigate in GRA tools and to choose the best suited tool depending on the needs.

Ethics Declaration: Ethics clearance was not required for the described research.

AI Declaration: AI tools were not used in the creation of the paper.

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Light Up: Educational Board Games with FLOW and Experiential Learning Theory

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Abstract: Games are powerful educational tools that enhance engagement, active learning, and problem-solving. While many sciences educational board games aim at teaching science concepts, they often struggle to sustain student interest. Integrating FLOW Theory with Experiential Learning Theory (ELT) in science board game design can create a more engaging and cognitively enriching learning experience. “Light Up" is a science educational board game designed based on FLOW Theory and Experiential Learning Theory. The game aims to help students understand the impact of carbon dioxide emissions from fossil fuel power plants. In the game, players need to strategize electricity production between coal-fired plants and wind power plants to supply electricity to a growing city. The cost of the power plants, the social cost and the environmental cost are part of the game as well as the interaction between players that simulate the current CO_2 situation among all countries. The Video Game Dispositional FLOW Scale (VGDFS) was chosen to measure the FLOW state of the gameplay. Participants were asked to evaluate VGDFS after the gameplay. Qualitative data from student interviews will reflective process, students were able to connect their in-game experiences to real-world concepts. Preliminary results reveal that students experienced FLOW, characterized by deep concentration, enjoyment, and challenge. Through qualitative interviews, students' immersion and engagement during gameplay were examined. The study found a positive correlation between FLOW states and learning achievement, emphasizing the potential of immersive gaming experiences to enhance education.

Keywords: Educational board game, FLOW and Experiential learning theory

1. Introduction

Games have long been valued as educational tools, offering interactive and engaging ways to learn (Gee, 2003). Unlike traditional lectures, games promote active participation, problem-solving, and decision-making, which enhance understanding and retention. Board games have been widely used across subjects, but many fail to sustain student engagement due to their lack of immersion and excitement, leading to reduced motivation and learning outcomes.

A key difference between highly engaging online games and educational games is the ability to induce FLOW—a psychological state of deep focus, enjoyment, and immersion (Csikszentmihalyi, 1990). FLOW occurs when challenge and skill are balanced, feedback is immediate, and players feel control over their actions (Cowley et al., 2008). FLOW has been shown to boost student engagement, persistence, and active participation (Hamari et al., 2016). However, educational board games often lack dynamic challenges, immediate feedback, and clear goals, limiting their ability to sustain FLOW and causing boredom and disengagement.

To address this, our project integrates FLOW Theory and Experiential Learning Theory (ELT) in designing *Light Up*, a science board game. FLOW Theory emphasizes deep immersion and enjoyment, while ELT focuses on learning through experience, reflection, conceptualization, and experimentation. Combining these frameworks, *Light Up* aims to enhance cognitive engagement and deepen science understanding.

The project’s objectives are: (1) to design an educational board game applying FLOW and ELT principles for an immersive learning experience; (2) to help students understand the environmental impact of electricity production, especially carbon dioxide emissions from fossil fuels; and (3) to evaluate *Light Up*’s effectiveness in promoting FLOW and improving science learning outcomes.

The study addresses these research questions:

RQ1. How does the FLOW experience differ between general games and science educational board games?

RQ2. How can a high-FLOW science educational board game be developed in a science context by integrating FLOW Theory and Experiential Learning Theory (ELT)?

RQ3. How does the FLOW experience change after enhancing FLOW elements in an existing science educational board game?

2. Literature Review

FLOW Theory

FLOW Theory, introduced by Mihaly Csikszentmihalyi, refers to a state of optimal experience in which individuals become deeply engaged and intrinsically motivated while performing an activity. This state is characterized by intense focus, a sense of control, and enjoyment that makes the activity feel rewarding on its own. FLOW arises when there is a balance between the challenge of the task and the individual's skill level—too little challenge leads to boredom, while too much causes anxiety. Csikszentmihalyi (1990) identified nine dimensions of FLOW: clear goals, immediate feedback, challenge-skill balance, merging of action and awareness, concentration, loss of self-consciousness, a sense of control, transformation of time, and autotelic experience.

Recent research has applied FLOW Theory to board game design to foster engagement and learning. Nauert et al. (2025) developed a FLOW-based mathematics board game for Thai primary students, incorporating clear goals, immediate feedback, and balanced challenge. Their study reported improvements in both achievement and motivation. Similarly, Chang et al. (2022) designed a chemistry game that induced high FLOW states, finding that wooden game tokens enhanced immersion through tactile experience. Chou and Chang (2023) examined FLOW in a university-level media literacy board game, comparing competitive and cooperative play. Both formats enhanced FLOW and learning outcomes, demonstrating the versatility of FLOW-based design. Tsai and Lin (2021) emphasized FLOW's role in mediating situational interest, suggesting that FLOW-enhancing mechanics help sustain engagement and reduce cognitive overload.

In summary, FLOW Theory offers a strong framework for designing engaging educational experiences through optimal challenge, clear goals, and feedback. Its use in board games has yielded promising results in motivation and learning across subjects. By promoting deep focus and enjoyment, FLOW-based games create immersive environments that sustain engagement. These findings underscore FLOW Theory's potential as a design principle for effective and meaningful educational games.

Experiential Learning Theory (ELT)

Experiential Learning Theory (ELT) provides a foundational framework for understanding how learners acquire knowledge through active engagement, reflection, and application (Kolb, 1984). This theory has been increasingly adopted—explicitly or implicitly—in the design of educational games. Many game-based learning approaches follow the experiential learning cycle, even if not explicitly labeled as ELT.

Alarcón et al. (2024) developed an escape-room style physics board game where players engaged in hands-on problem-solving and iterative challenges—concrete experiences that stimulated reflection and conceptual understanding, aligning with Kolb's model. Similarly, Chou and Chang (2023) incorporated structured debriefing activities after gameplay to support reflective learning and connect game experiences with real-world applications, aligning with the reflection and abstraction stages of ELT. Gee (2003) also argues that well-designed games naturally foster active learning through immersive problem-solving, reinforcing the situated nature of experiential learning.

In conclusion, ELT offers a robust foundation for designing educational games that promote meaningful learning through action, reflection, and application. Its alignment with game-based learning—whether explicitly acknowledged or not—demonstrates the theory's versatility and relevance. As shown in recent studies, integrating hands-on challenges and structured reflection deepens understanding and enhances engagement. These insights highlight ELT's enduring value in shaping educational experiences that are not only informative but transformative.

Integrates FLOW Theory and Experiential Learning Theory (ELT) into educational board game

This study proposes a novel game-based learning model that intentionally integrates FLOW Theory and Experiential Learning Theory (ELT) into both game mechanics and the learning cycle. While previous research has explored FLOW to enhance engagement or ELT to support reflection, few studies have systematically combined both theories in the design of educational board games. This research addresses that gap by developing a science-themed board game embedding FLOW elements (e.g., clear goals, challenge-skill balance, immediate feedback) within gameplay, while aligning ELT stages—Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation—with the game's progression and post-play reflection. The dual-theoretical framework aims to foster both deep engagement and meaningful learning.

In recent years, FLOW and ELT have been applied to digital and non-digital game design to create immersive, motivating experiences. Games that support FLOW can improve focus, persistence, and learning outcomes. Research such as Kiili et al. (2012) and Kiili (2005) demonstrates how games can be intentionally structured to promote FLOW by aligning challenge with player skills and providing timely feedback. Kiili's "Experiential Gaming Model" integrates FLOW and ELT by guiding learners through cycles of meaningful challenges, feedback, and opportunities for reflection and experimentation. These studies highlight ELT's compatibility with game-based learning and its potential for creating effective educational experiences.

Integrating FLOW and ELT offers a powerful approach to educational board game design. FLOW enhances emotional engagement and sustained attention, while ELT ensures reflection and real-world application. Although few empirical studies have implemented this integration, its theoretical synergy is well supported. This study builds on Kiili's conceptual model by applying it in practice, designing a board game that incorporates FLOW elements and ELT stages to support both cognitive and affective engagement.

3. Methodology

The research study on the *Light Up* educational board game employed a pre-experimental design (T1L X T2F T2L), which allowed for the assessment of both learning outcomes and FLOWFLOW experiences among the participants. This design aimed to capture the impact of the game on students' engagement and their understanding of energy concepts.

Table 1 Research Design.

T1L	X	T2F	T2L

- **T1L** represents the pre-test of learning outcome before using the science educational board games
- **X** represents the instructional intervention using the science educational board games
- **T2F** represents the FLOWFLOW assessment (VGDFS) after using the science educational board games
- **T2L** represents the post-test of learning outcome after using the science educational board games

Table 1 outlines the research phases aligned with both FLOW Theory and Experiential Learning Theory (ELT). The Pre-Test (T1L) gauges students' initial knowledge, representing ELT's Concrete Experience stage. The Intervention (X) involves playing *Light Up*, providing an immersive learning experience that fosters FLOW components like Challenge-Skill Balance, Clear Goals, and Unambiguous Feedback, while also reflecting ELT's Active Experimentation. The Engagement Phase (T2F) uses VGDFS to measure FLOW experiences during gameplay. Finally, the Post-Test (T2L) assesses knowledge gained, aligning with ELT's Reflective Observation and Abstract Conceptualization stages. Together, these phases demonstrate how the gameplay fosters both FLOW engagement and experiential learning.

3.1 Participants

Fifty students from grades 4–9 participated in this study during the first semester of the 2025 academic year. This diverse age range provided a broad perspective on the effectiveness of the *Light Up* game across different educational stages.

3.2 Instruments

The study utilized several instruments to collect data and evaluate the effectiveness of the *Light Up* board game

3.2.1 Educational Game – "Light Up"

FLOW Theory, plays a central role in shaping the game mechanics. It emphasizes the importance of achieving a balance between challenge and skill, which is key to fostering deep concentration, enjoyment, and immersion in an activity. *Light Up* is designed to create a balance between challenge and skill through several key approaches. The game is designed with a gradually increasing level of difficulty, beginning with simple scenarios—such as managing a small number of power plants—and progressively introducing more complex elements, including environmental costs and global events. It incorporates complex decision-making paired with immediate feedback; players must choose between coal or wind energy and instantly see the outcomes, such as changes in CO_2 emissions or the number of houses receiving electricity. This design ensures that challenges remain engaging yet manageable. The ability to replay the game allows students to deepen their understanding and develop increasingly effective strategies. Additionally, multiplayer interaction introduces unpredictability and dynamic challenges, requiring constant adaptation and strategic thinking. These aspects

help maintain an optimal FLOW experience, where players are challenged but not overwhelmed or bored. Carefully crafted game mechanics keep players within this FLOW zone, fostering concentration, motivation, and active engagement in learning through gameplay.

Experiential Learning Theory (ELT), developed by David Kolb (1984), outlines a four-stage learning cycle that emphasizes learning through direct experience(Kolb, 1984). *Light Up* incorporates these stages into its game design to enhance educational outcomes. The first stage of Experiential Learning Theory, Concrete Experience, takes place during gameplay as players make strategic decisions and interact with core game mechanics such as managing the recurring fuel costs of coal-fired power plants, which increase significantly when generating electricity for a large number of houses, unlike wind power plants that have no such ongoing costs. The second stage, Reflective Observation, occurs during post-game discussions, where players analyze their decisions and outcomes. For example, they may come to realize that although coal power appears cost-effective in the short term, it leads to higher long-term expenses—especially when event cards like coal shortages cause fuel prices to spike. The third stage, Abstract Conceptualization, enables players to connect their in-game experiences to broader scientific and environmental concepts, gaining a deeper understanding of the long-term economic and ecological impacts of different energy sources. Finally, the Active Experimentation stage encourages players to apply newly developed strategies in subsequent rounds—such as switching to wind power after accumulating enough money in order to reduce future fuel costs and emissions. By incorporating all four stages of the learning cycle, Light Up promotes deep engagement and meaningful understanding, allowing players to explore complex concepts through immersive and enjoyable hands-on experiences

Game Concept: "Light Up" – A Strategic Exploration of Energy Choices

In Light Up, each player takes on the role of a mayor of a city on an island, tasked with supplying electricity to their citizens while keeping carbon dioxide emissions within the designated limits. All players begin with an equal budget and must strategically choose between building coal-fired power plants, which are less expensive but polluting and require ongoing fuel costs, or wind power plants, which are more environmentally friendly but have higher construction costs. Players earn income each round by successfully providing electricity to their population. However, failure to meet the city's energy needs results in citizens migrating to other cities, while fully meeting demand leads to population growth. Carbon dioxide emissions from all players are collectively tracked, and if the total exceeds the allowed threshold, it negatively affects everyone. The game ends when a player accumulates the target amount of income while maintaining emissions within the acceptable range; if emissions exceed the limit, all players lose. The game encourages strategic decision-making about energy and environmental responsibility. The central challenge of the game lies in balancing energy production from two contrasting sources: coal-fired power plants and wind power plants. Players must carefully consider not only the cost of energy production but also the environmental impact and social consequences of their decisions, reflecting real-world dilemmas faced by energy planners globally.

The game is thoughtfully designed with several key features that enhance the learning experience for players. First, it presents strategic decision-making under various constraints. Players must generate enough electricity to meet the needs of citizens while navigating the complexities of energy production. Each type of power plant offers distinct advantages and limitations, requiring players to carefully manage resources and consider the environmental impact of carbon dioxide emissions. This scenario mirrors real-world challenges faced by energy policymakers and planners. Additionally, Light Up incorporates interactive gameplay that emphasizes the dynamics of international cooperation and competition in addressing carbon emissions. Since carbon dioxide from all players is accumulated as a collective total, the game highlights the interconnectedness of energy choices and their global environmental consequences. Moreover, the game includes dedicated phases for reflection and discussion, encouraging players to critically evaluate their decisions, share insights, and deepen their understanding through experiential learning. For example, players are prompted to reflect on the long-term costs of different energy sources—coal-fired power plants require ongoing coal expenses, unlike wind power plants which incur no fuel cost. Over time, coal becomes more expensive, and its emissions impact everyone in the game, reinforcing the idea that individual actions can have collective consequences. These reflective elements are essential to achieving the game's educational objectives, creating a well-rounded experience that integrates action, reflection, and meaningful learning.

Table 2: Integrates FLOW Theory and Experiential Learning Theory (ELT) into Light Up board game

FLOW Component	ELT Stage	Game Design Application
1.Optimal Challenge	Active Experimentation	Players apply strategies to solve challenges with increasing difficulty,

FLOW Component	ELT Stage	Game Design Application
		encouraging trial and error without overwhelming or boring them.
2. Clear Goals	Concrete Experience	Each game turn or mission presents specific and visible objectives that guide players toward purposeful activity.
3. Immediate Feedback		Additionally, real-time updates provided by the game mechanics support reflection after gameplay, reinforcing learning through feedback and experience.
4. Distraction-Free		The game design minimizes unnecessary complexity and external interruptions, allowing for uninterrupted engagement in learning tasks.

Figure 1: Game Setup: This figure shows the initial setup of Light Up. Each player gets a city board, starting budget, residential houses, and coal-fired and wind power plant options. Components are arranged on the table, highlighting readiness for strategic decisions. This phase helps players understand their resources and choices for the game

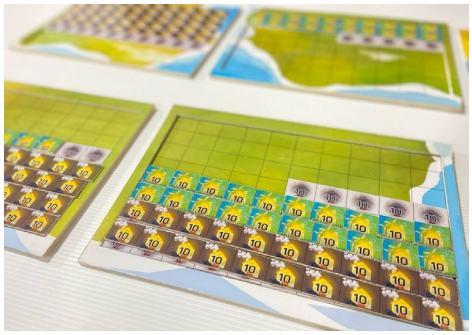

Figure 2: Power Plant Placement: This figure shows a player's city board with power plants placed over houses, indicating those homes receive electricity. Players decide based on budget and strategy—coal plants are cheaper but have fuel costs and pollution, while wind plants cost more but are eco-friendly with no operating costs. The image highlights resource allocation and strategic thinking in the game

Figure 3: CO_2 Emission Board: This figure shows the central CO_2 Emission Board tracking rounds and total carbon emissions from all players each turn. A marker indicates cumulative CO_2 from coal power. When emissions pass a threshold, a scenario card triggers global effects impacting all players. The image emphasizes how individual actions collectively affect the environment

This board game challenges students to manage electricity supply for a growing city using coal-fired and wind power plants. Players must balance costs, social and environmental consequences, and navigate international CO_2 scenarios. The game was developed through a rigorous process, including:

- A literature review on FLOW Theory and ELT.
- Feedback from experts and iterative revisions of the game design.
- Prototype Development: Create a prototype and refine it through playtesting. Try-outs with a pilot group, followed by final adjustments based on student interactions and advisor recommendations.

Game Design:

- Clear Goals: Set clear objectives for players (e.g., efficient energy production).
- Balance of Challenge and Skill : Incorporate challenges that match player skills.
- Immediate Feedback: Provide immediate responses to player actions.
- Playability : refers to how enjoyable, accessible, and functional a game is for players. It's a key concept in game design and evaluation, especially when designing educational games.

3.2.2 VGDFS (Video Game Dispositional FLOWFLOW Scale)

The VGDFS (Cai et al., 2022) was chosen for its specific focus on measuring the dispositional FLOWFLOW state in the context of video games. This scale provides a comprehensive assessment of the player's experience and includes several dimensions of FLOWFLOW. This instrument was employed to assess the nine dimensions of the FLOWFLOW experience: Challenge-Skill Balance (CSB), Clear Goals (CG), Unambiguous Feedback (UF), Concentration (CON), Action-Awareness Merging (AAM), Loss of Self-Consciousness (LSC), Sense of Control (SC), Transformation of Time (TT), and Autotelic Experience (AE). The scale utilizes a five-point Likert format, ranging from 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral), 4 (Agree), to 5 (Strongly Agree).

3.2.3 Learning outcome questionnaire

Developed to assess students' understanding of energy in daily life, this questionnaire underwent a comprehensive development process. It included an analysis of curriculum objectives, a literature review on learning assessment, validation by experts and advisors, and pilot testing for reliability.

3.3 Data Collection Procedure

The data collection process was structured as follows:

- Students completed a pre-test to assess their baseline understanding of energy concepts.
- They played the *Light Up* board game over 2–3 sessions, each lasting 30–40 minutes.
- After gameplay, students completed the VGDFS to assess their FLOW experiences.
- Students completed a post-test to measure any changes in their understanding of energy concepts.
- Semi-structured interviews were conducted to gather qualitative insights into students' learning experiences and their perceptions of the game.

3.4 Data Analysis

The data analysis involved both quantitative and qualitative methods:

- Quantitative Analysis: A comparison of pre- and post-test scores was conducted, along with an analysis of VGDFS component scores to measure the impact of the game on both FLOW experiences and learning outcomes.
- Qualitative Analysis: A thematic analysis of student interview data was performed to identify common perceptions of engagement, FLOW experiences, and conceptual understanding gained through the game.

Through this methodology, the study aimed to assess how the *Light Up* board game influenced students' learning and engagement, particularly in relation to energy concepts and environmental awareness.

4. Results

The results from the VGDFS (Video Game Dispositional FLOW Scale) revealed the following average scores across the nine FLOW dimensions.

Table 3: The results from the VGDFS.

FLOWFLOW dimensions	Result of Light Up
Challenge-skill balance (CSB)	4.18
Clear goals (CG)	4.56
Unambiguous feedback (UF)	4.40
Concentration (CON)	4.29
Action-awareness merging (AAM)	4.26
Loss of self-consciousness (LSS)	4.19
Sense of control (SC)	4.33
Transformation of time (TT)	4.42
Autotelic experience (AE)	4.47
Average	4.35

These preliminary findings indicate a promising trend in both student engagement and learning. Students reported experiencing a clear sense of FLOW during gameplay—particularly highlighting deep concentration, enjoyment, and a strong sense of control over their decisions. These elements align well with the core principles of **FLOW Theory**, which emphasizes full engagement and a balance between challenge and skill to sustain attention.

In addition, the post-game test results demonstrated a statistically significant improvement in students' understanding of energy-related concepts. This suggests that *Light Up* is effective in enhancing scientific knowledge, particularly regarding electricity generation, energy sources, and environmental impacts. Interview data further supported these findings. Students exhibited high levels of engagement during gameplay. For example, one student commented.

Table 4: Mapping Student Reflections to ELT Phases

Quote from Student Interview	ELT Phase	Explanation
"In the following rounds, once enough money has been accumulated, players may switch to coal-fired power plants to quickly generate income without incurring high production costs."	Abstract Conceptualization (AC)	Student shows strategic thinking and understanding of trade-offs between cost and production.
"While coal plants are effective for short-term profit, they are not suitable for long-term use due to their environmental impact and recurring fuel expenses."	Reflective Observation (RO)	Student reflects on cause-effect relationships and internalizes long-term consequences.
"At first, I thought the game was only about competition, but after a while, everyone had to work together to reduce CO_2."	Concrete Experience (CE) → Reflective Observation (RO)	Shift from individual to group goal awareness shows deeper engagement and cooperative learning.
"The student helping to reduce CO_2 said those who didn't were selfish and made everyone else suffer."	Reflective Observation (RO)	Social and ethical reflection occurs; student perceives interconnected consequences.
"If another city does not release carbon dioxide above the standard, my city will win because I plan to use clean energy. However, carbon dioxide levels exceeded the standard before I could switch from coal power plants to wind turbine power plants. In the next round, I hope everyone will help to reduce carbon dioxide emissions."	Abstract Conceptualization (AC) → Active Experimentation (AE)	Student realizes limitation of individual action and anticipates future group behaviour.

Quote from Student Interview	ELT Phase	Explanation
"I will change my strategy in the next round to use more clean energy because my people were affected when carbon dioxide levels exceeded the standard."	Active Experimentation (AE)	Student adapts strategy to avoid repeated failure — shows application of learned concepts.
"I didn't want to stop; I didn't even realize how much time had passed."	Concrete Experience (CE)	Student fully immersed in gameplay; time distortion is a strong FLOW indicator.

These reflective comments highlight the importance of post-game reflection—an essential element of **Experiential Learning Theory (ELT)**. Through this reflective process, students were able to connect their in-game experiences to real-world concepts. The interviews reveal that the game not only fostered active participation but also promoted meaningful reflection, deepened learning, and enhanced conceptual understanding.

5. Discussion

The integration of **FLOW Theory** and **Experiential Learning Theory (ELT)** significantly enhanced the learning outcomes associated with the *Light Up* educational board game. The game was carefully designed to maintain a balance between challenge and skill, offer meaningful choices, and encourage reflective thinking—factors that support both FLOW experiences and the comprehension of scientific concepts.

This study also underscores the value of embedding reflective learning activities directly into the game structure to strengthen knowledge retention. Game rules were designed so players understood the goals clearly, had direction, and never felt uncertain about how to play.

The game set both short-term goals—such as supplying electricity to keep up with population growth—and long-term goals—like accumulating enough money through electricity sales while avoiding excessive carbon dioxide emissions. Players received immediate and clear feedback on their progress toward these goals, which helped guide their strategic adjustments. For example:

- Players earned money when they supplied power to citizens.
- Population increased with consistent power supply.
- Wind power plants did not emit CO_2.
- Citizens decreased in number when power was not supplied.
- CO_2 levels increased when coal-fired plants were used.
- The cumulative CO_2 level was shown at the end of each round, with environmental consequences.

The game's challenges were carefully matched to player skill levels. For instance, players needed to anticipate how others' actions might impact them—such as rising CO_2 levels affecting the entire group. They also had to strategize to meet financial goals before other players.

The game required decision-making skills (e.g., choosing between different power plant types, weighing their advantages and limitations), money management, and planning to ensure full energy distribution without exceeding CO_2 limits.

Additionally, the game demonstrated strong **playability**, combining technical performance, interactive design, and game mechanics to create an engaging experience. *Light Up* encouraged experimentation with different strategies. A key mechanic required players to collectively manage CO_2 emissions, creating shared consequences that impacted all players. Players also had autonomy in their choices, including whether or not to purchase power plants, reinforcing freedom within the gameplay.

The findings from this study suggest that Light Up holds strong potential for use not only within formal educational settings but also in informal learning environments, driven by students' interests. Many participants expressed a desire to continue playing the game during their free time, citing its engaging mechanics, relatable themes, and opportunity for strategic thinking. This indicates that Light Up has the capacity to bridge formal and informal learning by aligning with students' intrinsic motivation—an important factor emphasized in both FLOW Theory and Experiential Learning Theory.

By integrating gameplay into extracurricular clubs, science camps, or community-based environmental activities, Light Up can foster deeper interest in sustainability and energy issues in a way that feels voluntary

and enjoyable. The game's real-world relevance and immediate feedback allow players to continuously experiment with new strategies, reinforcing their understanding of complex environmental concepts outside the classroom context. Furthermore, in non-formal settings, students are more likely to take initiative, collaborate with peers across age groups, and explore broader discussions—such as the impact of energy choices on global climate policy or local environmental challenges—thus expanding the depth and application of their learning.

In essence, Light Up supports a flexible and learner-centred approach, offering meaningful educational experiences that extend well beyond traditional instruction. Encouraging its use in student-led or interest-based settings can not only enhance engagement but also contribute to long-term awareness and action regarding sustainable energy use.

6. Conclusion and Recommendations

Light Up demonstrates that well-designed educational board games grounded in **FLOW Theory** and **Experiential Learning Theory (ELT)** can significantly boost student motivation and promote deep learning. The findings support the integration of realistic, experience-based games in science education, especially for complex topics like sustainability and energy. Moving forward, the game content will be expanded, game mechanics refined based on user feedback, and long-term studies will be conducted to evaluate the retention of learning outcomes over time.

Ethics declaration: Ethical clearance was not required, as the research involved teaching practices commonly used by educators.

AI declaration: In the preparation of this paper, AI tools were used to assist with English translation and language refinement. The use of AI was limited to linguistic support only; all ideas, analyses, and interpretations presented in this paper are the original work of the author.

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A Pilot Study Investigating Teachers' use of Video Games in Programming Lessons

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Abstract: Education systems worldwide are increasingly incorporating computer programming into school curricula. Within programming lessons, commercial, off-the-shelf (COTS) video games are being used as part of instruction. This approach has been shown to deliver many benefits, including increased engagement and positive attitudes towards the subject. Empirical studies have demonstrated that carefully selected COTS video games, primarily designed for entertainment purposes, have the potential to support pupils learning to program. For example, teachers can connect abstract programming concepts with concrete elements within the game. However, little attention has been directed towards the pedagogy employed in the classroom, including teachers' reasoning for the approaches used. In addition, there is limited evidence for the motivation for learning provided through the use of COTS video games when used to support the learning of programming concepts. The objective of my study is to examine teachers' and pupils' perspectives on how COTS video games are used within computing education to support primary (9 - 11 years) aged pupils' learning of programming concepts. The findings from my exploratory study will provide insights into classroom practices and contribute to the collective pedagogical content knowledge (PCK) for teaching programming. A qualitative, multiple case-study approach is used in this research. Schools are visited when a lesson involving the use of COTS video games to support pupils' learning of programming concepts is being delivered. Teachers' PCK is examined through investigating their pedagogical reasoning. For a planned lesson, data is captured through the completion of a Content Representation (CoRe) and a semi-structured interview. Teachers' pedagogical reasoning for their instruction and their subsequent reflections are elicited using an episodic narrative interview based on a video recording of the lesson. Self-determination theory is used to examine both teachers' and pupils' views on motivation for learning. Semi-structured interviews enable them to discuss intrinsic motivation and the fulfilment of their basic psychological needs. A pilot study has recently been completed in an English primary school. Within this paper, an initial analysis of the data is presented.

Keywords: Video games, Primary education, Programming, PCK, Pedagogy, Motivation

1. Introduction

The need for children to learn computer programming is recognised as a vital part of their education (Mannila & Heintz, 2023). There are many benefits of learning to program, including developing children's problem-solving skills (Fagerlund et al., 2021) and increasing their understanding of computing technology (e.g. (Alam, 2022). Across the globe, programming has been introduced within school curricula, including England (Department for Education, 2013), which is my study's areas of investigation. However, there have been many challenges to introducing this new curricular content (Royal Society, 2018). In particular, many teachers are unfamiliar with the subject having never studied it themselves. They therefore require support to develop their pedagogical content knowledge (PCK), as posited by Shulman (1986). Teachers with well-developed PCK are able to promote effective learning within their subject, including during computing lessons (Nijenhuis-Voogt et al., 2023). Whilst empirical studies have attempted to define the PCK required to teach programming (e.g. Hubwieser et al., 2013; Saeli et al., 2011), the proposals are often secondary specific and lacking in empirical validation. A number of the pedagogical approaches used to teach programming to primary pupils can be disengaging (Socratous & Ioannou, 2021). Empirical studies have also highlighted how pupils can find programming concepts challenging to learn (Sentance et al., 2017; Yadav et al., 2016).

Commercial, off-the-shelf (COTS) video games, developed for entertainment purposes, such as Pac-Man and Frogger, have been identified by teachers as increasing pupils' motivation for learning when used as part of their lessons' instruction (e.g. Allsop et al., 2015; Wastiau et al., 2009). The use of video games forms an integral part of primary aged children's daily lives, with the Children's Commissioner of England (2024) recently outlining how their most common motivation for playing is "to have fun" (p. 7). Ryan et al.'s (2006) empirical studies have demonstrated how individuals experience pleasurable feelings, such as fun and enjoyment, when playing video games. Video games are therefore seen as intrinsically motivating for the player through the inherent satisfaction they provide. Self-determination theory (SDT) (Deci et al., 1985) posits this motivation is fostered through the fulfilment of an individual's basic psychological needs.

Few empirical studies have examined the use of COTS video games to support primary aged pupils' learning of programming concepts. Within existing studies, there is limited evidence of the pedagogical approaches employed (e.g. Franklin et al., 2020; Basawapatna et al., 2019; Lakanen et al., 2019). In particular, these studies

fail to elicit teachers' PCK and their reasoning for the teaching methods used. Whilst a single study has been identified that collected data related to pupils' views on motivation for learning (Repenning et al., 2015), there is a lack of analysis in relation to motivational theories, such as SDT. Therefore, little is known about how COTS video games are used to support the learning of programming, such as teachers' knowledge and reasoning for the pedagogy employed. In addition, there is minimal empirical evidence on teachers' and pupils' perspectives regarding motivation for learning. My research aims to address these issues through examining the research questions outlined below.

2. Conceptual Framework

2.1 Pedagogical Content Knowledge (PCK)

Shulman (1986) introduced the concept of PCK and highlighted how it is a "special amalgam of content and pedagogy that is uniquely the province of teachers" (Shulman, 1987, p. 8). Shulman outlined how teachers need well developed PCK of subject specific content to facilitate effective pupil learning. Due to the multiple categories of a teacher knowledge that Shulman proposes make up their PCK, the concept is considered more complex than originally proposed (Kind, 2009). Refinements to Shulman's original definition therefore often add further components (e.g. Gess-Newsome, 1999; Grossman, 1990). Magnusson et al.'s (1999) conceptualisation is the refinement most cited within empirical STEM subject PCK research (Mientus et al., 2022). This includes when studying teachers of primary aged pupils (e.g. Hanuscin et al., 2011) and in computing education (e.g. Nijenhuis et al., 2023; Yeni et al., 2021; Barendsen et al., 2014).

The Refined Consensus Model (RCM) of PCK (Carlson et al., 2019) highlights how a range of broad, "professional knowledge bases" (p. 82), such as assessment knowledge and content knowledge, form a foundation for teachers' PCK. The RCM is often used within empirical studies examining classroom practice (e.g. Larsson et al., 2023), as it recognises the importance of a teacher's enacted PCK (ePCK) - the knowledge and skills an individual uses in a certain setting, with specific pupils, in order for them to learn aspects of the subject being taught. Empirical studies examining ePCK (e.g. Forsler et al., 2023; Behling et al., 2022) have highlighted how ePCK is influenced by a teacher's pedagogical reasoning (Shulman, 1987) - the cognitive processes employed when planning, delivering and evaluating instruction. A teacher's ideas, values and beliefs are seen as an integral part of these cognitive processes (Webb, 2002). A teacher eliciting their pedagogical reasoning, such as through stating their "reasons for a specific action" (Larsson et al., 2023, p. 591), can provide an insight into their PCK.

2.2 Self-Determination Theory (SDT)

Deci and Ryan's (Deci et al., 1985) Self-determination Theory (SDT) is a macro-theory of human motivation and personality (Ryan et al., 2023). SDT distinguishes between different types of motivation, including intrinsic and extrinsic. When individuals are intrinsically motivated, they engage in activities that provide them with inherent satisfaction - the experience of fulfilment from engaging in the activity itself. Extrinsic motivation involves the use of external factors, such as rewards, to engage individuals in activities (Ryan et al., 2020). SDT also posits that all humans have three basic psychological needs – autonomy, competence and relatedness (Ryan, 1995). When these needs are fulfilled, individuals experience psychological growth and well-being. The SDT mini-theory of Organismic Integration Theory (OIT) (Ryan et al., 2023) is of particular interest, as it posits the fulfilment of an individual's basic psychological needs leads to autonomous forms of motivation; including intrinsic motivation. Guay's (2022) systematic review highlighted the importance of autonomous forms of motivation in pupils' persistence and academic success within school.

Empirical studies (e.g. Ryan et al., 2006) have demonstrated how the playing of COTS video games can foster intrinsic motivation through fulfilling an individual's basic psychological needs. Studies involving primary / elementary aged children (e.g. Hamlen, 2011; Sherry et al., 2006) have highlighted how the fulfilment of basic psychological needs is also evident when children play COTS video games. Empirical studies examining the relationship between the perceived fulfilment of basic psychological needs when playing a COTS video game and motivation for learning have recently been undertaken (e.g. Rüth et al., 2021). However, it is unclear to what extent the results are applicable to computing education.

3. Aims

My research aims to explore how COTS video games are used to support primary (9 - 11 years) aged pupils' learning of programming concepts. The overarching research question is:

How are commercial, off-the-shelf (COTS) video games used by teachers to support primary aged children's learning of programming concepts?

The following specific research questions have been identified:

RQ1 - How is pedagogical content knowledge (PCK) evident through pedagogical reasoning within participant teachers' lessons that use commercial, off-the-shelf, video games to support pupils' learning of programming concepts?

RQ2a - How do participant pupils perceive the motivation for learning provided by commercial, off-the-shelf, video games when they are used to support their learning of programming concepts?

RQ2b - How do participant teachers perceive the motivation for learning provided by commercial, off-the-shelf, video games when they are used to support pupils' learning of programming concepts?

4. Methodology

My study uses a qualitative, multiple case study approach, which enables comprehensive data to be gathered on participants' views (Stake, 2006). A pilot study has recently been undertaken, as described in the next section. Five further schools will be visited when a teacher is delivering a lesson where COTS video games are being used to support primary aged pupils' learning of programming concepts. For RQ1, prior to the lesson taking place, the teacher completes a Content Representation (CoRe) (Loughran, Mulhall & Berry, 2004). A CoRe document enables teachers to elicit their planned ePCK through responding to specific prompts. This is followed by a semi-structured interview to ensure teachers' pedagogical reasoning is articulated for the planned instructional approaches. The teacher then delivers the lesson, which is video recorded. Parts of the video recording are viewed with the teacher following the lesson and discussed during an Episodic Narrative Interview (ENI) (Flick, 2000). The ENI enables teachers to elicit their pedagogical reasoning for the ePCK during instruction and when reflecting on the lesson. For RQ2a and RQ2b, SDT facilitates the examination of both teachers' and pupils' perspectives on motivation for learning. Semi-structured interviews are used to investigate participants' views on the fulfilment of their basic psychological needs, intrinsic motivation and their interest in the topic being studied.

To analyse the data, Yin's (2015) five stages of data analysis are followed. Interview data is transcribed and coded. Deductive coding is first used, with initial codes defined based on the related theoretical perspective (Bryman, 2016). Relying solely on pre-defined codes can limit the ability to identify new insights, so inductive coding is then undertaken. This is important for my study, which is exploratory in nature and might identify perspectives that have not previously been considered. A thematic analysis, in conjunction with analytical memos, enables the production of case study profiles and a cross-case analysis.

5. Pilot Study - Overview

A pilot study was recently undertaken to ensure the proposed methods could be used successfully in a school setting and that suitable data was produced for analysis. The pilot study took place in a primary school in the north-west of England. The teacher had been qualified for over 20 years and was experienced in teaching computing. The pupils in the lesson were aged 9-10 years.

The lesson involved the use of the COTS video game *Just Dance* (Ubisoft, 2025) to develop pupils' knowledge and understanding of algorithms and debugging. During the lesson, pupils undertook unplugged (without the use of technology) activities in groups. Pupils created a sequence of dance moves, which were adapted from the video game, to produce an algorithm. The algorithm was then performed to other groups. This enabled feedback to be provided to pupils and for them to debug their algorithms.

6. Pilot Study - Results

Initial results of the analysis for RQ1 from the pilot study are outlined below. Themes are discussed in relation to a teacher's PCK within a lesson that uses COTS video games to support pupils' learning of programming concepts. The themes are discussed with reference to the four components of Magnusson et al.'s (1999) conceptualisation of PCK, which is deemed appropriate for use in conjunction with the RCM:

Knowledge of Instructional Strategies and Representations (KISR) **- Teachers' knowledge of specific strategies, including activities and representations, for helping pupils understand a topic**

Knowledge of Students' Understanding (KSU) - Teachers' knowledge of concepts or topics pupils find challenging to learn, or may have misconceptions. Teacher's knowledge of prerequisites to learning specific knowledge.

Knowledge of Curriculum (KC) - Teachers' knowledge of the goals and objectives of the curriculum, including instructional materials and the organisation of content.

Knowledge of Assessment (KA) - Teachers' knowledge of the aspects of the subject to assess and how this can be done.

Quotations related to each area are also included. Pseudonyms are used throughout.

6.1 Ensuring Pupils are Familiar with Parts of the Video Game Being Referred to Within the Lesson

6.1.1 Knowledge of students' understanding

When discussing their KSU, the teacher outlined how she had selected a game her class had seen before, although it was still important to ensure pupils focused on specific parts of the game during the lesson:

They know Just Dance really well, because they've done lots in class with it from in golden time … I'm actually asking you to look at something specific within that. You're making them think before they do really, rather than just let's just do the dance routine. … It's fun, but I'm actually saying, well, actually, I want you to look at this bit

6.1.2 Knowledge of instructional strategies and representations

To support this process, the teacher's KISR showed how they introduced the specific part of the video game at the beginning of the lesson before discussing the lesson's objectives. This enabled pupils to start thinking about what the specific part involves:

> *I wanted them to think about the video game. I wanted them to think about the algorithm before we got there. … They had it when they came in … so they knew they were going to be doing? But I think it was important.*

The early familiarisation with the part of the video game also enabled the teacher to manage behaviour effectively, as immediately using the game as part of their teaching input could have led to pupils being over excited:

> *if I'd had just introduced that straight away [as part of the teacher input], they'd been dead excited and then … they'd been just like high as kites and they probably would not have focused as much.*

The teacher used both images from the video game and pictograms / pictocards (stick figure images) to represent dance moves from within the game, which they reported enabled pupils to interpret the game and use the moves when producing their algorithms:

> *it's weird. It's like subliminal, as they knew that, they all knew what that meant. … I didn't tell them what that movement looked like, but it was interesting that they all just got into that position, didn't they? … I also gave them the proper pictures as well if they wanted to use them, so there was a mixture of different imagery there.*

6.1.3 Knowledge of curriculum

The teacher's KC outlined how a range of games that pupils are familiar with could be used within the lesson to develop pupils' knowledge and understanding, although it was important to ensure they are age appropriate:

> *You've got to be really careful about your gaming choice. Children are using them at home, which we know they are. … So although they are doing [inappropriate game dances], does that … mean I should now do a lesson on it? No, it doesn't.*

6.2 Enabling all Pupils to Achieve

6.2.1 Knowledge of Students' Understanding

The teacher's KSU highlighted how some pupils find computing challenging, whereas the lesson within the pilot study enabled them to achieve:

> *you'll see children who may be, ordinarily, might find that a bit tricky, will have a go and they'll start to spot things and you can celebrate those children. I think it's that sense of achievement. So many times children just say I can't do it. But you say to them, just have another go and then they succeed. And that*

feeling that they get when they succeed … So you're trying to get rid of that negative emotion of, I can't do it.

6.2.2 Knowledge of instructional strategies and representations

When discussing their KISR, the teacher outlined how creating dance move algorithms related to the video game could be achieved be all:

You know, every child in there could come up with a dance move. I'm pretty sure of it. … So that's what's nice about it, isn't it? About that unplugged idea that they all get a chance to succeed, which I think is important, you know?

The teacher outlined how this was a particular issue as pupils lacked resilience, yet they could still produce dance moves related to the video game:

resilience, is a big one, isn't it? You know … that's a massive problem with children, as they just give up and they're not willing to have a go. And the older they get, the more embarrassing they get about making a mistake. Whereas something like this, it doesn't really matter, 'cause, it's like so fun and everyone can have a go at doing a dance move, can't they?

In addition, the teacher discussed how pupils might find parts of the lesson challenging, yet they will still be engaged due to the use of the video game:

some children will immediately switch off. Well, yeah, we're doing computing, but actually we're not going to go on a computer. We're actually going to do a Just Dance computer thing and they'll go, Oh, wow, that's exciting. So it's different, isn't it? You know, and I think that's when we talk about gaming, you know, doing something that they know and they love.

Whilst the pictograms and images outlined above could be used within pupils' algorithms, the teacher also discussed how other groups could draw or write their own moves. This enabled more complex algorithms to be produced, with the video game content used as a reference point:

For those who want to add their own [moves], well, they've got the pictograms again as a reference. Well, I need to put arrows on them, which they were doing, weren't they? … Emily's group were very much using the pictocards, whereas Yannis's group, they wanted to draw their own. All of them created an algorithm.

Following the lesson, the teacher outlined how they had adapted their instruction by singing the song used in the video game, rather than listening to the video game itself, to ensure pupils could produce an algorithm:

And I sung it rather than played it because the actual song is quite fast. And is it about them doing it at the speed of that song, or was it about them doing the algorithm so you make that decision?

6.3 Facilitating Peer Interaction

6.3.1 Knowledge of curriculum

The teacher's KC outlined how pupils working as a team is an important aspect of the lesson, although it does not form part of the formal planning:

some of those skills, you'll think, like working as a team. You know, that'll show me a lot about those children, how they can work as a team. Because those are skills that, although it's computing, they're skills that they struggle with working as a team, you know … I wouldn't write them in a lesson plan, but they are hidden skills

6.3.2 Knowledge of instructional strategies and representations

When examining the teacher's KISR, they highlighted how small groups are required to ensure everyone is involved. They also offer guidance to pupils on how they can work together to develop their dance moves if required:

I'll put them into small groups. So, I said 3 or 4 because any more than that, you start to argue and it's like teamwork thing again, but then a lot of the time, I'll probably say, well, how could you do this? How could you make sure that everyone has a part? … And we all put a move in each and then maybe add one more each, you know, think about that compromise rather than like, I'm going to say we're doing this. Is that what we do as a team and all that?

After the lesson, the teacher outlined how, when working in a group, all pupils were engaged in the activities:

> *they were all engaged. All of them were involved in it. … It was a leveller. … You know, if you asked him to do it on their own, there would be some of those who would do it on their own. Granted. But a lot of them wouldn't want to do it on their own would they?*

6.3.3 Knowledge of Assessment

The teacher's KA outlined how peer assessment could be undertaken through groups performing to each other, which enables algorithms to be debugged:

> *when they've done their algorithm, I'll say, right. OK. Groups 1, whatever, you perform to the other group. So they'll see them do their algorithm, then they'll swap over, do their algorithm, and then they'll say, OK, well, what I want you to do now is go and swap algorithms. See if you can actually act out dance out there, so they'll see it done.*

6.4 Using Technical Vocabulary Throughout the Lesson

6.4.1 Knowledge of students' understanding

The teacher's KSU outlined how it is important for pupils to be clear of the purpose of the session, which requires the introduction of technical vocabulary at the start of the lesson:

> *So we'll talk through these first. So that they're clear of where we're going by the end of the session. Because children, like adults, like to know what they're doing … we're doing it because we're going to write our own dance algorithm. That's what we're going to do. I'm going to use this to do it. So that's what they want to know, isn't it?*

6.4.2 Knowledge of instructional strategies and representations

Their KISR outlined the vocabulary is introduced through questioning, repetition of the vocabulary and definitions, and actions for each term:

> *Often I'll just start with the challenge and say, what does algorithm mean, have you heard of algorithm before? And that'll tell me, that's assessing them as well. Well, so if they know what it is, I've got the slide with all the definitions on I say, OK, do you remember what we said? Algorithm. And I'll then ask them read it out. So they were just reinforcing it again. … I've got an action for it. Here's my action, but have you heard of that word?*

The vocabulary and actions are repeated throughout the lesson, which enables pupils to develop their knowledge and understanding:

> *going over it again and again and again throughout the session. So you're probably going algorithm about 100 times. But the thing is, it's that reinforcement of that quote. You don't say at the beginning, they'll never mention it again. Yeah, you know, so what is why I'll keep doing it every time I say algorithm, I'll do the action so that they're seeing that physical side of it as well, so they know I could just do that and they'll go, oh, yeah, it's algorithm.*

The teacher outlined after the lesson how successful this strategy had been as pupils could remember the vocabulary:

> *And obviously the actions were great because that reinforced that vocab as well. So that was, I thought that was quite, I was quite surprised how much they remembered. That was a nice element to the first bit. So that meant that when we came to the vocab later on, it was just a case of a quick sort of recap.*

In addition, it had meant pupils were aware they were learning about programming, rather than about the video game:

> *We're doing this because we are going to create an algorithm, so I started straight away. Yes, we're going to be using Just Dance, but it was all about the algorithm and the programming; it was all about that. … It's a vehicle. It's a hook. It's a way to get them engaged and interested in doing that task. But ultimately there was no point that I didn't say it's not an algorithm here. We're using sequence. We're using decomposition. So it's coming back to that language.*

6.4.3 Knowledge of assessment

Finally, through stating their KA, the teacher outlined how examining the vocabulary at the end of the lesson provided an opportunity to check pupils' understanding:

Because it's ensuring their understanding, it's the assessment, isn't it? Of what they've understood in that session. If at the end for example, if I'd not said this is what an algorithm is and we've gone through it again, would they remember that it's an instruction? You know, your just clarifying that understanding even though they could write one. You come in, bringing it back full circle, aren't you? And that's really important.

7. Discussion

The pilot study results provide an initial insight into a teacher's pedagogical content knowledge (PCK) within a lesson that uses COTS video games to support pupils' learning of programming concepts. The brief discussion below is organised in relation to the four components of Magnusson et al.'s (1999) conceptualisation of PCK.

The results highlight how the teacher's Knowledge of Students' Understanding (KSU) enables lessons to be delivered that they believe are suitable for their pupils. The teacher discussed the importance of selecting appropriate video games for use in the lesson. Whilst recent reports had identified the integral role COTS video games play in the lives of young people (e.g. Children's Commissioner of England, 2024), the teacher recognised they may not be familiar with the title used. They also highlighted how their pupils experience a number of difficulties when learning programming, which echo those identified within empirical studies (e.g. Sentance et al., 2017). The teacher's KSU, along with their Knowledge of Curriculum (KC), identified the need to cover the English National Curriculum for Computing (Department for Education, 2013). They highlighted many further skills, such as teamwork, will be developed. However, these skills are not specified in either the National Curriculum content or their lesson planning. These wider benefits of pupils learning to program relate to those identified in Fagerlund et al.'s (2021) systematic review.

The teacher's Knowledge of Instructional Strategies and Representations (KISR) highlighted the importance of unplugged activities; particularly as they promote active participation in lessons (Royal Society, 2018) and pupil engagement, which can be challenging in computing lessons (Socratous et al., 2021). The teacher's KISR also outlined how they can facilitate achievement by all pupils; particularly as they recognise the lack of resilience pupils can exhibit, which has been identified as an issue when learning programming (Liu et al., 2025). Limited discussion was evident in relation to the teacher's Knowledge of Assessment (KA). Approaches to assessing programming can be challenging for teachers to implement (Basso et al., 2018). The peer and formative assessment strategies used by the teacher are suggested in teaching resources used by teachers in England (e.g. NCCE, 2025).

8. Next Steps

The pilot study demonstrated the appropriateness of the methods to examine the research questions. A number of minor modifications have been made to the methodology. In particular, the introductory text for the activities has been altered to emphasise the importance of the teacher expressing their views on the use of the COTS video game during the lesson.

During the analysis, the pilot study highlighted how the teacher's perception of the motivation for learning provided through the use of COTS video games within the lesson relates closely to their PCK and associated beliefs. When delivering computing lessons, Margaritis et al. (2015) posit a teacher's "beliefs and attitudes" (p. 215) influence their PCK, such as their beliefs related to teaching and learning. In addition, the RCM of PCK and Stefaniak et al's. (2021) more recent proposals outline how a teacher's beliefs impact on their pedagogical reasoning. However, not all these beliefs will be evidenced through examining enacted teaching approaches (Hutner et al., 2016). Further analysis of the responses to research question R2a and R2b is therefore ongoing and not reported here.

Five further primary schools from across England will be visited over a period of around six months. The findings from my research will provide insights into classroom practices and contribute to the collective PCK for teaching programming. This will be of interest to computing teachers, researchers and teacher educators worldwide. My study will have implications for lesson design and educational resource development; particularly with regard to the pedagogical approaches employed and the instructional representations used.

9. Conclusion

This paper has outlined research currently being undertaken in English primary schools to explore how COTS video games are used to support primary (9 - 11 years) aged pupils' learning of programming concepts. PCK and SDT literature has been discussed in relation to the topic under investigation. Details of the methodology have been provided, including the appropriateness of the methods for use in schools. Results of the pilot study have also been presented, with themes identified in relation to different components of PCK. Five additional primary schools will now be visited.

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Masters Research Papers

Tangential Learning in Board Game Design to Introduce Peranakan Culture

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Abstract: Lifelong learning is one of the main ideas in Sustainable Development Goal; this means we are encouraged to always learn about new things even when we currently don't need any new skill to solve a problem. People usually need some clue or stimulus to start that process, entertainment media such as games can be one of them. While educational games have a direct function to teach a specific subject using game system, it has been known that they're usually not very attractive for the general population. To make learning effortless, the person must first be interested in the subject while doing something fun. The game doesn't need to teach the whole concept about the subject; it can just bring awareness to their existence. That is Tangential Learning. Usually, it is used as a quality people mention in game research studies, rarely as a concept for game design. In this paper, we try to link Tangential Learning directly into game production through Eight Kinds of Fun. Combining them with Self Determination Theory and MDA framework, it is possible to design a game which indirectly encourages learning and not falling into educational games. Qualitative narrative research will be done to find out the market's current interest before starting the design. Information will be scattered all over the game dimension by designing all aspects of the game with reference to cultural artifacts, narrative foundation will be placed on significant historical events, and the gameplay will be designed in consideration to ludonarrative harmony to make sure the narration and the gameplay are coherent. In this condition, whichever aspect the player was interested in while playing will have something to learn further about. To sustain the player's interest longer and spark their intrinsic motivation to learn, strengthen the social aspect with cooperation play mode so people will work together for a common goal and discussion about the same subject is more likely to happen. The interactive nature of games also creates a sense of autonomy for the player to decide which subject they want to learn first or if they want to learn at all.

Keywords: Tangential learning, Self-Determination, MDA framework, Board game, Chinese peranakan, Culture preservation

1. Introduction

Most gamers would have experienced being intrigued by some aspect or specific term in the game they are playing and then looking it up online or in books, sometimes ending up finding lots of data and learning something new from it. The game itself might just use the subject as one aspect of the game or one of the existing items, but because the player is interested, it is possible for them to self-educate. This type of learning which occurs because of revelation to new information while doing something fun is called Tangential Learning (Floyd & Portnow, 2008). With Tangential Learning concept, it is possible to design a game to encourage learning in a subtler way while not falling into the realm of educational games. This is important because intrinsic motivation and interest are expected to be much higher in video games selected for entertainment purposes than those chosen for educational reasons (Ritterfeld & Weber, 2006). Tangential learning concepts reach out to people better because the main goal of the game isn't hammering specific knowledge into the player. They can do self-education if they're interested enough after interacting with the game. This concept goes well with Sustainable Development Goals number four, which is lifelong learning. Even when people are not in any formal education program, the possibility of starting to learn again will increase if they can get new hints from the entertainment media they enjoy. Unlike typical digital games which often fall into a certain gameplay format, many physical board games have unique gameplay which makes the option for gameplay broader. At the same time, the physical side makes sure it's kept as simple as possible.

Ascertaining the continuity of local culture is one of the Sustainable Development Goals. Chinese peranakan culture is a result of acculturation between Chinese descendants' culture with local Indonesian culture (Itjen Kemdikbud, 2023). In the history of Indonesia's Orde Baru era (1966-1998), the Chinese peranakan culture and descendants were oppressed (Putri et al., 2022) which results in the decline of their culture, even when the political oppression has mostly ended now. Incorporating the culture in the board game design is an effort to promote one out of many Indonesian cultures amid identity erosion because of globalization (Peng, 2023). Materials about the culture will be integrated into Geger Pacinan tragedy in 1740 to make the game's setting and conflict more precise and measurable. Chinese peranakan influences the local culture differently in each area and results in different culture artefacts in different provinces. Until today, there's still no digital encyclopedia for Indonesian's Chinese peranakan culture knowledge, they're mostly blended into other local ethnic group or province's list of cultural artefacts like Lasem batik (Java), soto mi (West Java), koko clothes

(Betawi moslem), or bakpia (Yogyakarta). The game can't feature all the culture artefacts that should be available because of the limitation of the product, but some of the card design will have QR code to link players to a web page which contains further information about the item to motivate players to start researching about the culture further.

2. Methodology and Literature Review

2.1 Game-Based Learning and Tangential Learning

Game-Based Learning is a concept of learning by playing games which are developed to reach predefined learning outcomes (Şendurur & Sendurur, 2022). These types of games are usually called Educational Games or Serious Games. Educational Games has a very similar definition to Serious Games. Educational Games are games specifically developed for the educational context (Concilio & Braga, 2019). They are designed to help people understand concepts, learn domain knowledge, and develop problem solving skills as they play games (Ge & Ifenthaler, 2017). Serious Games focus precisely on the design, development, use, and application of games for purposes other than entertainment by exploiting the increased user motivation and engagement to promote learning, construct knowledge, raise awareness or inspire behavior change (Vaz de Carvalho et al., 2021). The mechanic of the game must be appropriate to the learning objectives (Arnab et al., 2015) even though it might be not identical to the objectives of the game.

Tangential learning happens when people learn about a subject by being exposed to it in a context that interests them, rather than through direct instruction (Floyd & Portnow, 2008). This method of learning encourages self-education which is important for lifelong learning. The goal of the game might not be learning, but appreciation for the material can be grown. Considering the definition, Game-Based Learning is different from Tangential Learning, but it is possible for Tangential Learning to exist in serious games because to integrate materials for Tangential Learning is simpler than Game-Based Learning. Learning objectives of Tangential Learning doesn't require very deep understanding of the material. The important point is to make the game interesting enough so more people will be exposed to the information through playing rather than making sure the gameplay delivers the learning objectives accurately.

2.2 Self Determination Theory

Self-Determination Theory by (Ryan & Deci, 2000) says that there's three elements which can facilitate intrinsic motivation in people, that is autonomy, competence, and relatedness. Autonomy refers to freedom of choice the learners have. Competence means there's a sense of capability in oneself to do what's needed and then had the sense of growth or development as the learning progresses. This doesn't mean it has to be easy, but the hurdle must be just a little above the learner's current ability. Relatedness refers to the support from the people and conditions around the learner to pursue it. Competence and Relatedness can be translated into two out of eight kinds of fun by Mark LeBlanc: Competence to Challenge and Relatedness to Fellowship. Self-Determination Theory's element of Autonomy is already present in the game as it is an interactive medium and it is further imparted as a freedom to research more about the subjects or not after the game ends.

2.3 MDA Framework

Based on MDA Framework by Hunicke et al. (2001), there are three elements to consider: Mechanic, Dynamic, and Aesthetic. Mechanic is about the rules and objects in the game. Dynamic is about what the player does while interacting with the game. Aesthetic is about the feeling player will experience when they're playing, especially what will make them interested in the game. These three elements can be viewed in two directions: Mechanic > Dynamic > Aesthetic (game designer's point of view) and Aesthetic > Dynamic > Mechanic (player's experience). We want to design the game based on the player experience so the second direction will be used. These elements will be designed with the help of other disciplines' theories.

2.4 Eight Kinds of Fun

Eight kinds of Fun by LeBlanc (Hunicke et al., 2001) mentions Sensation, Fantasy, Narrative, Challenge, Fellowship, Discovery, Expression, and Submission as a list of types of enjoyment people can usually have when playing a game. The media which can be used by tangential learning to relay information is none other than the four main types of communication available: verbal, non-verbal, written, and visual. In this case, we can incorporate tangential learning into parts of Eight kinds of Fun which have an element of communication. One game can contain more than one of them. Sensation is the fun part of the game which can be felt with player's five sensory (vision, sound, smell, touch, and taste). Usually in a physical board game, vision is dominant, and it can be used as means of communication. For example, the graphics of the game element can be designed with

shapes and color meanings unique to the culture. Fantasy means the game becomes another world that the player can feel like living in. In a board game, this implies the world design, game system, and backstory which also can be used for communication. Environmental storytelling like illustrations of the environment, items and character can convey lots of things but doesn't interrupt gameplay (Bracikowska, 2020). Narrative means the game has a strong story element. Story is part of verbal or written communication media which can be used to convey moral values or intangible culture artifacts. Challenge means the game presents obstacles as an important or big part of the game. Fellowship means the game uses social feature as an important part of the game. Discovery refers to a kind of game in which the players explore the game world and open a new area in that way. Expression is the kind of game where the players have means to express themselves, for example a dress-up game or designing a room. Submission refers to the type of game which can be played idly. Our board game itself shall have at least five, which is Challenge, Fantasy, Fellowship, Narrative, and Sensation.

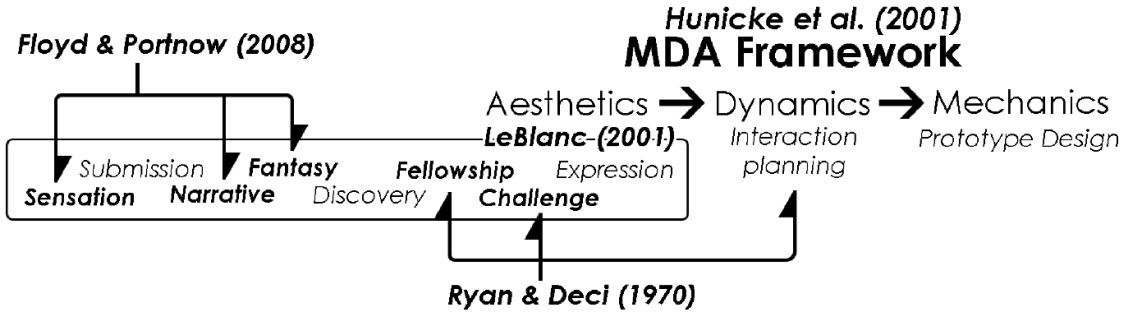

Figure 1: Theoretical Framework

2.5 Imperative Game Goal

In a game, it is possible to have several levels of game goals. The topmost level is the ultimate goal. They are usually more abstract, not directly tied to the game mechanic or dynamic. For goals which directly translate into game mechanics is called ludological goal or Imperative game goal. In Imperative Game Goal Typology made by Debus et al. (2020), there are ten types of game goal: Choose, Configure, Solve, Create, Find, Obtain, Optimize, Reach, Synchronize, and Remove. Choose is choosing the right answer among several options, much like a multiple-choice question. Configure is arranging answer pieces until they're all in the right place, for example a puzzle picture game. Solve is giving the right answer for several problems in which the clue or answer is not clear in the game, for example solving several item arrangements and pushing a button to get one door open. Create is crafting items needed for the goal. Find is finding the answer among the other items, such as looking for certain items in a very big picture. Obtain is gaining items needed to finish the goal. Optimize is for achieving the best possible condition in a limited number of times or turns. Reach is for reaching a certain spot or place for finishing, like in a race game. Synchronize is for replicating what the game asks, much like arcade dance game. Remove is for selecting and removing certain items or people to win. One game might have one or several combinations of this. For easier understanding, we will refer to this typology in the discussion about the game.

3. Result and Discussion

3.1 Genre Survey

To design a board game with tangential learning in mind means we need to know the target market's general interest first. In this case, game genre can be a starting point. Genre in board games usually means the core mechanic, theme, or components (Ristov, 2024). This also means one game can fit into several genres. Determining this is a crucial step before designing other aspects. To decide, the writer did a small survey of 15 respondents in the productive age (20-40 years old) who were gamers (but mostly digital games) and had a middle-to-high income. This survey was based on three alternative scenarios which can be developed into a game with integrated culture artifacts. The survey was done through online chat apps around end of March 2025.

Table 1: Scenario & genre alternatives

	Alt 1	**Alt 2**	**Alt 3**
Game Scenario	Collector, hoarding as much culture artifact as possible	18-19 th century merchant, growing business and building connection	Modern people got thrown to the past, on survival and looking for ways to come back
Genre	Monopoly	Resource management	Survival

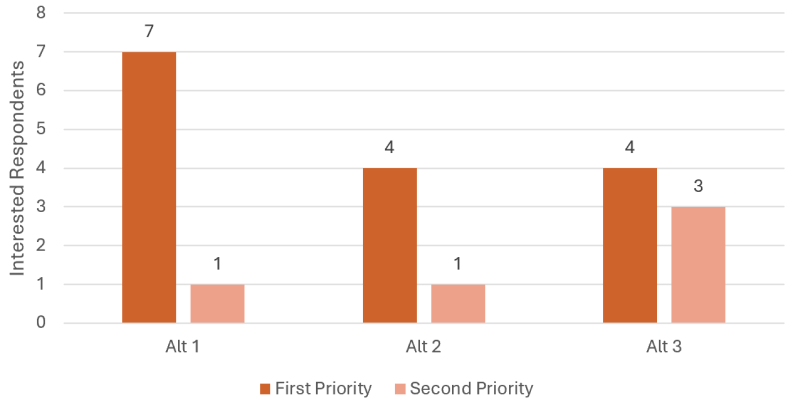

Figure 2: Result of survey

"First Priority" shows their first choice, "Second Priority" is an alternative, but wasn't compulsory. The result shows that the respondents like the first alternative more, but this result was followed by reasons. The respondents who choose the first alternative mostly don't want a complicated game or they prefer something they're more familiar with, with one of them wants to focus more on the message of the game. The ones who chose the second alternative mostly are the boardgame fans who like more challenging games which have many variables. The ones who chose the third alternative like the middle level of difficulty, with one of them was interested in the story.

From this result, the writer chooses to continue with the third alternative considering moderate level of difficulty which still has potential to appeal to beginners but at the same time is not too boring for experienced board game players. This can also be observed from second priority answers, which is the highest in the third alternative compared to other options. This shows that more respondents were interested in trying it out even though it was not their priority.

3.2 Game Blueprint

Survival genre is a subgenre of action games, set in hostile, intense, open-world environments. It is a blend of exploration, resource-gathering, crafting in an environment with some kind of ever-present risk or threat which the player must avoid or in some cases, fight (Lane, 2013). To set a proper base for the genre, the writer decides to use Geger Pacinan tragedy in Batavia 1740 because that's the moment where the Chinese Peranakan has already grown large in number and can be distinguished. They were largely concentrated in one place and there's a pogrom happening so it's a good base to develop the game according to the genre and featured culture artifacts.

3.2.1 Aesthetic

Tangential Learning wanted the process of learning to be done while the learner is doing something enjoyable, that means interaction in the game itself doesn't have to be educational, just needs to be fun. In this case, we should look at all dimensions the game and media have which can be used to convey information. Sensation fun sums up the dimension human's five senses can have. We can design the look of the game element in reference to visual of Peranakan Culture's visual like their architectural patterns or fabric patterns like in batik pesisiran or batik encim. Culture artifacts will be presented as rare items in the game. In game character stories can also be used to convey information, much like a witness's story. If players are given a main character to play, they can feel as if they live as a character in the game who is part of the situation. These are also two of LeBlanc's Eight Fun, Fantasy and Narrative.

Self-Determination Theory in Aesthetic part is used to help direct players' enjoyment to create an intrinsic motivation to learn, in this case: Challenge fun and Relatedness fun can be incorporated. Challenge refers to games that's competitive or with increasingly difficult challenges. Competence from Self-Determination Theory describes that to support the growth of intrinsic motivation, appropriate challenge and sense of progress are required. Survival games typically provide more challenges to finish compared to other genres; this can be made easier by designing several modes of play. Fellowship refers to games that's big on their social functions. Relatedness from Self-Determination Theory highlights the importance of the support from the people around to pursue learning and having a community which also has the same interest. While board games usually played with some friends, social element can further be strengthened with cooperation play mode so everyone will work together for a common goal and discussion about the same subject is more likely to happen.

3.2.2 Dynamic

The dynamic part will mainly be designed based on ludonarrative harmony in consideration for survival genre. Ludonarrative comes from a combination of ludus which means a game and Narrative which means a story. Ludonarrative harmony is used to describe when two separate elements work in sync with each other and simultaneously build a consistent experience. Ludonarrative dissonance refers to the experience of disconnectedness between the story and gameplay, in contrast, ludonarrative harmony is the experience of connection between the two (Ash & Despain, 2016). This aspect should be considered if the game has some kind of story going throughout the gameplay. Survival genre is generally more challenging, so we create several opposing forces for hindrance. To fit the theme, we decided that the main opponent in the game is VOC, which will be simulated by the game system, creating a confusing and oppressive situation. To imply the unpredictability and out of control situation, the conditions within city will be different every round, sometimes there might not be any soldier, sometimes one in each spot, sometimes more. There's also food or hunger problems every round and Malaria sickness within the city area. The cost for food at each round might go up as time goes by, this will make the condition gradually grow harsher as the players try to finish the goal as soon as possible.

The ultimate goal of the game is to finish a set of quests given in a goal card. There will be characters players can play as, characters player can rescue (victim), and items to collect. Each victim has their own story in several parts, triggering quest chains. The main imperative game goal is Obtain, but on a smaller scale there will be several other game goals, like Create and Reach depending on the tasks. The game will use a map which shows the city and surrounding area. The areas will be divided into several spots which have several character slots and a deck of cards which player can draw from if they're in that spot for that turn. Each round will have a day and a night turn to simulate daily character activities. There are also areas available only in one of the turns. Players need to gather various items from areas available and finish their quests to reach the ultimate goal.

3.2.3 Mechanic

The mechanic part will bring together the vision in Aesthetic and Dynamic part. The required objects and rules will be listed so a game prototype can be produced.

Genre: Survival

Gameplay: Chance + Strategy

Multiple players

Core mechanics: resource acquisition, challenges (quest) & rewards

Primary mechanics: action points, resource management, attack & defense

Secondary mechanics: weapon & equipment, skills

Components:

Main properties: area map board, character standee, money token, malaria token, hunger token, soldier token, character card, goal card, item card, situation card, daily quest card, dice, story booklet

Additional properties: player board

Area & system set up:

- Each area in the map has their own deck of item cards, except the city gate and sugar factory
- Each player picks one player character card and standee to use in the game

- All players start the game outside the city area
- After each round, renew the daily quest card and situation card
- Place soldier tokens blocking the character slots in each spot according to situation card in that turn
- Every character which satisfies the condition shall roll for malaria infection each round

Cooperation play:

- All players work together for 1 goal which will be drawn at the start of the game
- Each player has 3 AP every day/night turn
- AP is used every time a character move area, drawing a card from the pile in an area, battles without moving area
- The party can only keep as many victims as the players' total number (ex. 2 players = 2 victims, 4 players = 4 victims)
- Every turn the party needs to pay food cost X (number of players + victim kept).

4. Conclusion and Further Research

Tangential Learning is usually used as a quality people mention in game research studies, we have yet to see it as a concept for game design. In this research, we linked Tangential Learning directly into game production through Eight Kinds of Fun. It is possible to create a game which is informative but also encourages learning by merging Tangential Learning and Self-Determination Theory. Gameplay can be kept fun because the learning objectives are simpler. It started by defining the topic we want to introduce and then surveying the general market's interest. In this research, the survey is already based on several options, but it can also be done with broader options if the game development team has more time and resources. Detailed game design can start after the survey. Tangential Learning goes into the aesthetic part of the game, the Eight Kinds of Fun, and the game mechanic is still determined by the gameplay experience design, not directly by tangential learning itself. Self-Determination Theory in this case has a highlight on social function. The game needs to form a supportive group, community, or as simple as strengthening the bond of friends who can talk about similar subjects. Another important point is the sense of competence so people will keep playing, which can be supported by creating simple task systems with rewards.

It is important to note that this research hasn't included survey results from the game which was done with this framework. It is better if we can get comparative results about the culture knowledge from the players before and after they play the game also whether they feel any curiosity to explore further about the culture.

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Ethics Declaration: Ethical clearance was not required for the research.

AI Declaration: AI was used in the research to explore previous research and fix grammatical errors.

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Teaching the Solar System with a Video Game

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Abstract: This paper presents the design and development of an educational game centred on the solar system, aiming to combine scientific accuracy with engaging gameplay. With the advancement of technology, Game-Based Learning (GBL) has gained increasing traction as an effective supplement to traditional education. Digital games set in virtual environments have demonstrated their ability to boost learner engagement and enhance knowledge retention. However, topics like the solar system often remain abstract and challenging for students, due to complex concepts such as planetary motion, gravitational forces, and spatial scales. To address these challenges, this project leverages GBL principles and scientific simulation techniques to create an immersive learning experience. Players engage in exploratory missions where they defend the solar system's resources while learning core astronomical concepts. The game environment is designed to promote active learning through interaction, strategy, and problem-solving, fostering a deeper understanding of planetary science. This paper explores the theoretical foundations behind game-based learning and its application to science education. It further details the design methodology, including scientific modelling, gameplay mechanics, and narrative elements that support learning outcomes. The game integrates interactive features such as dynamic simulations, visual storytelling, and progressive challenges that align with key educational goals. Special emphasis is placed on ensuring that educational content is seamlessly embedded within the game experience, avoiding didactic interruptions that may hinder player immersion. The research is guided by four key questions: How can complex astronomical knowledge be effectively conveyed through a game? How can developers maintain a balance between scientific accuracy and engaging gameplay? Can this game improve players' comprehension and interest in solar system science? What methods can be used to assess the game's impact on learning outcomes? The findings aim to contribute to the growing field of educational technology by providing insights into the integration of accurate scientific content within interactive digital games, ultimately enhancing science education through innovative and immersive methods.

Keywords: Game-Based learning (GBL), Solar system game, Education game, Game, STEM learning, Scientific simulation

1. Introduction

With the development of technology, Game-Based Learning (GBL) has gained widespread attention in the field of education (Situmorang et al., 2024) (Mikrouli, Tzafilkou, and Protogeros, 2024). In recent years, digital educational tools have gradually become an effective supplement to traditional classroom teaching (Anastasiadis, Lampropoulos & Siakas, 2018) (Mayer, 2019) (Squire, 2003) (Team, 2017). Among these, games based on virtual environments have been proven to enhance learners' interest and better for keeping their knowledge. Astronomy is an important topic in basic science education, but due to the abstract nature of the astronomical concepts involved, and hard for experience, many students face difficulties in understanding concepts such as planetary motion, or the construction and scale of the universe.

Against this background, this project designs and develops an educational game based on the solar system, combining game-based learning theory and scientific simulation technology, to help players learn solar system-related knowledge through an immersive gaming experience.

Moreover, many educational games face difficulty in getting a balance between scientific rigor and entertainment (Egert and Phelps, 2022) (Cadiz et al., 2023). As a result, the content is either too monotonous and lacks engagement or overly entertaining, which causes inefficient knowledge transmission. For example, some existing space-themed games like Universe Sandbox, Kerbal Space Program, and NASA Eyes on the Solar System, focus more on observation rather than immersive exploration. Therefore, this project attempts to integrate a well-designed task system, storyline, and interactive exploration mode to enable players to learn and understand scientific concepts of the solar system through an immersive gaming experience.

2. Related Work

For GBL development, the virtual environments (VE) play a core role, virtual environments provide powerful tools for immersive learning, allowing students to engage with complex concepts in an interactive and intuitive way. These environments are particularly valuable in science education, where they enable learners to visualize and manipulate abstract concepts that are otherwise difficult to grasp through traditional methods. (Falloon, 2011)

In astronomy education, these virtual environments help develop spatial awareness by allowing learners to visualize and understand the relative positions and movements of celestial bodies. Furthermore, VEs help to promote scale perception, enabling users to observe and explore the vast astronomical distances and the immense sizes of celestial bodies. Crucially, these environments support conceptual learning by providing intuitive ways to explore complex physics features, such as orbital mechanics and fundamental astrophysics principles, these may be difficult to study through traditional methods. (Yu, K.C., 2005)

Some examples of virtual environments utilized in astronomical education include Google Earth VR, which enables users to explore planetary surfaces and celestial landscapes, and the Solar System Scope, it is a 3D model that visually represents planetary orbits and astronomical events. Other VR apps allow users to virtually visit the international space station, explore the surfaces of Mars and the Moon, and even experience the birth of a star. These experiences often utilize spatial audio and haptic feedback to further enhance immersion, making the learning experience more engaging and memorable. (Keet, 2023) This can transform learning from a passive reception of information to an active and enjoyable process. (Yu, 2005) (Rasheed, Onkar, & Narula, 2016) (Cooper, Thong, & Kok-Sing, 2024)

Simulating the solar system with high scientific accuracy is very important for educational purposes, as it allows learners to understand complex astronomical phenomena through interactive and observable experiences, otherwise, this may become impossible. Accurate simulations enable the visualization of celestial mechanics, the exploration of the huge scales, and the observation of phenomena with different timescales. (Yu, 2005)(Matovu et al., 2023)(Rasheed, Onkar, & Narula, 2016)

To ensure the scientific accuracy and credibility of educational games, real astronomical data and physical simulations are required. This is achieved through the integration of several key components: applying principles such as Kepler's Laws and Newtonian Mechanics to predict planetary motion based on gravitational forces and orbits; (Russell, J.L., 1964) N-Body Simulations are utilized for modeling the complex gravitational interactions between multiple celestial bodies, to provide a dynamic representation of the system's evolution;(Musgrave, 2025) and incorporating astronomical data integration by collecting datasets from sources like NASA, CNSA, and other institutions.(Haque et al, 2024) These data sets typically include precise parameters like orbital parameters, masses, sizes, and surface characteristics of planets, moons, asteroids, and comets. Integrating these real-world data can make sure that the simulation environment can reflect the actual solar system as accurately as possible within the simulation.

There are some educational games and tools that have been developed with the aim of teaching astronomical concepts, each possessing has strengths and limitations in engaging learners and conveying scientific knowledge. The representative existing solar system educational games and visualization tools will show their characteristics, so that to evaluate their effectiveness in facilitating learning, and identify areas for potential improvement, thereby providing valuable insights for the design of future educational tools in this domain.

Universe Sandbox, an interactive physics simulation game, serves as a powerful tool for demonstrating large-scale universe phenomena, such as planetary collisions, gravitational interactions, and stellar evolution. However, it can be a problem to start for learners who lack a foundation in astronomical concepts or prefer a more guided learning experience. Additionally, as a game, it may lack structured objectives and may require a higher configuration to run smoothly. Kerbal Space Program (KSP) is a complex spaceflight simulation game based on realistic orbital mechanics and rocketry, it focuses on scientific accuracy in simulating physics relevant to space travel. Players can design, build and launch spacecrafts to complete missions to learn orbital dynamics and space engineering. Even though, it may lack detailed information about the planets and moons themselves, which may lack educational value about the composition, history, and characteristics of the solar system, and it also has a steep learning curve. NASA Eyes on the Solar System, which is developed by NASA. It is a robust 3D visualization software with real astronomical data to provide a scientifically accurate, real-time or simulated-time representation of celestial body positions, movements, and space missions. It is an invaluable resource for visualizing the scale and spatial arrangement of the solar system and tracking real-world astronomical events and missions. Nevertheless, it lacks interactive challenges, explicit learning objectives, and reward systems inherent in educational game design to drive learning through active gameplay and structured progression. Its strength is in observation and visualization, not in interactive learning or knowledge assessment.

3. Game Design

The game is designed as an immersive educational experience that combines astronomy learning with an engaging storyline and interactive gameplay. This game is named *Wentian*, meaning “Asking the Heavens,” is inspired by Qu Yuan’s ancient Chinese poem *Tianwen* (Qu Yuan, 2011), symbolizing humanity’s pursuit of cosmic knowledge. It also references the “Wentian” module of China’s Tiangong Space Station, and by using this name in the title of a solar system educational game represents the player's journey in exploring the universe and learning astronomy.

3.1 Gameplay Overview

Unlike atmospheric flight, where aerodynamics plays a significant role, space flight in this game operates on principles suited to a vacuum environment. The space fighter is controlled by a player from a first-person cockpit perspective, and the fighter is equipped with vector engines, allowing for precise directional flight control, making use of force vectors rather than aerodynamic lift or drag (Keylor, E.K., 2014) (Roberts, S.A. & Lucas, S.M., 2012). The game is set during a future interstellar conflict in which alien invaders threaten the solar system’s essential resources. Players take on missions to protect these resources, fight enemies, and explore planetary systems.

The game combines serious educational content with immersive simulation. Its core modes include an exploration module with free roaming and celestial observation, a mission module with story-driven tasks tied to astronomy topics, and a challenge module containing physics-based fighting and exploration challenges.

The spaceflight system simulates zero-gravity motion by Newtonian mechanics, controlled by mouse for orientation (pitch/yaw) and keyboard inputs for specific actions. These keyboard controls include 'E' to turn on or turn off the vector engine, 'S' for engine reverse thrust, 'SPACE' to fire lasers with a cooldown, 'R' to stabilize orientation, 'SHIFT' to activate super boost with a cooldown, and '1-9' keys for teleportation to planets or the enemy space station.

3.2 User Interface (UI)

The user interface is a key teaching component of a game, since it provides the information display. The game’s UI adopts a modular design to ensure clear and intuitive presentation of information. There is a main panel to display a solar system overview, current mission objectives, and key UI components include several parts.

The radar system is a 2D user interface element designed to visualize the relative positions of objects around the player’s space craft in a 3D space. It provides spatial awareness by displaying targets within a specified range and color-coding (red to yellow) being based on their vertical distance relative to the player (see Figure 1).

The UI Information System provides real-time feedback to the player by displaying essential game data such as position, speed, orientation, health points (HP), boost cooldown status, and distances to nearby targets. This system ensures the player has the necessary data to navigate, manage resources, and make tactical decisions effectively. The HP and boosting cooldown status are designed by colour bar (from red to green) to display the status dynamically (see Figure 1).

Combat UI consists of a crosshair and an enemy indicator. The crosshair is positioned in the centre of the screen for aiming. The Enemy Indicator System is a UI component designed to provide visual feedback to the player about enemy positions relative to the camera’s viewport. This system helps enhance spatial awareness by displaying indicators when enemies are either off-screen or at a specific distance with a colour buffer (light red to dark red) (see Figure 1).

In this game, the mission UI serves as the core interface for displaying and managing the player's current tasks and introducing the current celestial body. It consists of the task list and the introductions. The mission list UI is designed to allow players to quickly understand the task's status and progress, while also providing easy access to detailed task information. According to the UI related figures, we could see how the mission list looks like (see Figure 1).

The core function of introduction UI is progressive reveal, to introduce the current celestial body to the player while showing related knowledge, the task's objectives, and its background. After the introduction, players can proceed by clicking the "Continue" button, which leads them into the game to begin the task. This approach

allows the game to convey solar system knowledge while ensuring that players are clear about the upcoming task goals and game progression (see Figure 2).

Figure 1: Game UI with damaged VFX and recovering HP

Figure 2: Introduction UI for learning

3.3 Effects

The special effects component primarily enhances the game's immersion and interactivity through a series of visual and sound design elements. Special effects not only improve the game's artistic presentation but also effectively convey the dynamic changes of in-game objects and events.

Visual effects (VFX) are crucial for enhancing player immersion and the overall gaming experience. This game implements various visual effects, including damage feedback (see Figure 1), explosion effects, and changes in the camera's field of view and teleportation effects (see Figure 3).

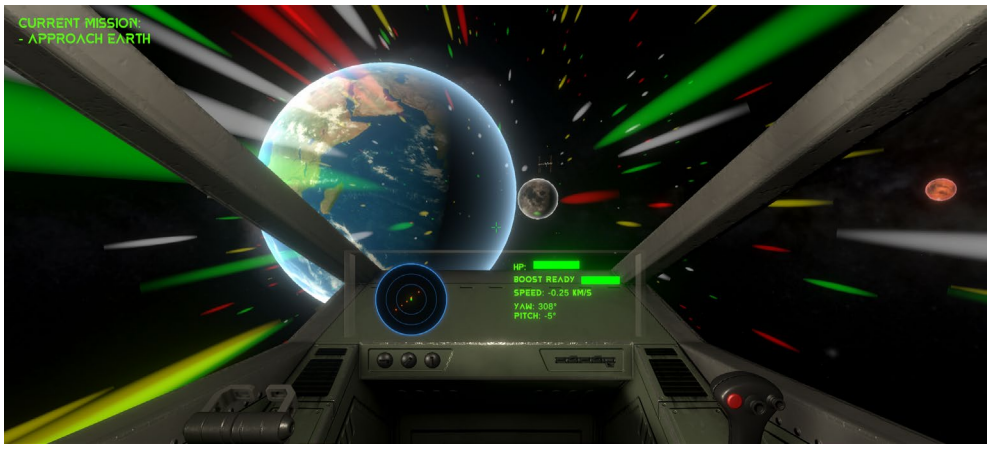

Figure 3: Teleport and FOV VFX

The implementation of sound is managed through *AudioSource* and *AudioClip*, with the goal of providing players an immersive gaming experience, enhancing the atmosphere and interactivity. The sound implementation includes background music, task sound effects, and combat sound effects. All sound effects are dynamically adjustable to adapt to different game scenes and task progress.

3.4 Teaching Content Overview

Firstly, the game helps players build an understanding of the overall structure of the solar system. Players can explore in a virtual environment, intuitively learning the relative positions and approximate distances of celestial bodies such as the Sun, the eight major planets and their main moons within the solar system. Through accurate simulation, the game presents a sense of the scale of the solar system, helping players overcome difficulties in abstractly understanding cosmic distances and the sizes of celestial bodies.

Secondly, the game provides detailed introductions to the characteristics and basic laws of motion of the main celestial bodies within the solar system. While performing tasks, such as planetary exploration, players learn about the composition, surface environment, atmosphere, geological features, and other knowledge concerning various planets, such as Earth, Mars, Jupiter, Saturn, and their moons, such as Earth's Moon, Europa or Titan. At the same time, the game simulates the rotation, revolution, axial tilt, and orbital inclination of celestial bodies, and demonstrates their modes of motion based on Kepler's laws and Newton's laws, allowing players to understand how planets orbit the Sun and the causes of phenomena such as day and night.

The game not only presents natural celestial bodies but also incorporates artificial objects and elements of human exploration. For example, the game simulates China's Tiangong space station. At the same time, combined with a space fighter powered by a vector engine, it creates a futuristic yet reasonably simulated world. Through this method, players not only learn about the natural composition of the solar system but also understand human efforts to explore the universe, combining astronomical knowledge, mechanics and motion, and aerospace technology background.

4. Implementation

As a huge and complex system, the solar system involves various aspects such as celestial body modelling, orbital mechanics, physical laws, and rendering natural lights. To get a balance between education and entertainment, this project uses the Unity engine to develop a realistic and high-performance solar system simulation framework. By combining real astronomical data with modern graphics technology, it provides players with a realistic scientific learning experience.

4.1 Solar System Environmental Simulation

The simulation of the solar system environment is built on the Unity engine, using a scale ratio of 1:10,000 km for scene construction, which means that one unit in the game represents 10,000 kilometres in the real solar system. This scale ensures the preservation of spatial relationships between celestial bodies and visual realism within the visible space.

Through modelling and creating a game environment based on the distances between celestial bodies and the Sun, players can intuitively observe the structure of the solar system and gain a direct understanding of the positions of celestial bodies within it.

Celestial body modelling is the basis of the solar system celestial bodies, ensuring that players can visually observe the shape, size, and surface features of the celestial bodies in an intuitive way. And the textures are publicly available images from NASA processed into 4K or 8K resolution.

In this project, geometric bases of celestial bodies are spheres based. By applying different mesh details and material layers, implement visual representations of celestial bodies. Each celestial object maintains an independent *GameObject* hierarchy, facilitating subsequent physics property binding, script control, and visual optimization.

Other environmental details include:

- A dynamic cloud layer (transparent effect) is added to some planets like Earth.
- The asteroid objects belt near Jupiter, which is a set of asteroid objects.
- Saturn's rings, which is multiple ring-shaped planes with a transparent texture.

Through these details, to enhance the game's visual realism and educational value.

The main natural celestial bodies are shown in Figure 4, including the sun, planets and moons (satellites).

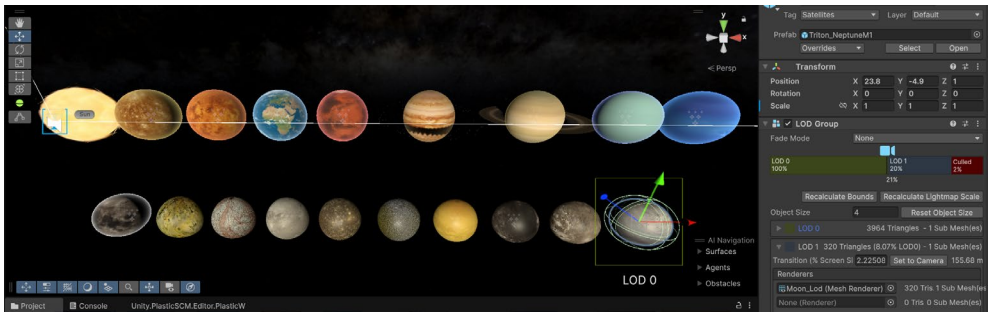

Figure 4: Natural celestial bodies

Additionally, there are two artificial satellites: The human Space Station (Tiangong), is designed as the location where the human base and the exit of the game are (see Figure 5). The enemy space station is designed as the enemy base in the solar system, and there is a simple exploration mission for it.

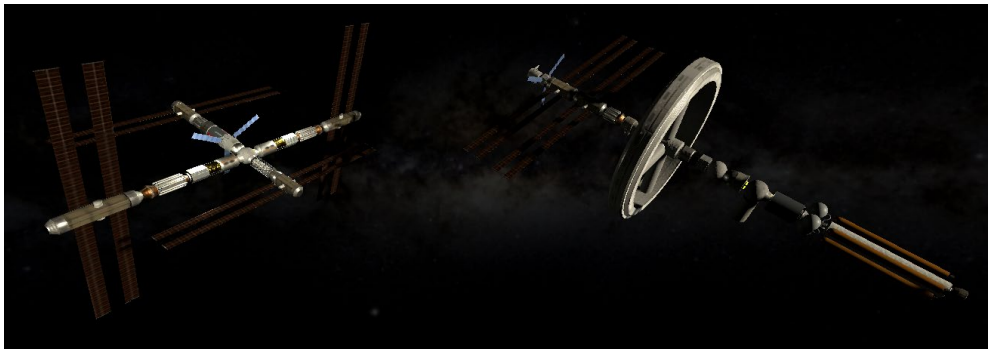

Figure 5: Tiangong space station (left) and enemy space station (right)

Orbital motion is key to simulating the dynamics of the solar system, ensuring celestial bodies move along accurate trajectories based on Kepler's laws and Newton's Law.

Kepler's laws define:

- Planetary orbits around the Sun are elliptical, with the Sun at one focus. (Russell, J.L., 1964)
- A planet moves slower when farther from the Sun and faster when closer. (Russell, J.L., 1964)
- The square of a planet's orbital period is proportional to the cube of its semi-major axis. (Russell, J.L., 1964)

Newton's Law defines: The object remains at rest or moves in a straight line at constant speed when no external force acts on it. (Encyclopedia Britannica, 2018)

Advanced graphics technologies simulate lighting, atmospheric effects, and material properties to enhance players' experience and learning interest. Main implementations include Physically Based Rendering (PBR) and Dynamic Lighting.

For Physically Based Rendering (PBR), there is a cosmic skybox in Unity using the Universal Render Pipeline (URP), rendering materials based on realistic lighting models. And surface textures, reflectivity, and roughness are implemented by physical maps to enhance realism.

Dynamic Lighting System simulated the Sun as the primary light source, which is a directional Light. Added a corona effect implemented by particle-based light glow. Based on Scattering Shader, simulate day/night transitions and atmospheric rim glow for Earth, Venus, and other celestial bodies with atmospheres.

4.2 Celestial Bodies Motion Simulation

All movements are driven by scripted programming and are adjusted based on the physical characteristics of the celestial bodies themselves, ensuring that their trajectories and velocities align with real astronomical features. Each celestial body's motion is based on its physical properties, ensuring that its rotation and revolution align with real astronomical data.

Different celestial bodies have different initialization logics. The sun's and planets' positions are set in the game world, and the moons' (satellites) positions are initiated by script. The sun is always at the world's centre at coordinates (0, 0, 0). Celestial bodies' initial positions are set relative to the Sun using the game's scale. All planets and the Sun align initially. Moons' (satellites) initial positions are calculated and generated by the script based on their parameters, like orbital radius and inclination, to avoid overlap or identical spawn points.

In real-world physics, celestial bodies orbit a central body (such as the Sun) along elliptical paths. However, in a game environment, where the world scale is much smaller than the real universe, the effect of orbital eccentricity becomes negligible. Therefore, we abstract these orbits as circular to reduce computational complexity, while still preserving core physical characteristics such as orbital inclination, orbital period, and radius dependency.

The spatial computation of orbital inclination is achieved through quaternion rotation, ensuring the establishment of non-coplanar orbits in 3D space. To build a physically accurate orbital system in a game, it is necessary to construct a rotation axis with an inclination, which serves as the orbital normal direction for revolution. Firstly, initiate the inclined axis, and each celestial body will revolve around this axis, resulting in an inclined orbital motion. In each frame, the revolution angle is updated based on the defined orbit speed.

Rotation is based on the configured *rotationSpeed*, and the object rotating around *Vector3.up* each frame. Revolution is implemented by Unity's *RotateAround*, the target as the centre, and a tilted *Vector3.up* (after applying orbital inclination) as the axis, then achieving inclined orbital motion. The inclined orbital axis is constructed using *Quaternion.Euler(0, 0, orbitInclination)*, allowing for a layered distribution of orbits with different inclinations.

4.3 Flight Simulation

Spaceflight simulation is a key component of this project that combines scientific accuracy and interactive gameplay. Players will use fundamental principles of dynamics to complete missions by piloting the fighter. The fighter's movement also follows Newton's laws with assist functions, rotations are implemented by quaternions.

The movement of the fighter in space follows real physical principles, including inertial motion and a propulsion system, following these rules: If no external forces (like boosting) act on it, the fighter is at rest or drifts in space. If an impact on the player's space craft occurs, the impacting force immediately affects the space craft until the player stabilizes it. The stabilization function simulates an effect like that of a reaction wheel, and it is designed for gameplay balance. Also, mouse inversion is used to simulate realistic joystick pitch control.

The direct control of translational force in the forward direction simulates the acceleration. The acceleration is a throttle-based increase in speed, limited by *maxSpeed*, simulating realistic propulsion constraints, which means closer to get the maximum speed, the acceleration becomes slower. In a vacuum, deceleration is controlled manually at a constant rate to simulate a reverse thruster.

5. Evaluation

The effectiveness and player experience evaluation of this Solar System educational game is tested through a user study, with 13 collected responses. The participants were aged between 20 and 30 years old. The majority were current students, with a smaller portion being working professionals. Regarding gender, there were 11 male and 2 female participants. All participants had fundamental gaming experience, with the male players having extensive gaming backgrounds.

This evaluation utilized a questionnaire survey to gather player feedback on various aspects of the game. The questionnaire consisted of 10 questions covering core game mechanics, audiovisual experience, challenge level, controls, reward system, educational value, integration of learning and gameplay, clarity of learning content, balance between learning and gaming, and game narrative. Each question used a 4-point Likert scale with options: "Strongly Disagree", "Disagree", "Agree", and "Strongly Agree".

The questionnaire results indicate a generally positive reception of the educational game among the players. Questions 1, 3, 4, and 5 received 10 positive responses each. Questions 7 and 9 received 11 positive responses each. Question 2 received 12 positive responses. Questions 6, 8, and 10 received 13 positive responses (totally positive feedback).

To determine if the positive feedback was statistically significant, a one-sided binomial test was carried out for each question. The test assessed the probability of observing the number of positive responses (Agree and Strongly Agree), if players were choosing randomly between positive and non-positive feedback (null hypothesis: p=0.5). The test parameters were *binomtest(number of positive feedback responses, total feedback number, p=0.5, alternative='greater')*. A p-value of less than 0.05 indicates statistical significance, i.e., the observed level of positive feedback for a question is unlikely to have occurred by mere chance, suggesting that players genuinely had a positive sentiment regarding that specific aspect of the game.

The following table summarizes the p-value results for each question:

Table 1: P-value result for each question

Q#	Question Summary	Positive Feedback	P-value	Significant
1	The combat mechanics make me feel excited and engaged.	10	0.0461	Yes
2	The visual effects and sound design enhance my immersion	12	0.0017	Yes
3	The gameplay is too challenging	10	0.0461	Yes
4	The controls are smooth and easy to learn	10	0.0461	Yes
5	The reward system motivates me to keep playing	10	0.0461	Yes
6	I learn knowledge about the Solar System	13	0.0001	Yes
7	The combination of the study and gameplay is done well	11	0.0112	Yes
8	The study part is clear and easy to read and learn	13	0.0001	Yes
9	There is a good balance between learning and playing	11	0.0112	Yes
10	The game story is logical and engaging	13	0.0001	Yes

As shown in the table, the positive feedback for all 10 questions reached statistical significance ($p < 0.05$). This strongly suggests that the players' positive ratings were not random and reflect a genuine appreciation for these aspects of the game. The extremely low p-values for questions related to learning (Q6, Q8) and story (Q10) indicate a particularly strong positive consensus.

Overall, the quantitative feedback and the statistical analysis demonstrate a significantly positive reception for the game. Players found the core gameplay engaging, the controls accessible, and the audiovisuals immersive. Crucially, the educational goals were met effectively: players felt they learned about the Solar System, the learning content was clear, and the integration with gameplay, along with the overall balance and story, was highly successful according to the participants. However, we acknowledge the low number of participants, which is reflected by the level of significance, which is in some cases just enough.

6. In Conclusion

Educational game is scientifically accurate and engaging to effectively enhance learning interests. This paper outlines the design and development of a solar system-themed educational game, illustrating how game-based learning principles can be applied to complex scientific content. These guidelines and methodologies provide a reference for researchers and developers interested in educational games. By these design principles, we can support understanding in science education to educational institutions and learners. Next steps involve a larger roll out in schools with more participants.

Ethics declaration: The development and research described in this paper did not involve human participants, personal data collection, or any procedures requiring ethical approval. Therefore, no ethical clearance was necessary for this study.

AI declaration: AI tool was used during the preparation of this paper to assist in the drafting and refinement of academic language, grammar correction, and structure optimization. AI tool is also used for converting the references into the required academic format.

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Enhancing Holistic Development Though Exergame-Based Learning

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Abstract: With the educational system balancing students' wellbeing and academic performance, being excessively digitalized and less physically active, new ways of active learning designs are needed. As digital tools offer potential for learning, increased screen time also raises concerns about physical inactivity and social disengagement, emphasizing the need for embodied and playful approaches in education. Current play-, game, and design research present today's education as striving for delivering playful and engaging learning experiences that support well-being, social engagement, and personal growth. One way to combat sedentary behavior and equip youngsters with key skills for a democratic society is to integrate movement in the design of academic learning. We suggest exergames as powerful tools as they use bodily movement, playful game experiences and screen-based play as a pathway to knowledge and holistic learning. Yet specific exergame design strategies to combine movement, academic learning and holistic development remain underexplored. Through the lenses of embodied cognition, we combine exergames with learning activities. For this purpose, this study uses constructive design research as a deliberate approach to frame the combination of theory and practice in the development of a design tool that addresses complex human-centered holistic needs and academic learning. This paper contributes by 1) emphasizing co-creation with 15 school children to inform the design process of constructing an exergame through three workshops and, 2) collaborating with a team of game developers in the making of a framework for creating exergame-based learning activities. Co-creating with the children revealed collaborative narratives, energy, and creative freedom as key elements of engaging gameplay and playful interaction. Further these insights were aligned with the game development team at LYMB.iO to create the Design Wheel of Exergame-based Learning (DWEL). DWEL is an eclectic design tool integrating play elements, game- and system mechanics, player aesthetics and aligns with the elementary school curriculum. The tool can be used for designing and evaluating exergames and to inspire future classroom activities when combining movement and technology for learning. Future research should look at the social-emotional, physical, and cognitive effects of using the DWEL developing exergame-based learning, for example, through platforms like Multiball or other exergame platforms.

Keywords: Movement-based design, Exergames, Co-Design, Embodied cognition, CDR, Play

1. Introduction

Integrating movement in the design of academic learning and human growth and wellbeing are challenges met by several researchers and practitioners. Cohen (2006) argues that academic success alone is not enough to prepare children for lifelong well-being and democratic participation, while Eccles & Roeser (2015) and Jessen & Balslev (2003) highlights that schools may go beyond cognitive achievements to foster emotional security, social belonging, and ethical engagement to prepare pupils for adulthood in a complex and democratic society.

Concerns are rising as The Danish Competition and Consumer Authority (2024) highlights how increased screen time contributes to social comparison, distraction, and reduced physical activity. These studies showcase how sedentary habits and social incompetence are negatively affecting overall well-being and human development. In this study we define human development as an embodied and holistic approach to developing affective, physical, and cognitive skills (UNICEF 2024). However, as digitalization reshaped educational environments, Bottino (2020) and Granic, Morita & Scholte (2020) highlight that digital technologies are integral to the cognitive practices embedded in today's classrooms. This is further highlighted by Syaukani, Hashim & Subekti (2023) and Dindler, Smith & Iversen (2020), whose findings align with the potential of digital tools to foster active and collaborative learning experiences when thoughtfully integrated into educational practices.

As play and games, including screen-based games and digital play, occurred as learning activities, schools strive to deliver playful and engaging learning experiences. Aloizou et al (2024) demonstrate that immersive technologies like movement-based learning platforms in kindergarten cultivate cognitive competencies though a one-year case study yet lack results from follow-up studies and control groups. Skovbjerg et al (2024) emphasize that playful learning strategies help establish social bonds, curiosity, and problem-solving skills but specific design guidelines to such strategies are absent. Steenholt (2013) and Händel (2023) frame how play and movement are culturally rooted and embodied practices for both teachers and children but ignore how we become embodied and playfully engaged. Lund et al (2024) conclude that learning with exergames played on the LÜ-platform increases learning motivation and engagement in curriculum topics while increasing participants physical literacy, however no results on softer skills are delivered.

These studies emphasize how play, games and movement – in the term of exergaming - contribute to holistic development by being cornerstones for embodied engagement, physical presence and social interaction in learning processes that enhance educational and personal growth. The studies bring valuable insights into the use of exergame-based learning but underscore the importance of the underlying design considerations.

Thus, we investigate: *What insights have been gained from movement-based co-design processes involving pupils and experts, and how did they inform the development of a exergame-based learning design tool?*

2. Bridging Embodiment to Learning Through Deliberation and Exergame-Based Design

Embodied Cognition (EC) offers a foundational theoretical lens to exergames and learning as embodied activities. Malinin (2019) frames EC as embodied, embedded, enactive, and extended, while Stilwell & Harman (2021) introduce a fifth "E"-dimension—emotive—through making physical engagement a primary agent for knowledge construction. Inspired from Bernard De Koven's work learning in movement-based contexts become playful and holistic through the interplay of connecting socially, engage physically and resonate emotionally (De Koven 2013), which aligns with modern learning theories (Waern et al, 2025; Syaukani et al, 2023; Jensen et al, 2025). Addressing the under-researched area in designing exergame-based learning our study draws on educational motivation and attitudes (Sabirli & Çoklar, 2020), game-based learning principles (Salen & Zimmerman, 2004), exergame design (Müeller et al, 2016), player experiences (Korhonen et al, 2009; Heunicke et al, 2004), child-centered play design (Druin 2001; Feder, 2020), and embodied interaction with technology (Loke, 2009; Segura et al, 2016). We believe exergames are powerful tools as they use bodily movement, playful game experiences and screen-based play as a direct pathway to knowledge and holistic learning (Oh & Yang, 2010; De Koven 2013; Kaos et al, 2019; Gao et al, 2018).

As seen, creating a design tool for developing and evaluating holistic development through exergame-based learning can be approached qualitatively (Skovbjerg et al, 2024; Aloizou et al (2024) and quantitatively (Goncalves et al, 2024; Gao, 2019). Koskinen (2011) and Emans & Murdoch-Kitt (2018) suggest constructive design research as a balanced and mixed method that intertwines theories and practices to add tolerance in the traditional field of science and design. We align with Koskinen (2011) and Emans & Murdoch-Kitt (2018) suggest that there is a need for different methods and methodologies in design practices and considerations, as the main difficulty is understanding how design research works and what value it brings.

Constructive design research often builds on experimental research with the involvement of user groups (Koskinen 2011). Taking inspiration from Bernard DeKovens' philosophy of learning and playfulness (2013), we align with his idea that *deliberation* is the deep engagement, the shared communities and the transcendence that arises when working and playing well together (De Koven, 2013). For this reason, constructive design research as a deliberate approach to working and playing with people offers the most sustainable path for enhancing both holistic development and academic learning as it integrates the body, mind and spirit of those you work with (Koskinen, 2011; Feder 2020, DeKoven 2013).

This paper first suggests that children as co-designers contribute to developing well-designed exergames by enlightening the early design process, and second, how the development of such exergames can be de delivered in form of a wall-sized screen-based exergame informed by game design experts. This paper contributes with new perspectives and guidelines that emphasize a holistic approach to design for academic learning and human development by developing the Design Wheel of Exergame-based Learning.

3. Case Description: From Ideation to Construction of Exergames for Multiball

The concept of bridging movement, learning, and technology emerged from experimenting with the SDU-mounted Multiball®, developed by LYMB.iO. Multiball features a metal frame attached to the wall, equipped with tracking that detects any object hitting the wall. A camera positioned at the top of the frame captures the moving body on the floor. Our passion for learning with technology led us to contact the Langeskov School.

The case involves two phases. First a collaboration with the Human Tech team (HUT) from Langeskov School allowing insights from children's perspectives on playful design to emerge. The second phase was an internship at LYMB.iO that involved expert game developers in the exergame design considerations. HUT was motivated to take part in and inform the project on learning with movement-based technology. HUT comprises 7 boys and 8 girls from 4th to 9th grade participating in the robotics and innovation competition First Lego League. HUT showed interest in movement-based technologies, a previously unfamiliar aspect of their everyday activities. HUT was enrolled in three workshops at SDU during the fall of 2024 (Table 1). As a result, HUT revealed essential insights incorporated into their prototypes of exergames for Multiball®. The prototypes

were planned to be further developed with LYMB.iO through 8 structured workshops and daily meetings during November and December 2024. As LYMB.iO strived to develop educational learning applications for Multiball, insights from the HUT workshops were used for exergame prototype development and informed further exergame design considerations. To renew educational exergames, we used HUT-insights, game knowledge from literature readthroughs and LYMB.iO experts to apply a holistic understanding of designing for exergame-based learning.

4. Methods: Constructive Design Research to Emphasize Co-creation and Exergame Design

The study is informed by Constructive Design Research (CDR) as an overarching methodological framework (Koskinen et al 2011). CDR originates from design practice where knowledge evolves from artifact creations and validations, while the design of the product benefits user needs and experiences, becoming the center of knowledge. Constructive design research (CDR) aligns with project goals of providing insights into exergame creation (Koskinen et al., 2011). CDR emphasizes co-creation and co-design (Sanders & Stappers, 2008), thereby pointing to collaboration between producers and users as a key value for making good design solutions and, in our case, good game design. In our use of CDR we are also informed by DeKovens' (2013) theory on coliberation. Deliberation is "What we have to give each other when we are at our best" (DeKoven 1992). In other words, coliberation is when we play each other well to experience a well-played game (DeKoven, 2023). As collaboration and coliberation were subtle parts of the workshops, focusing on democratic and holistic methods, CDR was well-suited as a design approach for this paper.

This ensured that HUT's voices and experiences played a key role in shaping design outcomes (Emans & Murdoch-Kitt 2018; Druin 2001). Supporting this purpose, Druin (2001) and Feder (2020) emphasize that pupils' participation in design fosters sustainable learning experiences. This aligns with Kumar's (2012) view that innovative processes and methods should be built on experiences, system-thinking, and iterative exploration. The design process involved two interconnected phases: co-design workshops with children and a practice-based internship with the exergame company LYMB.iO, where qualitative observations and interviews served as scientific methods to generate data.

We facilitated three co-design workshops with HUT that was structured as outlined in Table 1. All participants submitted informed consent as well as parental consent forms prior to the workshops and the school was informed. The co-creation workshops were grounded in movement-based design (Waern et al 2025; Segura, 2016) and playful learning principles (Skovbjerg et al, 2023). Movement-based design through 5M framework helped shape the workshop environment (Elbæk et al, 2023, Waern et al, 2025). Mood Setters energized the participants, Movement Methods structured activities, and Modifiers guided creative processes. Play was integrated as a catalyst for exploration, collaboration, and creative thinking (Skovbjerg et al, 2023). Playful activities supported and empowered children to embrace unpredictability and co-create shared ideas (Händel, 2023).

Then we gathered insights from HUT-workshops through semi-structured observations (Blandford, 2013) designed to capture children's physical engagement, social interaction, and input during the workshops. The observation data underwent an inductive thematic analysis (Braun & Clarke 2006) that gained synthesized insights. That to ensure consistency between categories and raw data points. Finally, the HUT-insights were brought to LYMB.iO for further exergame design consideration through an 8-week internship. The HUT-insights were applied in a flexible pattern matching comparison analysis to relate HUT-workshop data with theoretical findings. Using such mixed methods toolkit provided us with a theoretical foundation where emergent and unexpected insights can appear.

Table 1: Day schedule and duration for HUT workshop 1

Activity	Purpose	How
Moodsetting (15 min)	To form a bond and a safe space to be creative in	Clap Cross and Tumbler (MeCaMInD cards)
Introduction (15 min)	Explain, define and the Multibal	Group listening

Activity	Purpose	How
Multiball gameplay **(20 min)**	Exploration and reflection phase	Try, test and refine. Using modifiers to bring attention to various perspectives
Break (15 min)		
Moodsetting **(5 min)**	To sense and socialize	Bubblegum Queen (MeCaMInD cards)
Design phase 1 + playing Multiball **(30 min)**	Discover and reflect on movement ideas to enrich performance and feel in the gameplay	Bodystorming with props Explore movement What can I do with this? (MeCaMInD cards)
Introducing modifiers **(15 min)**		Group listening
Design phase 2 **(30 min)**	Groups explore the given boxes of modifiers. Choose max 15 modifiers. Can you make a game from mod. cards?	Goup work
Lunch (30 min)		
Moodsetting **(5 min)**	To energize	Slow fight (MeCaMInD)
Gameplay **(30 min)**	With their chosen modifiers they discover how their game is played out – others give feedback	Context playing
Sum up **(20 min)**	Take away notes and feedback	Brainwalk (MeCaMInD)

4.1 Workshops with Langeskov School (HUT)

The three HUT workshops were held from primo September to ultimo October 2024 at University of Southern Denmark. Each workshop had its own agenda, yet similar structure. An example can be seen in Table 1.

The workshops aimed to engage children in a playful, iterative design process focused on movement-based digital games using the Multiball system (figure 1). In Workshop 1, children explored and tested existing exergames through hands-on activities and mockups, while being introduced to the MeCaMInD design tools (Elbæk et al 2023). Workshop 2 used case-personas and empathy mapping to guide children in designing games that addressed cognitive, social, emotional, and physical growth potentials. At the final Workshop 3 HUT sketched, prototyped, and programmed their own interactive games in Scratch Jr. The activities encouraged dialogue and playful exploration and were used as context-near experiences to introduce theories (Figure 2).

Figure 1: Children from HUT playing "Countries" on Multiball during W1

Semi-structured guiding observational questions led to descriptions and reflections (Blandford, 2019). Special attention was given to observations focusing on physical gameplay, children's social interaction and their participation during the activities. The observation data went through a thematic analysis that followed Braun and Clarke's six-step framework (2006), ensuring systematic condensation and interpretation of findings. The observations were grouped inductively, allowing patterns and important elements to appear. Then we coded the grouped data into cognitive, socio-emotional and physical categories and cross-referenced them with the observation once again before giving them clear definitions and scope (Braun & Clarke, 2006).

Figure 2: HUT working with exergame design in groupwork session W2

4.2 Workshops with LYMB.iO

Insights from the HUT workshops were brought to LYMB.iO to be further developed. through weekly design sessions with one exergame designer and three exergame-developers. These were iterative sessions focusing on integrating educational elements into exergames using the HUT-workshop insights. This was done by applying a flexible pattern matching comparison analysis (Bouncken et al, 2021), aligning themes from HUT-workshop data with several theoretical underpinnings from game and design literature (Figure 3).

The literature identified relevant constructs and frameworks in exergame design (Mueller 2016; Lund et al 2021; Chow & Mann 2023), movement-based design (Segura 2016; Aloizuo et al 2025; Waern et al 2025; Loke 2009), play design (Feder 2020, Skovbjerg et al 2024), HCI-design (Druin 2001, Sweetser & Ozdowska 2024), gameplay mechanics and digital design (Korhonen, Montola, & Arrasvuori 2009; Schell 2001; Hunicke, LeBlanc & Zubeck 2004).

The literature reading was compared with the insights from HUT-workshops ensuring consistency between empirical data and theoretical patterns (Figure 4). We then integrated overlapping elements into a cohesive framework (Figure 5). Finally, we tested the elements of the framework by applying parts from the framework into a LYMB.iO-developed prototype exergame. This was an iterative process that involved several adjustments that required well-argued design considerations, beta-coding and continuous testing.

To understand how the framework is constructed, the following section describes findings from the HUT-workshops followed by findings from workshops with LYMB.iO. The results are refined in the construction of the framework.

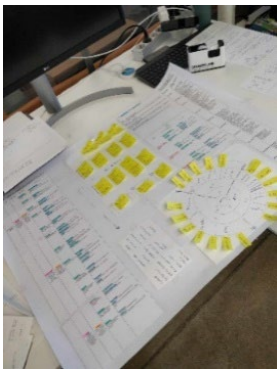

Figure 3: Aligning themes from HUT-workshop data with theoretical underpinnings from game and design literature

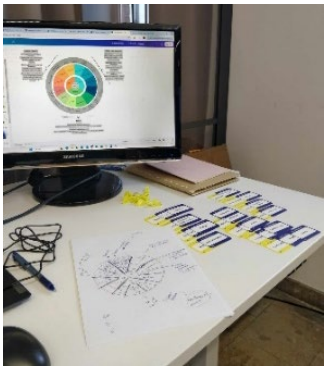

Figure 4: Comparing literature reading with the insights from HUT-workshops ensuring consistency between empirical data and theoretical patterns

Figure 5: Integrating overlapping elements into a cohesive framework

5. Results

The findings contributed to the children's experience of good gameplay and playful interactions. HUT-workshops revealed collaborative narratives, energy, and creative freedom as key elements of HUTs exergame design (Figure 6). Integrating these findings into design considerations, they were used at the LYMB.iO design stages to develop an exergame-based learning framework (DWEL).

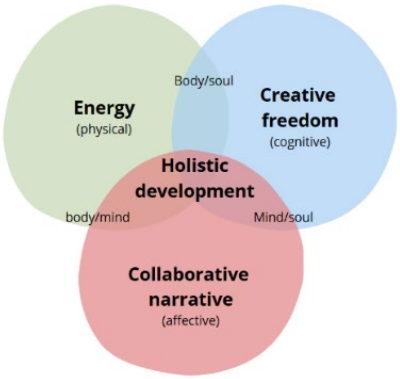

Figure 6: Key elements of HUTs exergame design linked to embodied cognition

5.1 Results from HUT

Informed by the HUTs' participation in the workshops, the semi-structured observational data shred light to what made the Multiball experience meaningful and fostered adherence. The following stages an observation from workshop 2.

> *I wanted to start Connect 4 (a slow-paced two-player game on Multiball). It was met with a "No, not 'four on a row". It's boring..." I asked why and a boy stated:" When something happens, you know, action-like, you really want to keep on playing. This? This is just kinda borring". I started Bombs instead (a high-paced multiple-player game). The teacher asked about the academic games, and I started*

> *Countries. A geography game (slow-paced and allows for collaboration). "That little guy, he's playing along now," says the teacher. (Sequence of the observation notes from W2, 30th September 2024)*

Using Multiball to facilitate learning through movement, we discovered that Multiball can create energy (green color, figure 6). However, energy might set boundaries for everyone to participate in the same game. As the quote shows energy was detected in shifts from high to low activity. It shows that going from *Bombs* (a fast and action-packed game) to *Countries* (a discovery game) sharpened their attention and slowed down the pace presented by their physical impression. The quote further shows that some exergames contributing to collaborative engagement when the game can be done together (red color, figure 6). The "little guy", that the teacher refers to, did not want to join the fast-paced games. But as he sees that he can contribute, he joins. When I asked him why he joined this game and not the other, he said:" The *best is that we can collaborate to get something done. I am good at geography, so I know stuff." (Boy, 11 yo)*.

In a sequence from workshop 3, they were presenting their prototypes. I noticed every pitch started with a storyline. They have all created a common narrative that was important to them, and one they all could relate to. The quote shows that playing action paced exergames encouraged more active physical play. The action games enhance uncontrolled play, while slow-paced and more strategic games require very precise action and are restrictive to where you can hit a target. The action games thereby allowing the players to throw at any target having more freedom to choose where to go in the game. Another time creative freedom (blue color, figure 6) was present when using the MeCaMInD-modifiers. They offered a structured, yet restricted way to apply ideas and thoughts into design considerations. This obstacle was to some extent "… *a little annoying (…), a little difficult to figure out." (Girl 14 yo).* However, as they kept playing with the modifiers and came to understand what they were used for. The girl later stated; "… *it was pretty cool to figure out that you were able to create something. They [the modifiers] were inspiration and we found out that we could be really creative with them. Sometimes silly creative." (Girl 14yo).*

As shown in Figure 6, these insights strengthen the bridge between embodied cognition and practical examples of holistic development. Energy (green) was found to be expressed through the physical body but was also connected to the emotions of the pupils. A sedentary brainstorming-task expressed less bodily interaction, while twisting brainstorm to brainwalk forced the pupils to move around while placing sticky notes around the room, created shared laughs and physical touches. This shows energy as embodied as enactive and embedded actions emphazises dynamic interaction between environments and agents that supports exploration and making sense of the world through sensorimotor interactions (Stilwell & Harman (2021).

Creative freedom (blue) was a way to express themselves either through the body or through their reasoning in deeper tasks. As HUT got to play with various tools and materials to physically build their re-constructed exergame (workshop 1), they utilized external objects to extend their cognitive abilities. Relying on extended and embedded perspectives the insights show how cognitive processes are shaped by the contexts, the environment and opportunities that can extent our cognitive abilities Elbæk et al, 2022; Stilwell & Harman (2021).

Collaborative Narrative (red) was generated through bodily awareness when playing together but was also tied to connecting emotionally with a task. Using case-personas with problems which were familiar to the HUT, they deeply intertwined with the case-persona influencing their perception and decision making towards creating solutions that could help them. This shows that affective development is deeply intertwined in the emotive perspectives of learning Elbæk et al, 2022; Stilwell & Harman (2021).

It is by linking mind/body, mind/soul and body/soul that we claim that holistic development occurs (the overlapping center in Figure 6) through extended, embodied, enactive, emotive, and embedded interference with the object and world around us (Stilwell & Harman (2021), Elbæk et al, 2022).

In the last workshop HUT were prototyping their own exergame in Scratch. It was by reviewing and cross-refering the themes from the observational data concerning physical, cognitive and socio-emotional elements with the themes emerged in HUT prototypes we defined energy (green), collaborative narrative (red), and creative freedom (blue) as being essential insights for playful interactions and for the feeling of good and engaging gameplay. These insights were used in later workshops with LYMB.iO.

5.2 Results, LYMB.iO

As energy, collaborative narrative, and creative freedom was insighs that formed HUTs idea of exergames their protoypes were delivered to LYMB.iO. However LYMB.iO prefered to use the HUT co-design insights to inform

the future design process of educational Multiball exergames. This stimulated the creative process of drafting the *Design Wheel of Exergame-Based Learning* (DWEL) – an eclectic tool designed to integrate holistic development and academic learning.

The following section describes the process of creating DWEL as a part of the results in the design sessions with LYMB.iO.

5.3 The Design Wheel of Exergame-based Learning

The multiple sessions with LYMB.iO resulted in the development of the *Design Wheel of Exergame-Based Learning (Figure 7).* The HUT-insights and the literature pattern matching fueled LYMB.iO's own desire to make educational exergames founded on the principles of playful and holistic learning. Aiming to assist LYMB.iO construct and design such exergame, a framework was made in a wheel format. DWEL is made of four circles integrating school subjects, playful elements, game and system mechanics, and player aesthetics representing holistic learning opportunities.

The outer circle represents the school subjects. The aim is to select a specific subject within the curriculum that game design should meet. The second outer ring is playful elements (Feder, 2020; Elbæk et al, 2923). These represent the connection between play, movement and learning. Placing the playful elements here forces the designer pay attention to a holistic approach in game design. For instance, incorporating "Mastery" into the game experience can enhance the feeling of success. "Communication" can improve the conversation and collaboration between participants during gameplay. "Performance" can support the effort to strive or playing each other well. The second inner ring is game mechanics and structures (Korhonen, Montola & Arrasvuori, 2009) Multiball® offers. The designer can choose to add "Rewards" or "Quests" to increase adherence or add "Time" or "Points" to enhance immersive and engaging gameplay. This circle contains elements and game mechanics that keep challenging the players by making them concentrate for longer. However, it does not contribute to a well-played game itself (DeKoven 2013). The inner ring the 'player aesthetics (Hunicke, LeBlanc & Zubeck, 2004)', describes how the player should feel while playing. Choosing, e.g., "Discovery" lets the player feel a sense of exploring uncharted territory in the game. "Submission" as an aesthetic to support the feeling of playing might reduce boring spare time. Letting the participant engage emotively with the game make a pleasurable experience for the player (Loke 2009).

Figure 7: The Design Wheel of Exergame-based Learning

The wheel-form makes the framework adjustable and informs design points. As an iterative activity, the design process utilizes the DWEL adjustable feature, allowing the designer to choose any starting point. DWEL ensures that each design choice supports the overall balance of academic learning and human growth by using the core-colored themes of energy, collaborative narrative, and creative freedom as guidelines for the design. We provide an example of the use in the following discussion and concluding section.

6. Concluding Remarks and Future Perspectives

Grounded in Constructive Design Research as a deliberate approach, co-design workshops with HUT and LYMB.iO, showed the bridging holistic potential of exergame-based learning design as it combines movement, technology and academic learning.

We saw how holistic development occurred through playful approaches grounded in creative embodied cognition (Malinin 2016). The design of movement-based learning environments, as used in the HUT-workshops, should inspire future classroom sessions to emphasize co-creation and coliberation. HUTs insights of energy, collaborative narrative, and creative freedom were central to generating important insights into holistic domains of child development. To guide such learning environment exergame developers and designers are invited to use DWEL as it frames play and movement into socially embedded practices in educational settings. This was tested throughout an early-stage prototype for the Multiball at LYMB.iO.

The exergames success on holistic development depends on how exergames are designed, integrated, and moderated within the educational context. Trying to do so, we worked strategically with DWEL to develop a math-game. Note that the wheel has been adjusted after this game was created (Figure 8). Starting from the outer ring, we literately constructed our game. We chose the school topic we wanted to address. Then we chose how we wanted the player to feel while playing. Then what opportunities Multiball could give us from the mechanics. And lately what playful elements we wanted to incorporate. When these characteristics were chosen, we started to draw our game. First on paper and then made a prototype in Unity®. We ended up with the game in Figure 9.

Figure 8: First version of using DWEL

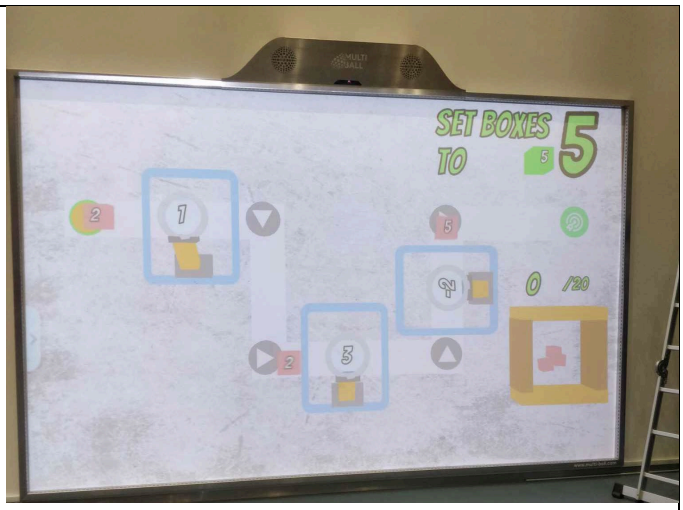

Figure 9: Math Game prototype

As stated in the introduction; a critical question for moving forward is whether we can design exergames to become sustainable tools for cultivating not just knowledge, but whole-child development in schools (Aloizou et al, 2024, Skovbjerg et al 2024, Steenholt, 2023, Händel, 2023, Lund, 2024). DWEL covers the gap between strategic exergame design and children's learning opportunities in the 21st century. Thereby contributing to the field of movement-based learning designs that provide practical guidance for developers, educators, and researchers to create playful, holistic, and educational exergame experiences that meet the evolving needs of children in today's schools.

The study suggests that integration of digital technologies and exergames holds considerable promise for fostering holistic development, when integrated and monitored thoughtfully. Digital tools are no longer external additions to learning environments but are embedded in both cognitive and social fabrics of today's classrooms (Aloizou et al, 2024, Dindler, Smith & Iversen, 2020). Our study showed that playing well-designed exercises can

support collaboration, creativity, and personalized learning pathways when facilitated properly. As we saw in the HUT-workshops, exergames can be powerful tools for immersing students through interactive, playful experiences that seem to engage them in their activities throughout the workshops. However, the potential for exergames must be balanced against concerns around unstructured use, lack of digital competencies and implementation obstacles (Bottino, 2020; Dindler, Smith & Iversen, 2020). That made us use the insights from HUT-workshops to reflect core dimensions of holistic development and serve them as foundational pillars in creating the Design Wheel of Exergame-Based Learning (DWEL).

We recommend that future design adopt the DWEL framework as a tool for balancing educational aims with playfulness, bodily engagement, and movement-based activities. Games in the format of our exergame-based learning should not be seen merely as gamified activity but as a strategic, holistic approach to 21st-century education as Dindler, Smith & Iversen points out (2020). While DWEL offers a promising framework for bridging movement, play, and learning, it raises important questions for future research: Can exergame-based learning promote sustained holistic well-being and academic success over time? How do different school environments, cultural contexts, and technological access impact its effectiveness? Longitudinal studies and real-world applications are needed to assess whether exergames can move beyond short-term engagement to foster lasting physical, cognitive, and emotional development in children.

Ethics declaration: This study involved workshops with schoolchildren and followed University of Southern Denmark's Ethics Committee guidelines.

AI declaration: ChatGPT has been used for adjustments e.g. merging text pieces and spell- and grammar checking during the writing of this article. The adjustments suggested have been used as inspiration and informed the content rewritten in own words.

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Impact of Ashiyan Board Game on Iranian Students' Understanding of Native Vertebrates

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Abstract: Contemporary pedagogical research emphasizes active learning strategies to enhance cognitive engagement in primary education. This study investigates the pedagogical efficacy of "Ashiyan" (whose English equivalent is "Nest"), an interdisciplinary board game developed, modified, and tested during a graduate course on educational games to bridge Iran's fourth-grade Science (ecology) and Social Sciences (geography) curricula. The main goal of the game is to familiarize students with the five main groups of vertebrates and their characteristics. This familiarization is achieved through native vertebrate specimens so that students not only repeat and practice what they have learned but also become familiar with Iran's native vertebrates. The research method employed a mixed-methods design. The first part adopted a quantitative quasi-experimental approach with a pre-test/post-test design and an experimental group and a control group. In a quasi-experimental design, participants are not randomly selected, but they are randomly assigned to the experimental and control groups after selection. This method ensures that the assignment to groups is not biased, even though the initial selection of participants was not random. In this study, 120 participants were selected from six Iranian primary schools, and they were randomly assigned to two groups using stratified randomization to balance demographic variables. Following the intervention, learning and retention assessments were administered to both groups, and results were analyzed using inferential statistics to determine and compare the effects and results. In the qualitative phase, the data, gained from thematic analysis of interviews with 10 teachers and class observations, helped the researcher identify recurring patterns in the educational outcomes. A 28% improvement in accuracy ($p < 0.01$) of species identification was found for the experimental group participants compared to those of the control group, as measured by standardized assessments. Furthermore, a 35% higher retention of ecological relationships after a 4-week period was observed in the experimental group participants compared to those of the control group, as measured by standardized assessments. Qualitative data from 10 teacher interviews and classroom observations highlighted enhanced motivation, with 80% of students voluntarily engaging in post-game conservation activities. Thematic analysis identified three key drivers for this engagement: "Gamified rewards", "Supportive peer interactions", and "Real-world ecological storytelling" embedded in the game design. "Ashiyan" presents an adaptable framework for converting rigid academic material into culturally responsive, interactive programs, fostering students' development as proactive environmental guardians. Researchers can adapt its mechanics, dynamics, and narrative for other ecosystems and compare cross-contextual outcomes. Additionally, the study bridges traditionally separate domains, advancing educational sustainability science.

Keywords: Educational board games, Interdisciplinary learning, Ecological literacy, Primary education, Culturally responsive pedagogy

1. Introduction

Despite the critical role of science and social studies in shaping students' scientific thinking and environmental responsibility, Iran's primary education system still faces challenges such as traditional teaching methods, lack of connection between curriculum content and students' lived experiences, and declining learning motivation (Shayestehnia et al., 2024; Taherian, 2024). In many classrooms, scientific and environmental concepts—such as species identification, habitats, and ecological relationships—are delivered abstractly and theoretically, with little connection to real-life contexts. This disconnect reduces cognitive engagement and prevents meaningful internalization of content (Ardoin, Bowers, & Gaillard, 2020).

To address these challenges, educational researchers have increasingly turned to active and interdisciplinary learning strategies, particularly the use of educational games, which promote experiential, competitive, and interactive learning (Lin & Hou, 2016; Tsai et al., 2019; Garcia & Miralles, 2022; Hashim et al., 2023). However, most existing educational games either lack alignment with formal curriculum objectives or focus on general, non-local ecosystems (Javidi-Kalateh-Jaferabadi & Jahangard, 2018).

In this context, the board game "Ashiyan" was developed to help students understand the characteristics of five major vertebrate groups native to Iran—fish, amphibians, reptiles, birds, and mammals—through active gameplay. These characteristics include breathing, reproduction, body covering, dietary patterns, and habitats. The game aligns with content from Grade 3 Science and Grade 4 Social Studies textbooks and presents

ecological learning in an engaging, narrative-based, and culturally relevant format. Players aim to earn the highest score by correctly identifying features of animals, turning content mastery into a strategic, motivating experience.

Considering the utility of the game described above, the current paper aims to adopt a mixed-methods approach, combining a quasi-experimental pre-test/post-test design with a control group and qualitative data from classroom observations and teacher interviews. Quantitative findings from the present study reveal that students who played "Ashiyan" demonstrated 28% greater accuracy in species identification and 35% higher retention of ecological relationships compared to that by control group. These promising results raise a central research question that this study seeks to answer: Can the educational board game "Ashiyan" enhance primary students' understanding of the five main vertebrate groups in the context of native vertebrate animals of Iran?

Beyond their entertainment value, educational board games have shown significant potential to promote conceptual understanding, collaborative learning, and problem-solving skills across various subjects (Plass, Homer, & Kinzer, 2015). In the context of science education, gamified approaches—especially those involving tactile and visual components—have been linked to increased motivation, deeper engagement, and enhanced long-term retention of knowledge (Alsawaier, 2018; Martindale & Weiss, 2019; Ardoin Bowers, & Gaillard, 2020). Moreover, board games provide structured opportunities for students to practice decision-making, receive immediate feedback, and apply learned concepts in simulated, low-risk environments (Noda, Shirotsuki & Nakao, 2019). When designed with local contexts in mind, such tools also contribute to culturally responsive pedagogy, helping students form meaningful connections between scientific content and their sociocultural environment (Gay, 2018; Ladson-Billings, 1995). This is particularly relevant for ecological education, where fostering a sense of place and environmental stewardship has been shown to depend on localized, experience-based learning (Liefländer et al., 2013; Hammady & Arnab, 2022). By incorporating native species, real habitats, and region-specific storytelling, "Ashiyan" aligns with these principles while offering a curriculum-linked alternative to more abstract instructional methods.

2. Methodology

The current paper employed a mixed-methods design. In the quantitative phase, a quasi-experimental design, featuring a pre-test, a post-test, a retention test, an experimental group, and a control group, was used. In this quasi-experimental approach, participants were not randomly selected; however, they were randomly assigned to either the experimental or control group. A total of 120 students were selected from six Iranian primary schools and randomly assigned to experimental and control groups using stratified randomization to ensure demographic balance. Both groups took a pre-test before the intervention. The experimental group then received the instructional program, while the control group followed the regular curriculum. After the intervention, a post-test was administered, followed by a retention test four weeks later to assess long-term effects. A standard teacher-made test was used to measure learning, with face validity confirmed by experts and acceptable internal consistency. Prior to applying repeated measures ANOVA, assumptions including normality (Shapiro–Wilk), homogeneity of variances (Levene's), equality of covariance matrices (Box's M), and sphericity (Mauchly's) were tested and all met ($p > 0.05$).

In order to probe the educational aspects of the Ashiyan game, the current research conducted semi-structured interviews with 10 teachers and attended class. This section aimed to reveal differences in the motivation and the social interaction as well as environmental attitudes in between before and after the game experience of all students.

The interview questions dealt with: how much they had been actively involved, signs of motivation, acts of support in the environment, their interest in the environment and any transfer of learning to action. Interviews were recorded and transcribed verbatim and analysed using Thematic Analysis. This analysis occurred in three stages: Basic Themes, Organizing Themes and Overarching Themes.

3. Findings

3.1 Quantitative Findings

Table 1: Means and Standard Deviations of Learning and Retention Scores in Experimental and Control Groups

Test	Group	Mean Score	Standard Deviation
Pre-test	Experimental	12.3	2.1
Pre-test	Control	12.1	2.3
Post-test	Experimental	15.7	2.0
Post-test	Control	13.0	2.2
Retention Test	Experimental	17.0	1.8
Retention Test	Control	13.3	2.1

As shown in Table 1, while pre-test scores were similar between the experimental and control groups, the post-test and retention test scores of the experimental group were considerably higher. The experimental group showed a 28% increase in results of learning and a 35% increase in results of the retention test compared to those of the control group. These differences were statistically significant, with a p-value of < 0.01, indicating that the results are not due to chance and demonstrate a strong effect of the intervention.

3.2 Qualitative Findings

Qualitative analysis resulted in the recognition of 3 Overarching themes the entire coding process is included in Table 2. These themes are:

3.2.1 Gamified rewards

The motivational factors in this Ashiyan game is added to by the competition and visual point rewards included in the application that directly enhanced a student's intrinsic motivation.

> *"Even after the game is complete, students wanted to go through more cards and guess the characteristics of other animals." (Teacher 3)*

3.2.2 Supportive peer interactions

While the game had an individual focus, the game period did witness an increase in friendly exchanges and banter between students.

> *Teacher 7 described, "In the game, the students exchanged their opinions for the animal's features voluntarily, and a friendly class climate was formed."*

3.2.3 Real-world ecological storytelling

The use of real stories that tackle Iran's ecosystems resulted in enhanced positive environmental attitudes among students.

> *"One of the students said, 'I wish we could save the endangered animals of Iran." (Teacher 5)*

Table 2 illustrates the coding process for Basic Themes, Organizing Themes and Overarching Themes and the logic involved in the data.

Table 2: The Process of Qualitative Data Coding

Basic Themes	***Organizing Themes***	***Overarching Themes***
Desire for more points, enthusiasm for healthy competition, enjoyment of mental challenges, effort for personal progress, eagerness for positive competition, insistence on participating in subsequent rounds of the game	Increased intrinsic motivation	Gamified Rewards
Informal consultation about animal characteristics, friendly exchanges of opinions, mutual support, encouragement of classmates after correct guesses	Supportive Peer Interactions	Supportive Peer Interactions
Reduction in boredom in class, active participation in class discussions, expressed satisfaction with the game process, excitement about	Increased class engagement	

Basic Themes	*Organizing Themes*	*Overarching Themes*
discovering animal characteristics, increased scientific questioning during the game		
Curiosity about specific animal traits, attention to living conditions, expressed concern about the protection of endangered species, suggestions for forming animal protection groups, expressing interest in wildlife	Growth of environmental attitude	Real-world Ecological Storytelling
Ongoing discussions about animals, asking questions beyond the game, researching native habitats, reading zoology books, expressing interest in visiting natural habitats, designing crafts	Stimulating self-driven learning	
Studying supplementary resources, voluntary participation in environmental activities, creating volunteer groups at school, involvement in environmental science festivals, encouraging friends to care for nature, following environmental news, raising self-awareness about the importance of species conservation	Development of sustainable learning	

Classroom Observations

Observations in the classroom in the current study indicated the following:

- There was a notable increase in the degree of active engagement by students. Not only were students physically active during game play, but motivation to engage and perform also spilled over into post-game behavior. Such voluntary actions included environmental drawings, recommended areas to visit natural habitats, and even establishment of parent-foster volunteer group for scientific and environmental events.
- Some students initiated researching videos and articles about indigenous animal species and proposed a visit to a forest and other natural places. In sum, behaviors such as the informal chatting soup group activities and reinforcing group relations within the game have been seen, pointing to a pattern of supportive peer interactions occurring in the classroom.
- Analysis of interviews and observations indicated that about 80% of the students were willing to engage in environmental activities after playing the game. Examples of supporting quotes and observational evidence from students are included in Table 3.

Table 3: Samples of Quotes and Observational Data from Students

Basic Themes	*Organizing Themes*	*Overarching Themes*	*Quotes/ Observational Data*
Desire for more points, enthusiasm for healthy competition, enjoyment of mental challenges, effort for personal progress, eagerness for positive competition, insistence on participating in subsequent rounds of the game	Increased intrinsic motivation	Gamified Rewards	"I always wanted to get more points because I really wanted to win and beat the others."
Informal consultation about animal characteristics, friendly exchanges of opinions, mutual support, encouragement of classmates after correct guesses	Supportive Peer Interactions	Supportive Peer Interactions	"After I guessed correctly, I told the other students how to guess and helped them."
Reduction in boredom in class, active participation in class discussions, expressed satisfaction with the game process, excitement about discovering animal characteristics, increased scientific questioning during the game	Increased class engagement		"When the teacher asked us to name the characteristics of vertebrate animals, everyone raised their hands to answer. We were so happy that we could help."
Curiosity about specific animal traits, attention to living conditions, expressed concern about the protection of endangered species, suggestions for forming animal protection groups, expressing interest in wildlife	Growth of environmental attitude	Real-world Ecological Storytelling	"My dad told me we're going to the forest. I'm really excited to see more animals up close."
Ongoing discussions about animals, asking questions beyond the game, researching native habitats, reading zoology books, expressing interest in visiting natural habitats, designing crafts	Stimulating self-driven learning		"Every day I read with my dad about endangered animals and how we can save them."

Basic Themes	*Organizing Themes*	*Overarching Themes*	*Quotes/ Observational Data*
Studying supplementary resources, voluntary participation in environmental activities, creating volunteer groups at school, involvement in environmental science festivals, encouraging friends to care for nature, following environmental news, raising self-awareness about the importance of species conservation	Development of sustainable learning		"We formed a group at school with the guidance teacher to learn more about protecting endangered animals. We want to do activities like gathering information and making a bulletin board for the school festival."

4. Discussion and Conclusion

The current paper evaluated the effectiveness of a board game called “Ashiyan“ as a novel educational approach for learning and retention of educational knowledge in the field of environmental concepts and native vertebrate identification in Iran. The findings suggested that this game was effective in improving students' species recognition skills and ecological comprehension. In terms of quantitative results, students who played “Ashiyan“ demonstrated a 28% increase in accuracy in identifying species compared to the control group and a 35% increase in holding ecological relationships to memory after a four-week lapse. These statistically significant improvements ($p < 0.01$, as reported in the findings) highlight the game's strong impact on concrete learning outcomes. The substantial gains suggest that the interactive engagement with “Ashiyan“ translated into a measurable enhancement of students' ability to accurately identify species and recall complex ecological relationships over time, directly addressing the study's primary research question regarding the game's efficacy. Serving as a powerful tool for teaching and consolidation of the knowledge of science, the game is supported by the research results. It is especially useful in the field of ecology and biodiversity. This is shown in “The Game of the Sea“ (Arboleya-García and Miralles, 2022). This study demonstrates the effectiveness of board games in teaching ecological concepts. Similarly, in the current study, the use of board games was highly effective in enhancing the understanding of ecological concepts. Like in “The Game of the Sea“, that employs board games for instruction of ecosystem and marine life, the game “Ashiyan“ deals with native species and both marine and terrestrial ecosystems of Iran, showing the game-based instruction as effective in transferring complicated scientific knowledge.

In the qualitative part, drawing upon interviews with teachers and classroom observations, three emerged as the major themes, all of which focused on the beneficial effects of the game on the learning and interaction of students. Additionally, analysis indicated that approximately 80% of students voluntarily engaged in post-game environmental activities, supporting the effectiveness of the intervention beyond the classroom.

The first quality theme was “Gamified Rewards“. The teachers confirmed that “Ashiyan” had enhanced students’ motivation as well as the game players earned scores for the correct guess and each position of their pieces in each round. This reward system increased their motivation to learn and advance, so that they could feel a sense of achievement. This heightened motivation and active participation, driven by the game's reward system, likely contributed to the increased effort and focus during learning activities, which in turn could explain the significant gains in species identification accuracy and knowledge retention shown in the quantitative results. This pattern echoes the results of “The Design of an Ecosystem-Education Board Game Integrating Role-Play and Peer-Learning Mechanism and Its Evaluation of Learning Effectiveness and Flow“ (Lin & Hou, 2016), which emphasize the role of a reward mechanism in promoting student's engagement. Lin & Hou (2016) also employed a similar rewarding scheme and found that game rewards had potential to enhance student learning motivation and engagement. This approach being used in “Ashiyan“ also promotes learning environment as it involves the students themselves to take part in the learning and handling of environmental concepts.

The second theme, retrieved from analysis of the interviews, was “Supportive Peer Interactions”. Irrespective of the fact that “Ashiyan“ is an individual game, teachers claimed it benefits positive interactions among students. After all, these interactions resulted in a deeper understanding of scientific issues and more engagement during lessons. This deeper understanding and increased engagement, fostered by supportive peer interactions, are plausible contributors to the enhanced learning outcomes evidenced by the 28% greater accuracy in species identification and 35% higher retention of ecological relationships observed in the experimental group. These results are consistent with the study “Using Board Games To Teach Socioscientific Issues On Biological Conservation And Economic Development In Taiwan" (Tsai et al., 2019) that highlights the role of the interactions in groups in the learning process. Though being an individual game, “Ashiyan“ deepens

the classroom interactions, helping students better align themselves with concepts and enhancing their motivation. Tsai et al. (2019) also emphasized role of the interactions among the students that the interactions could help students to learn about complex social and environmental issues.

The third theme was "Real-world Ecological Storytelling". Teachers observed that through this game, students not only acquired knowledge of ecology but also learned about actual environmental problems in nature. The fables of these natural inhabitants of Iran had helped us understand many of the ecological concepts and make us feel responsible towards our environment. This connection to real-world contexts and the emotional engagement fostered by storytelling likely enhanced the meaningfulness of the scientific content, thereby facilitating the deeper comprehension and improved retention of ecological concepts demonstrated in the quantitative findings. This is also consistent with the "Taphonomy: Dead and Fossilized" study (Martindale & Weiss, 2019) that demonstrates the effectiveness of educational games in teaching complicated science lessons through experiences in daily life. Martindale and Weiss (2019) also found that games dealing with actual scientific concepts are effective in helping players focus on science in a direct, and interactive way. This supports deeper comprehension of the subject matter. This similarity indicates that "Ashiyan" ,as a game, can be equally effective in providing real environmental issues through eco-narratives in raising environmental awareness in scientific concept in the same way any other game acts.

Overall, the findings of the current study have demonstrated that educational games can serve as an effective and novel instructional tool for its potential raise cognitive engagement, and promote more active learning. "Ashiyan" not only assisted in learning scientific ideas but also positively influenced students' environmental and social attitudes, and in this way their sense of responsible behavior towards the environment.

Nevertheless, our study had some limitations as well: The first, the small sample size, derived from only six schools in Iran, that made it difficult to generalize the findings; The second, the short duration of the program (four weeks) that did not allow the researchers to assess the long-term effects of the intervention. There should be further research exploring the long-term effects of educational game, particularly on altering environmental behaviour and foster critical thinking as advocated in the case of "The Effect of Educational Board game on Students' Reflective Thinking Skill in Learning Subject Nutrition in Food" (Al Mustafid, Aristiawan & Cahyani., 2024).

For future studies, it is recommended to increase the sample size in order to be able to generalise the effects of educational games in various cultural and geographical backgrounds. Moreover, the use of hybrid games, games that integrate digital technologies, may enhance the teaching-learning process and increase students' motivation, in line with the findings from "Using Board Games to teach Socioscientific Issues" (Tsai et al., 2019) that reported on the advantages of combining physical games with digital games to learning.

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Ethics declaration: This research was conducted in research-focused schools, and since the Ashiyan game is part of the official curriculum of schools in Iran, there was no need to obtain consent for participation in the study. All research procedures were conducted in compliance with ethical standards and relevant regulations.

AI declaration: In this study, AI tools were used to access resources and translate the article. These tools assisted the authors in the process of research and translation, significantly contributing to the improvement of the research quality.

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Rewriting History: How Digital Games are Revolutionising NSW Secondary History Classrooms

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Abstract: Despite the significant growth in educational digital gaming, secondary History teachers in Australia lack have clear guidelines regarding gaming pedagogy, and as a result, may use digital games inconsistently. While there is a push from the Department of Education (DoE) for schools in New South Wales (NSW) to engage with digital learning technologies, professional development on digital game use is limited. The Schools Digital Strategy (SDS) is a comprehensive project driven by the DoE. Implemented in 2019, it aims to improve digital services to public schools through addressing existing issues such as connectivity, equality, and investment in devices, networks, and infrastructure. Whilst the SDS Full Report (2019) mentions computer games, the lived realities of secondary History teachers in NSW attempting to implement digital games has not previously been studied. A significant research gap exists in the academic literature on the use of digital games in secondary History classrooms in NSW. This study investigates how secondary History teachers in NSW implement digital games in their classrooms and the purpose of their use. Furthermore, identification of barriers that History teachers face when using or attempting to use digital games will be mapped against the SDS. A mixed method research approach was employed. A scoping literature review was undertaken to gain a baseline for current academic research, as well as an audit of NSW initial teacher education (ITE) programs offering units where digital game pedagogy is delivered. Additionally, surveys and interviews of secondary History teachers in NSW were conducted to understand the lived realities of the teachers, and the barriers they face while attempting to implement digital games in their teaching. This study has implications for teacher education and professional development programs to support effective implementation of digital games into the History classroom.

Keywords: Digital game-based learning, History education, Teacher professional development, Digital divide, New South Wales (NSW)

1. Introduction

Video game use in education is not a novel pedagogical practice. Their use in teaching and learning practices has increased due to benefits students acquire when engaging in video game play. Research identified that it enables students to develop key skills including leadership (Kee et. al, 2011), 21st century learning skills such as collaboration (de Freitas et al., 2013) and critical thinking (Gee, 2004), and improvements in motivation (Gomez & Porras, 2018) and engagement (Annetta, 2008).

The Oregon Trail (MECC, 1971), one of the most well-known historical education games, has seen multiple iterations released and subsequently used by generations of American students. Since then, games such as *Sid Meier's Civilization* (MicroProse,1991), *Assassin's Creed Origins Discovery Tour* (Ubisoft, 2017), and *Age of Empires* (Ensemble Studios, 1997) have been used in History classrooms across the world. Moreover, the seminal work of James Paul Gee's (2004) *What video games have to teach us about learning and literacy*, encouraged a plethora of articles, frameworks and models designed to aid teachers' use of video games in their classrooms: TPACK-G (Hsu et al., 2013), the Four Dimensions Framework (de Freitas & Oliver, 2006), and the Foundations of Game-based learning (Plass et al., 2015). To aid Australian educators using serious games, Southgate et al., (2017) also developed a model, however it does not cover all forms of video games, let alone video games for use in History secondary classrooms. Therefore, there remains a significant gap between theory and practice regarding the pedagogical applications of video games in NSW secondary History classes. As a result, this study aims to identify current video game use by secondary History teachers in NSW schools. This will be achieved through engaging in a mixed methods research process, allowing the exploration of the lived experiences (van Manen, 2003) of teachers within NSW, and then mapping the results against key areas of the SDS; a comprehensive plan that outlines the strategies identified to improve the technological abilities of the NSW public school system (Department of Education, 2024).

To address the research gap, the following research questions were considered:

RQ1: What insights can be gathered from the existing body of literature regarding digital game use in NSW : secondary History classrooms?

RQ2: Which digital games are currently being used by teachers in NSW secondary History classrooms?

RQ3: How are digital games currently being used by teachers in NSW secondary History classrooms?

RQ4: How do the research findings compare against the NSW Department of Education's Schools Digital Strategy?

For the purposes of this study, the definition outlined by Clark et. al in 2016 will be used in reference to digital games: "a digital experience in which the participants (a) strive to achieve a set of fictive goals within the constraints of a set of rules that are enforced by the software, (b) receive feedback toward the completion of these goals (e.g., score, progress, advancement, win condition, narrative resolution),and (c) are intended to find some recreational value." (Clark et al., 2016, p.9). The term digital games was used to identify a range of video games for use within classrooms which included the following:

- *Serious games*: games whose purpose it is to educate as opposed to entertain (Arnab et al., 2015).
- *Digital game-based learning*: the use of digital games to encourage players to achieve learning goals (Gee, 2004).
- *Drill games:* the use of repetitive game play with increasing difficulty to build skills (Alessi & Trollip, 2001).
- *Gamification:* when gaming elements, such as scoreboards and avatars, are used to encourage and motivate learning activities (Kapp, 2012).
- *Commercial off-the-shelf (COTS):* those which can be purchased and/or accessed with ease and often align to historical events (Pallavicini et al., 2021).

Due to the variations of digital/video game definitions, virtual and augmented reality have not been included in this study as they are not often used for enjoyment (Gibson et al., 2001) and therefore do not meet the definition.

2. Methodology

A mixed method research approach was undertaken to answer the research questions; this included a scoping literature review, survey, interviews, NSW ITE program audit, and mapping results against the SDS. Onwuegbuzie and Leech (2007) argue that when undertaking qualitative research, smaller sample sizes are appropriate when the study is exploratory. Using both surveys and interviews will allow for data triangulation (Brannen, 2004) and provide relevant material for mapping against the SDS. Ethics approval was obtained in April 2025 through Western Sydney University (H16510).

2.1 Scoping Review

The scoping review was used to identify current practices regarding digital game use in secondary NSW History classrooms, in line with RQ1. Outlined by Arksey and O'Malley (2005), the purpose of a scoping review is to gain an overview of the research providing direction for further study. Search parameters previously identified by Cole et al. (2023) were used to guide the creation of the search terms as well as the pre-identified definition of digital game (see Table 1).

Table 1*:* Scoping review search terms

Block 1: Population	Block 2: Subject	Block 3: Location	Block 4: Digital Games
"secondary school" OR "high school" OR "middle school"	History	"NSW" OR "New South Wales"	"video gam*" OR "gamification" OR "game-based" OR "educational gam*" OR "edutainment" OR online-multiplayer OR "electronic gam*" OR "digital gam*" OR "serious gam*" OR "game-based pedagog*" OR "computer gam*" OR "drill game"
*Asterisks serves as the Boolean truncation to capture words ending in alternative forms			

Inclusion and exclusion criteria were also devised using Cole et al. (2023) as a reference point. Additional terms were included to ensure the capture of relevant citations in relation to the research questions and aim of the study (see Table 2).

Table 2: Scoping review inclusion and exclusion criteria

Study variables	Inclusion criteria	Exclusion criteria
Population	Studies within a high/secondary school	Primary schools, early childhood centres, TAFE, universities
Subject	History	Subjects that are not History
Location	NSW	Locations outside of NSW, including other states/territories within Australia, international studies
Digital game definition	Drill games, game-based learning, gamification, video games, educational games, serious games, computer games, digital games	Virtual reality, augmented reality
Literature	Peer-reviewed, published after 2000	Published prior to 2000, grey literature (including conference papers)

2.2 Survey

A survey capturing qualitative and quantitative data questions was used to answer RQ 2 and 3. Likert Scale questions identified teacher perceptions regarding barriers to digital game use, impact of digital games on learning outcomes, and ability for digital games to teach content. All Likert scale questions were numbered 1 – 5, with 1 being *not effective at all* and 5 *being very effective*, therefore providing numerical data for analysis (Cohen et al., 2017). Response boxes allowed participants to justify answers and provide additional information. Surveys were distributed through social media channels (Facebook groups) to recruit participants.

2.3 Interviews

Participants were self-identified through the survey who were interviewed via Zoom using semi-structured questions. The audio was recorded for the purposes of transcript creation for data analysis (Cohen et al., 2017). The use of Zoom also mitigated issues of geographical distance and significantly reduced costs (Creswell & Guetterman, 2019). The questions were designed to aid the answering of RQ2 and 3.

2.4 Mapping Against SDS and University Audit

After the completion of the survey and interviews, the results were analysed and coded. The code was devised using a top-down approach guided by the scoping literature review (Urquhart, 2013). During the process, additional codes were developed based on responses (Stake, 2010), thereby creating a middle-range coding process (Urquhart, 2013). This allowed for the triangulation of the data to be mapped against the SDS. The SDS identifies nine strategic focus areas that outline overarching objectives for the initiative, with #3 addressing the need for teachers' effective use of technology to enhance teaching and learning, and #7 improving the current inequity issues to devices because of geographic, technical, and professional differences (Department of Education, 2019). Both focus areas were planned to span all 4 Horizons (stages) and therefore had a completion date of late 2022/early 2023. The final stage, Horizon 3, was to be completed within 3 years of the rollout of the initiative and indicates that there should be 'equity in education access' and 'advanced digital literacy the norm' (Department of Education, 2019, p.10). These elements were identified for analysis as they were likely to be reflected in the survey and interview responses, and to answer RQ4. An audit of NSW ITE programs identified if any included video game pedagogy for further mapping against strategic focus area #3. Universities and courses offered were identified through the AITSL Accredited Teaching Program list (AITSL, 2025).

3. Results

3.1 Scoping Review

No sources were identified using the search terms in Table 1. Three further iterations of search terms were developed to capture relevant citations. The second iteration removed 'NSW' from Block 3: Location and replaced it with 'Australia' which resulted in two citations. To identify any digital game use within secondary classrooms in Australia, Block 2: Subject, was removed, resulting in 18 citations identified. The final iteration of

the scoping review search terms reintroduced Block 2: Subject, but removed Block 3: Location, to capture citations regarding the use of digital games in History classrooms internationally, which generated 82 citations.

Together, 109 citations were identified from the four iterations of searches. From 109 originally identified citations, 27 remained after the application of inclusion and exclusion criteria. Figure 1 outlines the screening process.

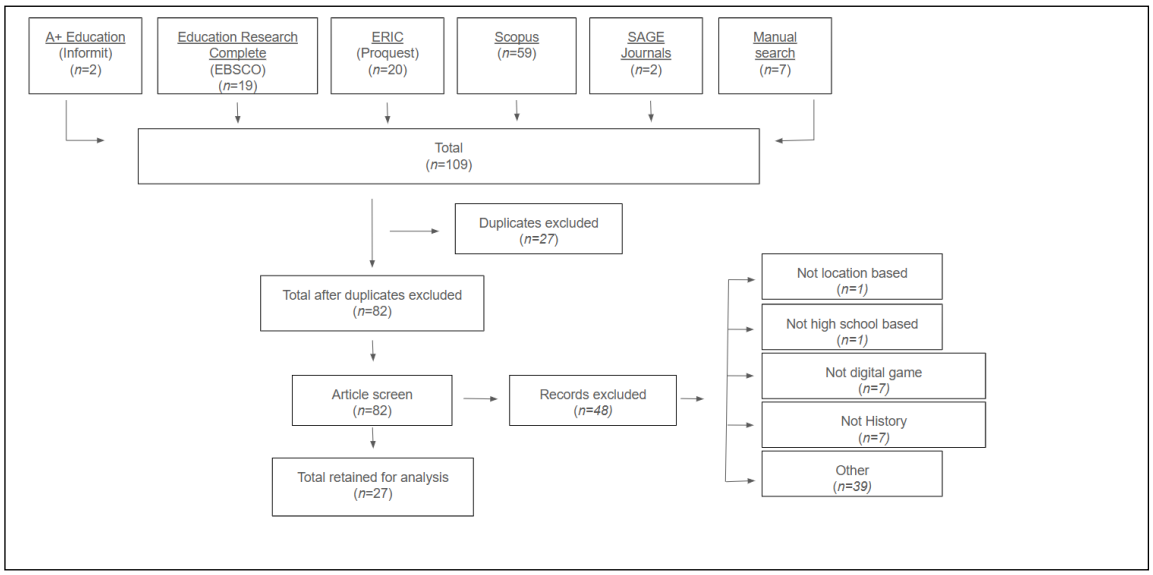

Figure 1: Screening process for scoping review

3.1.1 Demographics of retained studies

A total of 3440 students participated in the studies across 49 different schools with 53.03% of participants females (*n*=499) and 46.87% were males (*n*=441). There were 237 teachers identified as participants across six studies; however, it should be noted that seven studies mentioned teachers but did not provide numbers regarding participants. Of the retained citations, 55% (*n*=15) were published in the past ten years, with 33% (*n*=9) from within the past five years.

3.1.2 Location of studies

Table 3 identifies the location of the studies. While there were no citations that were captured in the initial search, the later iterations captured results from within Australia and internationally.

Table 3: Location of identified studies

Search	Location of search	Results	Retained result locations
1	NSW	0	0
2	Australia	2	0
3	Australia	4	New South Wales (2) Western Australia (2)
4	International	16	Greece (2) Taiwan (3) Canada (2) USA (6) Israel Poland

Search	Location of search	Results	Retained result locations
			Germany
Manual	International	6	Australia (Queensland) Australia (New South Wales) Australia (Western Australia) USA (3)

3.1.3 Research Question 2 - digital games used

All the captured citations made mention of/used digital games. There were 81 games identified with 85% (*n*=23) of the studies using digital games in their research. Within that group, 47% (*n*=11) used COTS and the remaining studies (*n*=12) used digital games designed by the researchers. Results demonstrated that the most popular genre of games used were strategy games including games from the *Sid Meir's Civilization* franchise and the *Age of Empires* franchise. Strategy games were identified 63 times within the retained articles as games for use in schools.

3.1.4 Research Question 3 - purpose of digital game use

The most frequent use for digital games was to teach content at 69% (n=16). Engagement and motivation were identified as research objectives in 48% (n=11). Additionally, digital games used as supplementary materials were used by 8% (*n*=2), and 13% (*n*=3) for 21st century learning skills.

3.1.5 Additional area of interest

The need for teacher training (both in-service and pre-service) was highlighted in several studies. Gutierrez et al. (2023) identified that teacher's self-efficacy and positive attitudes towards using digital games improves because of undertaking professional development. Additionally, Kessner and Harris' (2022) creation of the 'opportunities to practice' model not only allows students to refine skills and develop knowledge, but also acknowledges that teachers would also benefit from its use as it enables them to identify learning opportunities for students, as well as to think critically about how digital games can be used to improve historical thinking skills.

3.2 Survey

Twenty-one participants were recruited through social media and completed the survey between 15th and 25th April 2025, with 18 meeting the inclusion criteria. Demographic data identified 83% (*n*=15) were from government schools, 17% (*n*=3) and from Catholic schools. 11% (*n*=2) taught only History, whereas 83% (*n*=15) taught both History and Geography. Teaching experience followed a classic bell-shaped distribution, with most having between 6 and 15 years (see Table 4).

All participants had used digital games in their teaching. The most frequent game was *Kahoot!* (Kahoot, 2013) (*n*=14), followed by *Blooket* (Stewart & Stewart, 2018) and *Minecraft* (Mojang, 2009) (*n*=13). Other digital games included the *Age of Empires* and *Assassin's Creed* series.

The use of digital games to teach content was identified by 83% (*n*=15) of respondents as the main reason for their use, with formative assessment, as a reward, or to fill in time as the least selected reason for use.

Participants identified the biggest barrier to using digital games was access to devices (*n=15*) and professional development (*n=10*). Results identified that 75% (*n=12*) of participants either somewhat or strongly disagreed that student interest in digital games was a barrier to using digital games in their teaching and learning activities.

Table 4: Survey participants

Question	Option	Number of responses
3. Age range	18 - 30	5
	31- 40	5
	41 - 50	3

Question	Option	Number of responses
	51+	5
4. Teaching experience (in years)	0 - 5	4
	6 - 10	3
	11- 16	6
	16 - 20	1
	21+	4
5. School type	Public	15
	Catholic	3
	Independent	0
6. Subject/s taught	History	2
	Geography	1
	History and Geography	15
7. Digital game use	Yes	18
	No	0

3.3 Interviews

Two interviews were conducted during the research period and were recruited through the final survey question. A middle-range coding process was undertaken which identified several categories and codes. The use of digital games as a pedagogical approach was the most frequent category mentioned (*N*=82), in particular the codes for differentiation (*N*=23) and engagement/motivation (*N*=25). Interestingly, the most frequently cited code was within the implementation barriers category: technology and infrastructure/internet issues (*N*=36). "John", Head Teacher HSIE in a Western Sydney high school, also frequently mentioned the lack of confidence from teachers (*n*=11) (see Table 5).

Table 5: Interview participants

Pseudonym	Age	Teaching experience	School type	Subjects taught
John	18 – 30	6 – 10	Public	History and Geography
Sally	18 – 30	0 – 5	Public	History and Geography

3.4 Mapping Against SDS

From the SDS Full Report (2019), Strategic Focuses #3 *Support improved teaching and learning*, and #7 *Strengthen equity foundations*, were targeted for mapping data against due to their alignment with teaching and learning activities, and device equity. Results identified three key areas regarding the use of digital games in NSW secondary History classrooms: the lack of access to devices as a barrier, the need for professional development, and the need for NSW DoE recognition of digital games as a legitimate teaching and learning tool.

Survey data outlined the lack of professional development was a barrier to the implementation of digital games in NSW secondary History classrooms. This was supported in the interview with "John" "*… some teachers that don't have the full kind of confidence in themselves to be able to teach through a game.*" An element of Strategic Focus #3 was designed to support teachers effectively using digital technology, including digital games and gamification, through ongoing and innovative professional development (Department of Education, 2019). The SDS identified a completion target of two years after the initiative roll out, in 2019.

As identified in survey and interview results, a lack of access to devices was identified as a barrier for using digital games. The SDS outlines in Strategic Focus #7 that device equity should have been achieved by early 2023 (Department of Education, 2019). The most significant barrier to using digital games in classrooms identified by survey participants was access to devices, and this was supported in interviews, in particular, bring your own device (BYOD) which makes it difficult to design teaching and learning activities (Janssen & Phillipson, 2015). "Sally" outlined the struggles of implementing digital games and not knowing if students' devices would support the program "Bring your own device is really frustrating… five kids have Chromebooks, the rest have MacBooks… iPads or tablets." This was mirrored by "John" - "Every faculty has about… 30 to 60 Chromebooks and that's for every class that's on at the same time…". The Rural Access Gap program (an initiative within the SDS) aimed to

reduce the digital divide between metropolitan and rural schools. The program was able to reduce the student-device ratio from 1:6 to 1:4 (NSW Department of Education, n.d.), much higher than the Digital Education Revolution target of 1:1 back in 2008 (Newhouse, 2014).

It should also be noted that the SDS states that 'By 2025 NSW Education will be an education leader in a digital world' where 'digitally literate pre-service candidates thrive in the digital school environment'. (Department of Education, 2019, p.15). Additionally, the NSW DoE also acknowledges that "We need to address existing areas of digital debt" by "demonstrating to our pre-service staff - our next generation of teachers - that we have a modern working environment." (Department of Education, 2019, p.34). An audit of NSW ITE programs between March 8th and March 20th, 2025, offering ITE programs identified 15 institutions offering 75 degrees, and within those degrees, there were 64 mandatory technology units. Of those 64 mandatory technology units, only two units briefly mentioned digital/video games for examination. Both units were at a large metropolitan university, with only one of the units available for ITE secondary students. Considering survey and interview results, as well as the statements made within the SDS, there is no clear evidence that the NSW DoE supports the claim that use of digital games can "make learning more meaningful, authentic, accessible and engaging." (NSW Department of Education, 2023).

4. Discussion

Several key themes were identified for further discussion regarding the use of digital games in NSW secondary History classrooms; strategy games used for teaching content, barriers to using digital games, and a clear digital disconnect between government initiatives, ITE training, and the experiences of secondary History teachers in NSW.

4.1 Strategy Games Used for Teaching Content

While the survey results indicated that quiz-based games (i.e. *Kahoot!*) were the most frequently used, interviews with NSW secondary History teachers identified that strategy games were used to teach content. This reflects the results of the scoping review where strategy games were used in 45% (*n*=5) studies using COTS games. Strategy games such as *Sid Meier's Civilization* are colonial-based games, where the focus is on exploitation, expanding, and ultimately extermination (Emrich, 1993). The settler-colonial perspective in strategy games is the status quo (Loban, 2023), yet the Australian Curriculum and Reporting Authority (ACARA) has included Aboriginal and Torres Strait Islander Histories and Cultures as a cross-curricular priority across each key learning area (Australian Curriculum and Reporting Authority, 2022), including History. This digital dispossession of Indigenous people from digital games (Bird, 2021) perpetuates colonial perspectives. It is vital that secondary History teachers understand the implications of using strategy games to teach content (McCall, 2023) and develop teaching and learning activities which encourage students to recognise and question colonial practices.

4.2 Barriers to Digital Game use

Survey participants identified that the most prominent barrier to digital game use is student access to devices. At the conclusion of the National Secondary School Computer Fund (New South Wales Government, 2009), schools moved to a variety of BYOD models where students can either bring in any device, bring a school specified device, or a device provided by the school (Janssen & Phillipson, 2015). Unfortunately, these options prove difficult for students living in low socio-economic areas, resulting in limited access to technology (Australian Bureau of Statistics, n.d). A report released in 2024, some two years after Strategic Focus #3 was to be achieved, identified that students in Western Sydney "...have the lowest levels of digital inclusion across all metrics - access to devices, internet connectivity and digital literacy." (Dastyari et al., 2024, p11). The inability for students from low socioeconomic backgrounds to access devices creates a significant equity gap, as digital game use as a teaching and learning tool has been demonstrated to develop 21st century skills (Southgate, et al., 2017), improve learning outcomes (Mustafa et al., 2013), and increase student engagement (Connolly et al, 2012). This disparity in access perpetuates existing educational inequalities and hinders students' ability to develop skills essential for academic and future success.

4.3 The Digital Disconnect

This study has highlighted a disconnect regarding the SDS targets, professional development, and the lived realities of secondary History teachers in NSW. Although the SDS projected device equality by the beginning of 2023 (Department of Education, 2019), the results indicate ongoing challenges in this area. As well as students' inability to access devices as a barrier to using digital games, the limited number of ITE programs providing video

game pedagogy demonstrated in the university audit also indicates an inadequacy to prepare future teachers. Research identified in the scoping review outlined the need for teacher professional learning, at both the in-service and pre-service levels, to ensure effective digital game pedagogy (Gutierrez et al., 2023; Kessner & Harris, 2022). This is supported by an Australian study undertaken by Magen-Nagar et al. (2019) which outlined the benefits (such as the use of constructive learning environments and 21st century skills) gained by in-service teachers when undertaking learning of video game pedagogy. Secondary History teachers in NSW are using digital games in their classrooms with limited technological infrastructure and pedagogical knowledge, however, with support in place, could further improve the learning outcomes of their students as outlined in the literature review.

5. Limitations of the Study

Due to the nature of the research questions and aim of the study, citations of relevance may have been missed. In particular, the decision to not include AR or VR may have been a missed opportunity to explore new technologies and is suggested for inclusion in future studies. Due to the limited time frame to capture survey responses, the results cannot be said to directly reflect the perspectives of all secondary History teachers in NSW. An extended window of time to capture additional responses will improve the reliability of results.

6. Conclusion

This study provides key insights into the use of digital games by secondary History teachers in NSW. Although 100% of survey participants use digital games, there is a significant gap in in-service and pre-service teacher learning opportunities, despite academic studies identifying the benefits. Results of the interviews identified that NSW History teachers were more likely to use digital games such as *Kahoot!* or *Blooket* in their classrooms, whereas academic studies demonstrate COTS strategy games, such as *Sid Meier's Civilization*, are beneficial in delivering content. However, the use of COTS strategy games engenders concerns regarding ongoing colonial perspectives embedded in these games, therefore highlighting the need for digital game pedagogy within ITE programs and as ongoing professional development opportunities.

These pedagogical challenges are further compounded by student access to devices and infrastructure issues is a crucial barrier to digital game implementation in History classrooms. Although this study is narrowly focused, the results extend universally across subjects and Australian classrooms, therefore the implications are substantial. BYOD policy revision and delivery of a Metro Access Gap program are required by the NSW state government to ensure they achieve the legacy of the SDS and close the digital divide for students.

Future research on pre-service teacher digital game pedagogy, government policy regarding student digital inclusion, and the benefit of digital games for NSW secondary History students, is required to ensure students are supported by a future-focused government.

Ethics declaration: The author(s) did not receive support from any organisation for the submitted work. The author(s) has no relevant financial or non-financial interests to disclose.

AI declaration: NotebookLM was used for the initial summary of a select number of articles. Claude AI was used to provide feedback regarding clarity of writing.

Authors' note: This research was conducted based on the 2019 Schools Digital Strategy document, which had been identified by members of the NSW Department of Education as the most current version available during the data collection period. Subsequently, a 2022 version has since been confirmed as the most up to date. The findings and analysis presented in this article reflect the 2019 version that informed the research design and data collection.

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Enhancing Programming Learnability for Children Through Video Games

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Abstract: This paper explores the potential of video games as an effective medium for teaching programming concepts to children leveraging gamification principles to enhance engagement. Through the development and testing of an educational game called "Codonia" implementing challenge-based learning and interactive feedback, this research examines how game mechanics support problem-solving and logical thinking. After a qualitative and quantitative study, the results indicate that gamification fosters increased motivation and confidence, suggesting that well-structured educational games can complement or surpass traditional teaching methods. By demonstrating how digital learning environments encourage experimentation and sustained engagement, this study contributes to the broader discourse on innovative educational tools for programming instruction.

Keywords: Gamification, Video games, Edutainment, Learnability, Children, Programming

1. Introduction

The research paper aims to prove games can be a tool for education. Through the power of gamification, adding game mechanics into non-game environments, like a website or teaching management system to increase participation. The goal of gamification is to engage with consumers, employees and partners to inspire collaborate, share and interact (BI WORLDWIDE 2024).

The mobile video game which was created uses gamification elements and was based on two hypotheses that are related to the research questions. First, gamification increases the motivation of learners, and second, gamification increases the self-perceived competence of learners. These two hypotheses motivated the following research questions: Are learners more motivated when learning with a game? (RQ1) Is the self-perceived competence higher with learning with a game? (RQ2) Does gamification have a higher learning outcome than traditional teaching? (RQ3) Through a demo experiment and feedback from a group of participants we can conclude if the game can be further developed for education.

The focus of the research is to see how motivated students will be if they are to study programming through a video game. Using many elements from gamification, a mobile game was created that will get them interested to learn the basics of programming through narratives and challenges. Video games have been viewed as entertainment and a leisurely activity for a long time. Being able to capture the attention of users and teaching new skills. However, now they are seen as a potential learning tool. Researchers have explored new opportunities which will take interactive platforms and use them for an engaging lesson plan. This paper includes unexplored sides of games as a medium for learning, especially when it comes to programming languages.

The study conducted for this research aims to prove that there is positive feedback in using video games to teach the modern brain of the children of this generation. Video games have been used for entertainment providing countless hours of immersive game play. They offer a form of interactive storytelling that can be deeply engaging, and the fun and enjoyment derived from playing games can lead to hours of sustained attention (Harvard Graduate School of Education 2021).

The motivation in RQ1 refers to the players wanting to finish the levels and get to the end of the game, needing to know more about the storyline and still being engaged while playing the game. Self-perceived competence are the players own assessment of their ability to perform a task and achieve goals. In simpler words, it is the confidence that a player has in knowledge and skills in a specific area or task.

Codonia, the educational game we created, aims to be a part of edutainment. A game where children can learn programming through playing a video game. The video game includes a storyline for entertainment, a main objective for motivation, characters who guide the player through the levels and user interface that is easy to understand and navigate.

2. Related Work

Using gamification for teaching and learning has been a n important topic in both academic research and practical applications in schools and at universities for along time now.

“CodeCombat” is an educational game that teaches programming skills through interactive coding challenges. Players write code to control their characters and solve puzzles, learning programming concepts such as variables, loops, and functions along the way (Kapp,2012).

“Classcraft” gamifies the classroom experience by turning learning into an epic adventure. Teachers can customize the game to align with their curriculum, providing incentives for participation and engagement while fostering a collaborative learning environment (Kapp, 2012).

“Foldit” is a puzzle video game that challenges players to solve complex protein-folding problems. The game's competitive elements, leader boards, and collaborative gameplay motivate players to explore different strategies and solutions, leading to breakthroughs in scientific discovery (Kapp, 2012).

Studies have also shown that Scratch helps students develop skills such as abstraction, decomposition, and algorithmic thinking. Studies have reported positive learning outcomes, including increased engagement, motivation, and self-perceived competence among learners who use Scratch (Steward,2023).

A study made for a gamified programming course (Imran, 2022) had 450 registered learners, 374 completed the course, with a 16.88% dropout rate. Participants were divided into three gamification levels: Zero (ZLG), Low (LLG), and High (HLG), with HLG consistently showing higher motivation (5.89), engagement (5.94), and performance (6.71) compared to LLG and ZLG ($p < 0.001$). HLG learners also reported the most significant skill development (7.18) and participation (6.14).

The “Stack Game” (Dicheva and Hodge, 2018) is an educational game designed to help students understand the Stack data structure in a Data Structures course. The game challenges students to use stacks for solving problems such as converting arithmetic expressions from infix to postfix notation and evaluating postfix expressions.

“Sleuth” is a gamified platform designed for teaching introductory programming through interactive code puzzles, using a detective-themed narrative to engage students. The platform is currently used for online and campus-based teaching with around 1200 active students at any given time (Katan and Anstead, 2020).

3. Gamification Basics

To grasp how the concept of video games can further aid education into a more advanced era, we need to understand the basics of gamification. What is the motivation behind gamification? Are we trying to get users to aimlessly be addicted to games? Is there any result? Well, gamification aims to increase user engagement. This encourages them to spend more time completing tasks and challenges without noticing the time passing.

According to Karl Kapp gamification is a careful and considered application of game thinking to solving problems and encourage learning using all the elements of games that are appropriate (Kapp, K.M. 2012). The motivation is creating fun and addicting elements from game mechanics and applying them to real-world applications. In other words, take programming and make it gamified. With the same building blocks or component that are used in video games, we can create an educational platform that will not feel like studying. With the power of gamification, any lesson can turn into a competition with yourself or your peers.

Game mechanics are designed to increase user engagement for games that do not necessarily have anything to do with gaming. They enhance the gaming experience for users. These are the elements that can fit every kind of user personality depending on what they aim to do in a game. Each of these items have their own game elements that help with engagement, motivation, and loyalty:

- Points and rewards
- Challenges and quests
- Feedback
- Leader boards
- Storytelling and narrative
- Social interaction
- Customization
- Unlockable items

Poorly applied game design elements, however, may undermine these basic psychological needs by the over justification effect or through negative effects of competition. Educators must, therefore, clearly understand the benefits and pitfalls of gamification in curricular design, take a thoughtful approach when integrating game design elements, and consider the types of learners and overarching learning objectives (Rutledge et al. 2018). If you do not apply gamification properly it can lead to over justification and the negative effects of competition.

Over justification effect occurs when you offer too many rewards or incentives to a player who was already interested in completing the task. This can cause them to change their motivation from enjoying the game to now playing it for a completely different reason. That is, adding game design elements to increase extrinsic motivation, motivation that you get from outside sources, can have an adverse impact on learners who already started with a strong intrinsic motivation, self-motivation.

Reading research papers that talk about how to teach programming can be a fascinating topic. Researchers often deep dive into topics that have to do with development. *Algorithmic Development* is where the focus is creating new algorithms to solve problems in a more efficient way. Developing new programming languages or improving the ones that exist. Creating a more structured and secure language that is also more powerful. Researchers also often talk about Artificial Intelligence. *Artificial Intelligence* who concentrates on developing new models and techniques. Finding a way to make Artificial Intelligence more human-like. Studying how the users interact with the software so it's more effective and intuitive with its answers.

These topics are being also studied through different methods. Conducting experiments and conducting case studies. Testing new approaches to validate their effectiveness. Collaborating with other experts in fields like linguistics to innovate a new programming language foundation.

The question arises how does researching "how to teach programming?" differentiate from how we actually teach programming in schools? The lesson plan needs to be thoroughly written for each step of the difficulty level. It should progress naturally, without feeling like they took a big leap from learning how to walk. The levels that were played in the demo were simple, easy to understand although they would not uphold in the long run. Because this was supposed to be an introduction, easy concepts were chosen. Meaning, to continue developing Codonia more challenging levels have to be introduced through each stage.

To create a successful lesson plan these are the six steps that need implementing into the levels as they progress to harder terms and definitions.

- Clear learning objective
- Progression system
- Immediate feedback
- Long-term feedback
- Social interaction
- Rewards and recognition

Each of these steps are counted as milestones as to how much the game has progressed itself. Clear learning objectives are the basis of our learning step. We can imagine an empty Lego plate that will be used to build upon. The learning objectives must be defined in a simple manner, without adding any unnecessary steps.

4. Codonia: The Game

Our video game "Codonia" has been created in the Godot Game Engine using its embedded language GDScript. It is intended to be a mobile game, although it can also be played on a laptop with a touch screen. The design is simple, which ensures children to have a clear understanding of what each element's purpose is. The levels are created in-between cut-scenes and dialogue scenes. Before they start to play the game, there had to be a storyline that would get them interested in continuing.

To provide players with a purpose to continue engaging with the game, a narrative was created focusing on a fictional kingdom named Codonia. This kingdom was ruled by their queen, Ada, who had been captured by an evil villain, Nullify. The children are introduced to their objective early in the level, so they get a basis of what their mission is. While working on the demo, additional attention was given to the different types of elements we can add so the interaction does not feel repetitive.

The game is in 2.5D and some of the levels even being top-down. A 2.5D game is a two-and-a-half dimensional game. This design technique is used to add a bit of depth to a video game. While your character can move

through a 3D environment, their only options are going up, down, left, right. The environment is set in layers, so each object in the game has its own position in the world.

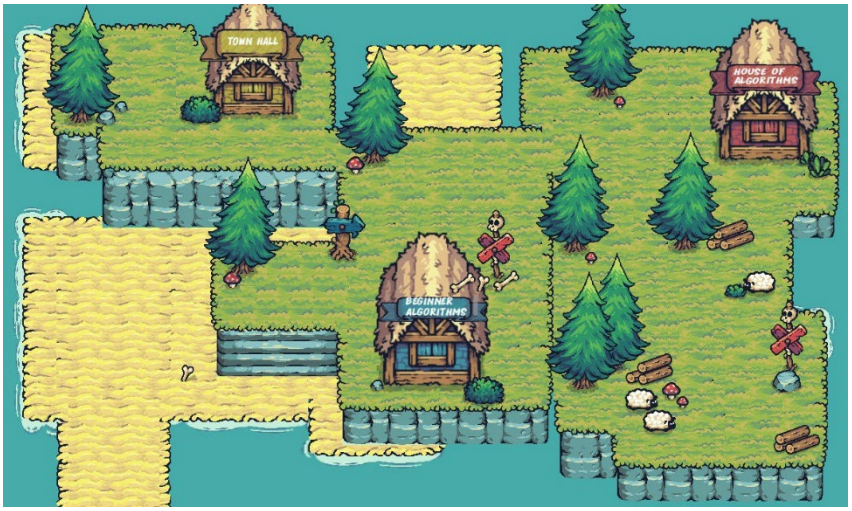

Figure 1: Codonia level design

Codonia has three different layers of tiles. To create an illusion of a 3D game, on top of the water there are individual islands of sand. The sand is the foundation for the real platform that the players will use. The third tile, which was accessible, is the ground. The stacking of different layers gave the perception of depth. Although, to be able to have the player move around the map, smaller islands were created to connect with bridges. One of the levels includes getting answers correct in a quiz to be able to show hidden bridges. Even though there is a sense of freedom when playing the game, it cannot be completed without finishing the objective.

A good example is one of the Algorithm levels where character is stuck in a forest with a lot of trees, with no road in sight. They must depend on a list of step-by-step instructions they found on a sign that give the way out. The instructions clearly state how many steps they need to take toward a direction to be able to navigate the forest. In gamification positive reinforcement is crucial. The psychology of every player is different although the main component that makes them keep playing is the thought of finishing the game. One way to make sure that the students who are playing these educational games do not get discouraged enough to leave the game, is to give them explanations.

Educational games should not have that kind of outcome since we want to motivate children to get involved, nevertheless, they need to know that there are repercussions. Giving an explanation to the player why they answered wrong is part of a feedback with a consequence. It shows the player that that they cannot guess answers while trying to finish the level. It gives them a sense of responsibility for the towers. Through narrative we are connecting the players to the characters on the screen. If something were to happen to the towers or a character in the game, the player needs to understand the consequences of their actions. This in a way forces the players to take the game seriously to not concurrently restart the level. This negative feedback also needs to have a positive effect on their psyche.

Immediate feedback follows after a wrong answer is pressed. In one level design, there are trolls that are waiting for a command. The command, in our case is answering the questions through a quiz, will tell the troll to either not react or destroy a tower. This is the kind of feedback that makes it thrilling for kids to remember the right answer by repeating the level every time they fail answering the questions correctly, in our case by memorization. As the questions are simple, “What is GDScript used in?” and the only answer would be “Godot”, memorization is acceptable.

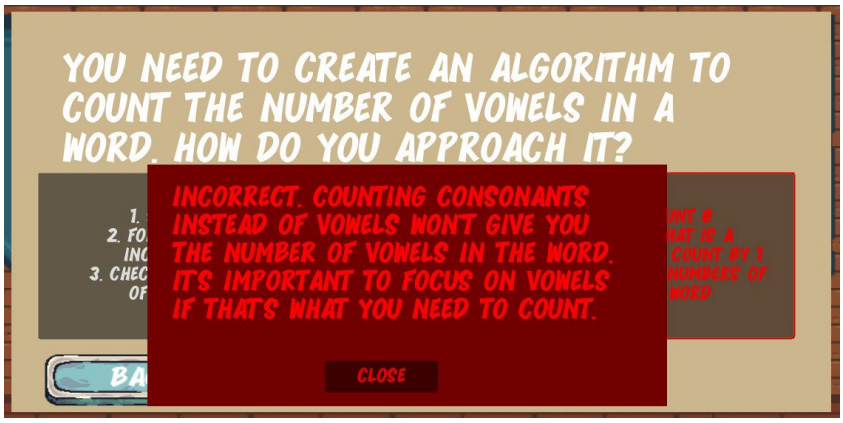

Figure 2: Example of immediate feedback

Meanwhile, *long-term feedback* is the opposite of *immediate feedback*. They do not get to see their behaviour right after playing a level. This is data that is accumulated throughout the game and would be shown in different scenarios. The first scenario would be after the player has finished a chapter which would be equal to one lesson plan, around ten levels for each lesson plan, they get a detailed summary on their performance.

he words they missed the most, the objectives where they made the most mistakes and a suggestion on which levels they can replay. It is anticipated that the children will be able to play and focus in a more calming manner knowing in the end they get feedback that will help them in the future. It takes away one less worry of trying to remember the checkpoints of their less highly performed levels.

The dialogue would explain what they need to do including a piece of information about the characters or introducing the villain early on to give the children motive to continue playing. There was limited time to prove why this thesis could work, the experiment had to be harder.

The children only had one shot in understanding the concept, solving the problems and re-iterating what they had learned. This realization would set for those children who would try to skip a conversation and get perplexed. Next level they performed better, paying higher attention to the dialogue and the tasks.

5. Evaluation

To evaluate the effectiveness, a qualitative and quantitative study was carried out that included twenty-five participants. The focus was on their feedback on what makes the game more enjoyable to play while keeping the learning elements. The questionnaire focused on the enjoyment level, learning, game play, motivation, difficulty, excitement, and interest.

A *Binomial test* is a statistical test that determines if the proportion of success in a binary outcome. This outcome is compared to the hypothesized proportion. In this study there are only two outcomes that can be possible, either a success or a failure. The steps that determine a binomial test are shown in *Table 1.*

Table 1:Binomial Hypothesis

Step	Details
Define the Hypothesis	Null Hypothesis (H_0): The proportion of successes is equal to the hypothesized value (p_0). Alternative Hypothesis (H_1): The proportion of successes is not equal to the hypothesized value (p_0).
Collect the Data	Count the number of successes (x) and the number of trials (n).
Calculate the Test Statistic	The test statistic in a binomial test is based on the binomial distribution.
Determine the p-Value	The p-value is the probability of obtaining a result as extreme or more extreme than the observed value under the null hypothesis. It is calculated using the binomial probability formula or statistical software.
Compare the p-Value to the Significance Level (α)	If the p-value is less than the significance level (commonly α = 0.05), reject the null hypothesis. Otherwise, fail to reject the null hypothesis.

Since the questions were multiple-choice answers, the analysis implemented a binomial test using Python. A custom was created that counted “strongly agree” with “agree” as positive feedback and “strongly disagree” with “disagree” as negative feedback (see *Table 2*). The focus is on having one scale, either they agree or disagree with the demo, eliminating neutralization.

Table 2: Survey responses

Question	Positive Responses	Negative Responses
I feel confident about understanding Algorithms after playing the game	25	0
I can explain what an Algorithm is in my own words	25	0
I feel confident about understanding Loops after playing the game	23	2
I can explain what a Loop is in my own words	19	6
I found the game to be engaging	25	0
The game did not keep my interest while playing	4	21
I will likely play the game if more levels come out	22	3
I felt excited while playing the game	24	1

Since it was important for me to get high-precision answers, the reliability measurement ensured that the responses were consistent across all different types of questions. This helps identify whether those who respond truly understand the topic of the question and the question itself. Another important reason is reducing biased responses.

If everything is positively phrased, the children will go through each question without a second thought. Prioritizing the effectiveness of the video game rather than getting positive feedback ensured its content was thoroughly designed and implemented to justify those responses. The script took each answer individually and ran a test. This way we can count exactly which part of the demo failed and which was successful. The result of the feedback form was then fed into a Python script. This is code for performing a one-sided binomial test. Binomial tests are very straight-forward. There are only three steps to the process.

We want to test a Null Hypothesis: we are testing if our experiment failed or succeeded. It seems like a ruthless scale, although it helps in the long run to create a successful project.

Table 3: Binomial test results and explanation

Question	P-value	Explanation
1	0.0000	Strong evidence that the proportion of positive responses is greater than 0.5.
2	0.0000	Strong evidence that the proportion of positive responses is greater than 0.5.
3	0.0000	Strong evidence that the proportion of positive responses is greater than 0.5.
4	0.0073	Evidence that the proportion of positive responses is greater than 0.5.
5	0.0000	Strong evidence that the proportion of positive responses is greater than 0.5.
6	0.9999	Strong evidence against the proportion being greater than 0.5, aligning with the negative framing of this question.
7	0.0001	Strong evidence that the proportion of positive responses is greater than 0.5.
8	0.0000	Strong evidence that the proportion of positive responses is greater than 0.5.

To understand the answers we got, the table explains the P-value and what it means. If you look at the *Table 3 Binomial test results and explanation*, each statement concludes a positive connotation. Looking through the answers, the only prominent answer that stands out is Question 6 with a P-value of 0.999.

This answer could not be further away than the 50 percent we are looking for. All the evidence that we see from it suggests that is the most negative answer. Now, let’s look at the *Table 2* and read out question number 6.

The negatively written question ''The game did not keep my interest while playing the game'' also concludes a positive answer. This is very important because after looking at *Table 3*, each question falls into the positive category, confirming that each statement has been approved. The Binomial test results also confirm the research questions.

If we were to make this into a two-sided binomial test for this question only, we would get a p-value of 0.00091. Meaning the value is too low for the distribution (4 positive vs. 21 negative) of answers was a coincidence. Combining the negative responses with the negative question posed, we get a strong positive sentiment.

6. Discussion

Looking at the responses, we can confirm that video games do enhance learnability. Once a balance has been found between teaching them while making it fun, there is not a single lesson or topic that cannot be taught. Seeing how these children have reacted throughout the game play and their enthusiasm after finishing the demo, is enough motivation and proof that we need to continue researching how to make games more education oriented.

This approach can let players have a hands-on chance to take educational content and learn through experimentation. Games that are educational only get boring quickly, since the children are constantly being fed new information without the fun aspect. Most of the school subjects like math, history, language classes have turned into game development, this also means that different learning subjects can become more appealing and approachable.

Table 4: Research Question Result

Number	Research Question	Conclusion
RQ1	Are learners more motivated when learning with a game	Yes
RQ2	Is the self-perceived competence higher with learning with a game	Yes
RQ3	Does gamification have a higher learning outcome than traditional teaching	Yes

These are the questions that got successfully answered in the research paper. There is concrete data for each answer that proves that gamification does work.

As can be seen in *Table 4 Research question result*, RQ1 answers the question whether their motivation is boosted from video games instead of learning the traditional way. Understanding the feedback from this data can be beneficial to the educators who can then design motivational educational tools.

RQ2 focuses on the competence or rather the confident of students while playing and finishing a game. The research wants to know if they believe in their abilities when learning through a game. This is crucial for a student's success since it will influence their willingness to try harder challenger therefore learn more complex material.

RQ3 seeks to determine if game elements that are introduced to a student would lead to a higher learning outcome rather than traditional teaching. Through digitization we can measure their learning outcomes, knowledge retention, problem-solving skills and their critical skills. This lets the researchers measure the effectiveness which can later be used to build even education tools with an improved overall learning experience.

Looking into the possibilities of educational video games we can tell that it can be adaptive. Applying variants of educational themes to the design of the game, developers can cater to many a wide range of edutainment. A term that has been created in 1954 is now making a comeback, edutainment. Educational entertainment, meaning that learning and play can co-exist.

In conclusion, video games have grown from mere entertainment to being powerful tools in education. This revolutionary method can be used to teach children programming from an early age. The study explored a new research area where video games are used for instructional purposes. Video games provide constant feedback and use a reward system that encourages children to continue learning. The merge of video games and learning new skills is a fast-approaching method that can be used more frequently in the future.

The main objective of the research was to demonstrate that video games can be used to learn programming, encouraging positive results from the design concept and creating an immersive environment that can teach debugging, problem-solving, and logical thinking. The feedback from the children showed that they were highly motivated, encouraged, and ready for new, harder levels.

The key takeaway of the thesis is that video games can be a powerful tool for education. By integrating lessons with a combination of storytelling, interactivity, immediate feedback, and reward systems, we create an environment that is safe, fun, and informative.

With children growing up in a world increasingly dominated by technology, it's more important than ever to teach them the correct way to use it. Incorporating programming into their daily routine through video games ensures the effectiveness of education at a high standard. Children will be excited by learning new concepts, sharing them with their friends, and developing new logic and problem-solving skills. This gives them passive life skills, where they learn how to communicate with others in group projects or debugging without complete frustration that will help in their future educational career.

The study proved that digital evolution in the educational system is not just about traditional teaching methods but also leveraging new tools to engage students. Video games have the power to become a learning tool that combines entertainment and learning to create the ideal environment for teaching programming. Video games can evolve from the purpose of pure entertainment into an educational platform. The first research question, are learners more motivated when learning with a game, has been proven right through the figures that I have showed positive data.

The second research question, Is the self-perceived competence higher with learning with a game, has also been proven from the data that shows that students would play the game again if there are new levels coming. The third research question does gamification have a higher learning outcome than traditional teaching has yet to be determined. There are two data figures one which has a high acceptance that they would rather learn from a game rather than a textbook.

Through the stages of effective learning—which include fail-safe environments, motivation, learner automation, and so on (Cambridge English 2023) children can feel safe to fail until they succeed. From these stages, we can see results because they cover the most important topics for teaching such as fail-safe environment where children can experiment fearlessly, knowing that failure is a stepping stone to success. Video games provide a safe space where trial and error lead to mastery.

Motivation through immediate feedback where gamified learning offers instant feedback. Whether it's solving puzzles, debugging code, or completing quests, players receive real-time responses that keep them motivated. Engagement through narrative in which video games immerse players in captivating stories. As they progress through game worlds, children forget they're learning—they're simply part of an exciting adventure.

The digitized era, where technology permeates every aspect of our lives, sees video games stand out as powerful educational tools. The American Psychological Association (APA) conducted a comprehensive review of research on video game effects, concluding in a paper that highlighted the positive impact of video games on learning, health, and social skills (Kirriemuir, J. 2002). Video games can be turned into a friendly tool that will continue to nourish and raise children with higher level knowledge in programming, collaboration, and problem-solving skills.

Codonia provides an immersive and interactive platform for children to learn programming. By integrating learning into the game play, it makes the process of learning programming concepts engaging and enjoyable for children.

Ethics declaration: I did not need ethical clearance for the research referred to in this paper.

AI declaration: No AI was used in the writing of this paper.

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Non Academic Papers

A Serious Game That Builds Energy Literacy Through Communication and Collaborative Gameplays

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Abstract: We developed a serious educational card game on renewable and alternative energy sources called "Fact or Fiction: Energy Edition". This game aims to bridge the learning gap between Singapore school's science curriculum and our national commitment to reach net-zero emissions by 2050. The original gameplay is a hybrid between two familiar games: "Trivial Pursuit" and "Mafia". Each player, depending on their assigned roles, will have to read either a factual or fictitious statement relating to alternative energy sources. Collectively, players must determine who is the Fraudster, i.e. the player reading the fictitious statement, and ban him/her from the game. Three additional gameplays, "Team Challenger", "Presenter Challenger" and "Quiz-Quiz-Trade" were created to be played in a classroom setting and meet the learning needs of different students' profiles. "Team Challenger" and "Presenter Challenger" are collaborative gameplays aims to enhance communication and collaboration among students. "Quiz-Quiz-Trade" is designed to promote communication in younger, or lower-progressing students. We conducted a pilot test for three gameplays, "Role-Playing", "Team Challenger" and "Presenter Challenger" in a Secondary school (six classes, 232 students). The "Quiz-Quiz-Trade" was trialled with one class of 25 Primary Six students. We received promising results that highlighted the game's potential to increase students' content knowledge on renewable and alternative energy but also promote communication and collaboration among students.

Keywords: Card game, Renewable energy, Alternative energy, Collaborative gameplay, Science curriculum

1. Introduction

Climate change is increasingly affecting many countries worldwide as global average temperatures reach new highs annually. Since 2015, addressing climate change has been the primary focus of the UN Climate Change Conference, with the Paris Agreement legally binding countries to limit their carbon emission. As part of Singapore's Long-Term Low-Emissions Development Strategy (LEDS), the government has developed a nationwide plan to achieve net zero emissions by 2050 (NCCS, 2022). This decision was made to meet the national commitment to climate action under the Paris Agreement (MFA, no date).

1.1 Learning Gaps Identified in Formal Science Curriculum

Singapore's formal science curriculum introduces renewable energy concepts progressively across educational levels. Primary science (Grades 3-6) covers three basic renewable energy sources: solar, wind, and hydroelectric energy (MOE, 2023). The lower secondary science curriculum (Grades 7-8) expands this knowledge to include geothermal, biofuel, and nuclear energy sources (MOE, 2024). Both curricula emphasise the scientific principles behind energy conversion and environmental impacts, with increasing complexity at higher grades. While civic literacy education at the secondary level specifically focuses on solar energy's advantages and limitations in Singapore as this emphasis reflects the nation's geographical constraints. Being a small, densely urbanised country, Singapore has limited access to wind, hydroelectric, geothermal, and biomass resources, making solar energy the most viable renewable option (MSE, 2019).

As Singapore embraces low-carbon economy, we have identified the following learning opportunities that could bridge the formal curriculum with fast-growing and fast-changing alternative energy sources:

- Describe the advantages, challenges, and limitations of different energy sources;
- Appreciate STEM concepts in the context of energy production;
- Demonstrate awareness of environmental and social impacts of energy productions; and
- Identify examples of local, regional and global initiatives, issues, and trends in energy transition.

By presenting a diverse range of facts and scenarios related to various energy sources, including those not extensively covered in the textbook such as hydrogen, the game seeks to deepen students' understanding and increase their appreciation of this critical energy topic.

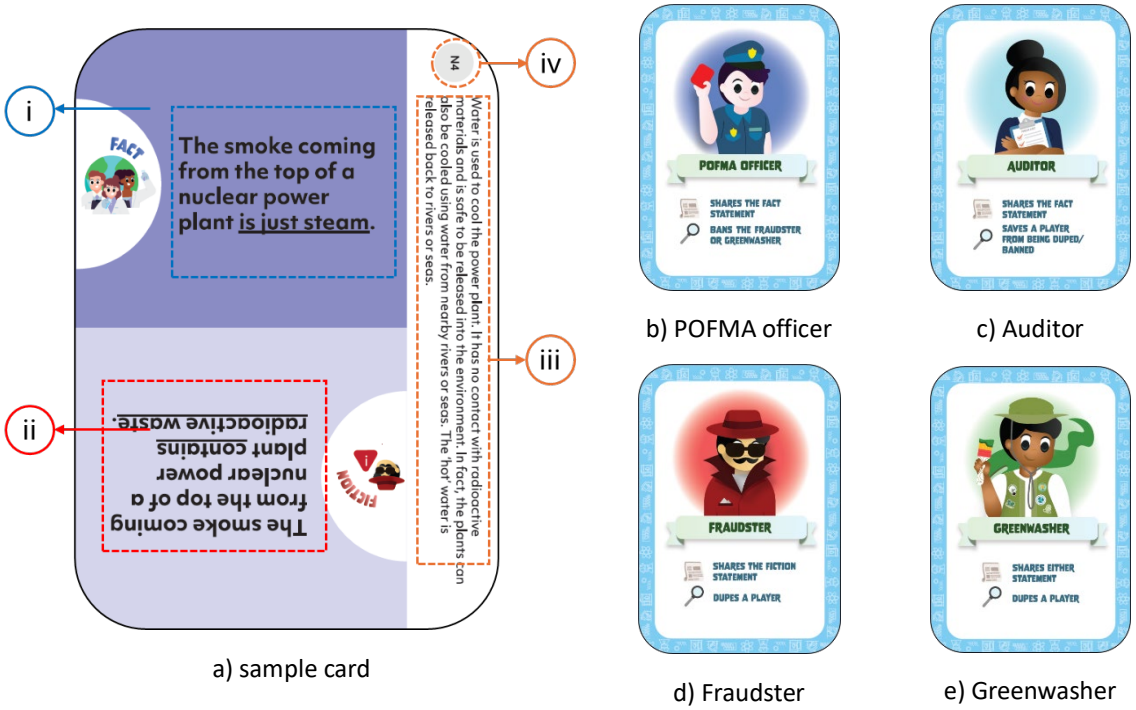
2. Theoretical Perspectives

The implementation of educational games in student learning has been demonstrated to enhance learning outcomes and increase student engagement (Fonseca et al, 2023). Game-based learning and gamification create

student-centric environments that facilitate the comprehension of broader concepts. Our team adopted this approach to engage students more effectively in learning about complex topics that they rarely encounter in their daily lives, such as clean and/or renewable energy sources.

2.1 Game Mechanism for Fact or Fiction: Energy Edition

The game "Fact or Fiction: Energy Edition" (FoF) presents players with the chasm between a factual statement and a fictitious statement on alternative energy sources. For example, in Figure 1a, the *Fact* and *Fiction* are: "The smoke coming from the top of a nuclear power plant *is just steam* or *contains radioactive waste*. This dichotomy is reinforced with contrasting colour schemes: dark background for facts, and light background for fictions (see Figure 2). The fictitious statements were crafted to highlight common misconceptions, in this Figure 1 example, it addressed the public fears on the safety of nuclear power generation.



a) sample card

b) POFMA officer

c) Auditor

d) Fraudster

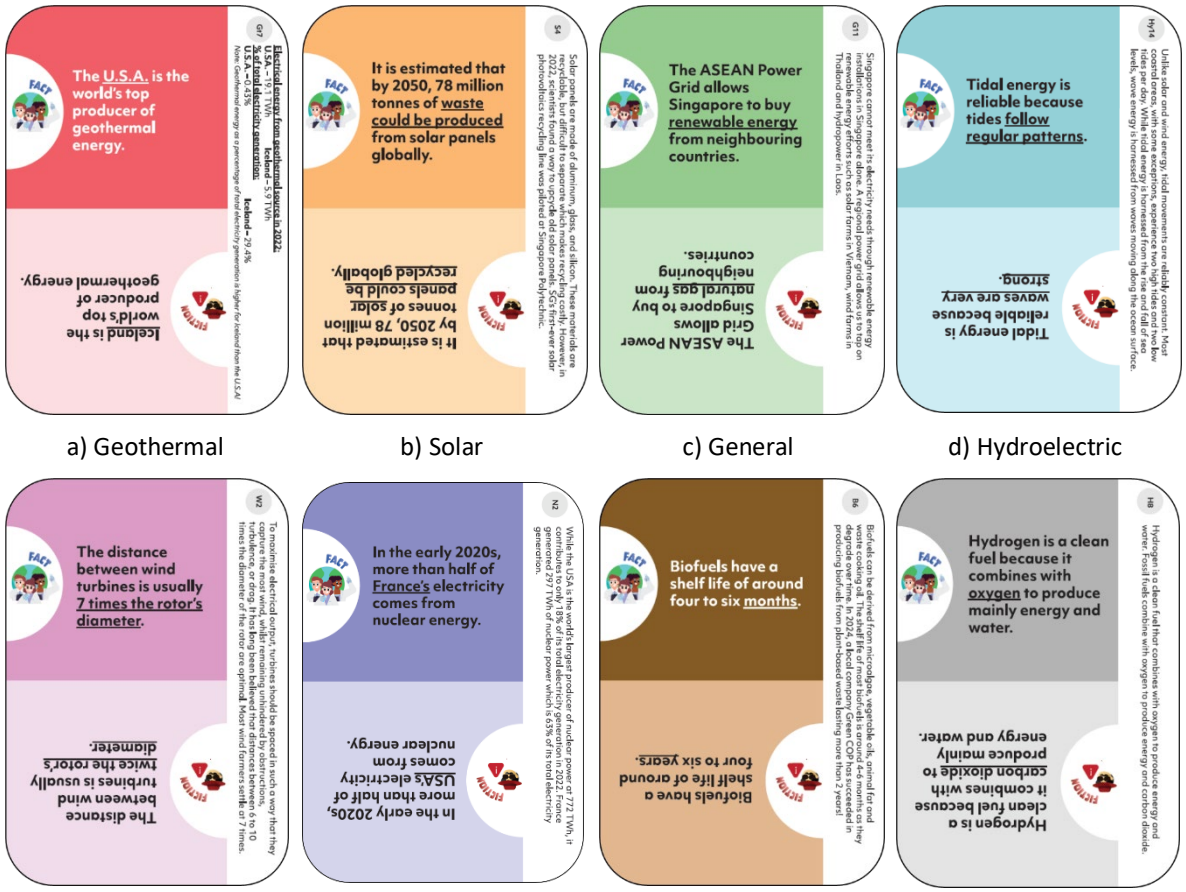
e) Greenwasher

Figure 1: a) Info card's features (i) fact, (ii) fiction, (iii) background information, (iv) reference; and b-e) sample roles: POFMA officer, Auditor, Fraudster and Greenwasher

The game consists of 120 information cards (i.e. Info cards) organised into eight energy-related categories, each distinguished by a unique colour scheme to facilitate visual organisation and thematic representation (Figure 2). The content spans across eight themes: local (Singapore), regional (Association of Southeast Asian Nations, i.e. ASEAN), global, technology, science, environment, social, and policy. For instance, Figure 2b illustrates an Info card explaining the global environmental impact of solar panels, while Figure 2c highlights Singapore's decarbonisation policies and regional initiatives.

Similar to the game mechanics in "Trivial Pursuit", students take turns to ask and answer *trivia* questions relating to alternative energy sources (Salen and Zimmerman, 2004). This game design of FoF aims to increase the general knowledge of students by serving them with a wealth of factual statements on this topic rarely encountered in their daily lives.

The distribution of themes across FoF card deck is shown in Table 1. The three most prevalent themes across all energy sources are technology (57 instances), science (43 instances) and local context (30 instances). This distribution aligns with our objective of providing a comprehensive understanding of renewable energy, emphasising technological advancements, scientific principles and local relevance.



a) Geothermal b) Solar c) General d) Hydroelectric

e) Wind f) Nuclear g) Biomass h) Hydrogen

Figure 2: A sample Info card from eight energy categories: a) geothermal, b) solar, c) general information, d) hydroelectric, e) wind, f) nuclear, g) biomass, and h) hydrogen

Table 1: Distribution of themes across FoF card deck

	ASEAN	Local	Global	Technology	Science	Environment	Social	Policy
Geothermal, red	2	2	1	9	8	5	2	1
Solar, orange	3	6	4	11	4	5	0	1
General, green	3	7	3	0	2	2	2	5
Hydroelectric, blue	2	2	2	8	5	3	2	1
Wind, lilac	1	2	0	11	3	5	1	1
Nuclear, purple	1	1	5	7	8	5	4	2
Biomass, brown	2	8	0	5	5	2	2	2
Hydrogen, grey	0	1	1	6	8	3	0	2
Total	14	29	16	57	43	30	13	15

The FoF card deck features a modular design that allows for flexible content management. This adaptability enables primary school teachers to curate age-appropriate content. For example, a primary school teacher can select Info cards such as those shown in Figure 2a, b, d and f, while excluding more complex content (such as those shown in Figure 2c, e, g and h). Furthermore, this versatility facilitates regular updates to reflect current

energy trends, as exemplified by the Info card in Figure 2g, which incorporates 2024 technological advancement in biofuel.

Each Info card includes background information to explain the context of its factual statement. For instance, the statement in Figure 1 clarifies that the visible steam is actually cooling water for the power plant. Facts were derived from multiple sources and tagged with alphanumeric identifiers for systematic categorisation (e.g. N4 represents the fourth card in the nuclear category). The icon "a network of scientist" serves as a visual reminder that all factual statement should be backed by peered-reviewed scientific research, whereas information without scientific backing is considered fraudulent and denoted with a fraudster icon.

Apart from the six alternative energy sources covered in Singapore's lower secondary science syllabus, the game incorporates two additional categories: general information and hydrogen energy (Figure 2c and h). The general information category introduces broader energy related facts that could not be classified into any of the energy categories. For example, the Info card in Figure 2C describes countries endowed with abundance of renewable energy can export their excess energy via the regional power grid. The hydrogen energy category was included as it was identified as a key economically viable low-carbon technology for Singapore to achieve net zero emission goal by 2050.

3. Four Gameplays

3.1 Original gameplay: Role-Playing Gameplay

The original gameplay adapted mechanics from the social deduction game Mafia (Salen and Zimmerman, 2004). FoF game simulates conflict between two groups: an informed minority, the Bad Guys, and an uninformed majority, the Good Guys as detailed in Table 2. This structure was chosen to mirror the inherent conflict between *Fact* and *Fiction*. This gameplay requires a moderator and multiple participants who take on roles including Greenwasher, Fraudster, Whistleblower, Auditor, POFMA officer, and Citizen, each representing real-world actors in an environmental discourse. The Greenwasher and Fraudster roles embody different forms of misinformation: the former exaggerates environmental initiatives without substantial impact, while the latter deliberately disseminates false information about renewable energy. The POFMA officer role was inspired by Singapore's Protection from Online Falsehoods and Manipulation Act (POFMA). This adaptation reflects contemporary efforts to combat misinformation, particularly relevant during the COVID-19 pandemic (POFMA, no date). The Whistleblower and Auditor roles emphasise individual responsibility in reporting wrongdoing and doing fact-checking. This reinforces learners that everyone can play their part to maintain information integrity.

Table 2: Summary of the Good Guys and Bad Guys roles for Role-Playing gameplay

Good/Bad Guy	Role	Similar to Mafia role	Description of role
Good Guy	POFMA Officer	Police officer	Has the power to ban Bad Guys
Good Guy	Auditor	Doctor	Has the power to save any player
Good Guy	Whistleblower	Detective	Has the power to check identity
Good Guy	Citizen	Villager	No special power
Bad Guy	Fraudster	Mafia	Has the power to dupe a player
Bad Guy	Greenwasher	Mafia	Has the power to dupe a player and read either the Fact or Fiction statement

The gameplay begins with each player receiving a role card explaining their responsibilities (Figure 1 b–e, Table 2) and drawing three Info cards. The game progresses through three stages: publication, voting, and review. In the publication stage, players take turns to read out either a *Fact* or a *Fiction* from one of the three Info cards, as determined by their assigned role. This stage includes an open discussion period where players can interrogate each other's statements and defend their claims using the background information provided on the cards. This interactive component serves as the game's educational cornerstone, enabling students to simultaneously learn about alternative energy sources while developing communicating skills. The voting stage follows, where players nominate and vote to ban suspects for the Fraudster or Greenwasher roles. In the subsequent review stage, players with special roles can exercise their special powers to save, dupe or ban players. E.g. Auditor can save a player from being duped (see Figure 1c).

These three stages repeat until one of two conditions is met: either Bad Guys equal the Good Guys in number, or both the Fraudster and the Greenwasher have been banned.

3.2 Collaborative Gameplay: Team Challenger and Presenter Challenger

3.2.1 Rationale for collaborative gameplay

In the Role-Playing gameplay, the opportunity for active discussions and debates relied on students' ability to speak convincingly and think spontaneously. Unlike their counterpart in the West, Singapore students generally do not actively participate in class discussions for the following reasons identified by Sim (2018):

- If a student speaks well, he/she might be afraid that speaking out might make one appear outstanding, thereby making their peers look bad by comparison. This may cause their peers to be embarrassed, or even worse, leads to resentment from them.
- If a student volunteer to speak up yet reveals his/her "true abilities" as worse than one's peers, it might lead to embarrassing oneself and thereby inhibiting himself/herself from attempting to speak up again.

To address students' public speaking anxieties, we redesigned the gameplay by eliminating individual roles and developed two new gameplays: Team Challenger and Presenter Challenger. This modification shifted from individual competition to group-versus-group dynamics, fostering collaboration rather than personal confrontation. The design choice of three to four members per group was informed by research on optimal group interactions (Laughlin et al, 2006). While a two-person group may face decisional deadlocks, and a larger group size of five or more may risk passive participation, a three- to four-person group maintain dynamic conversations while ensuring each member's active engagement. This optimal group size maximises learning and conversational opportunities from all members.

3.2.2 Team Challenger gameplay

In this gameplay, teams of three to four students each receive five Info cards. Teams have to strategically select one member to present a *Fiction*, while other members present a *Fact* each. The presentation sequence is determined by team consensus, with three to four statements read depending on team size. The additional Info cards serve as strategic alternatives rather than required reading material. After the sharing team presents, the guessing team must identify which team member in the sharing team presented a *Fiction*. Correct identification results in the sharing team forfeiting a token to the guessing team, while incorrect guesses lead to token loss for the guessing team. This process continues for four additional rounds with different team combinations, and victory is determined by the highest token accumulation.

3.2.3 Presenter Challenger gameplay

The Presenter Challenger format maintains most elements of Team Challenger but introduces a whole-class dynamic. In each round, one group (sharing group) presents their statements to all other groups simultaneously. After each presentation, non-presenting groups (guessing group) can question the statements. These guessing groups then independently vote to identify which presenter delivered the *Fiction*. Each guessing group that correctly identifies the *Fiction* presenter earns one point.

Table 3: Summary of Gameplay instructions for Team Challenger and Presenter Challenger

	Team Challenger	**Presenter Challenger**
Size of group	**Groups of 3 or 4**	**Groups of 3 or 4**
Fraud mechanism – Sharing phase	One player in the group will share a *Fiction*, while the remaining players in the group will each share a *Fact*.	
Detecting mechanism – Guessing Phase	As a group, players decide who amongst the sharing group is telling the *Fiction*, i.e. the Fraudster. If the group guessed correctly, they score a point (token). If they guessed wrongly, they lose a point (token).	
Game procedures	In each round, two teams face off each other. One team will 'share', while the other will 'guess'. Determine the winning team and exchange token. Teams will swap roles, i.e. sharing team becomes guessing team while guess team becomes sharing team.	In each round, a sharing group will read out their statements at the front. The remaining guessing groups can question the statements. Each guessing group will have to deliberate on who the Fraudster is with one vote. Groups who get the most points from guessing the Fraudster wins.

	Team Challenger	**Presenter Challenger**
Size of group	**Groups of 3 or 4**	**Groups of 3 or 4**
	The teams will face off other teams in the next round. Teams who get the most token wins.	

3.3 Gameplay Suitable for Younger Students: Quiz-Quiz-Trade

During one of our initial teacher engagement sessions, a primary school teacher working with lower-progressing Primary Six students proposed a new format called "Quiz-Quiz-Trade" (QQT), designed to be more accessible for her students. This format adapts a cooperative learning strategy where students engage in paired knowledge assessment through an interactive quiz format (Wong et al., 2022). In our adaptation of QQT for the FoF game, each student receives one Info card and several tokens. Students work in pairs, taking turns to share statements while their partners determine whether these are *Fact* or *Fiction*. Correct deductions result in token exchanges between partners. After completing their exchange, students find new partners, creating multiple opportunities for peer-to-peer learning and content review. This simplified format maintains the game's educational objectives while reducing cognitive load through one-to-one interactions.

Table 4: Summary and breakdown of the game mechanics in all four gameplays (Upshall, 2020).

	Avatar/ Role-playing	**Competition**	**Cooperation/ Collaboration**	**Points/ Scoring System**	**Trade/ Economy**
Role-Playing	✓	✓	✓		
Team Challenger		✓	✓		✓
Presenter Challenger		✓	✓	✓	
Quiz-Quiz-Trade		✓			✓

4. Methods

4.1 Pilot Test #1: Role-Playing, Team Challenger and Presenter Challenger

A pilot study was conducted at an all-girls' secondary school, involving six classes of mid- to high-ability Secondary One students (Grade 7, ages 12 – 13). Each class had between 38 to 39 students. Two classes were assigned each of the three gameplays: Role-Playing, Team Challenger and Presenter Challenger. A post-game electronic survey was administered. The survey questions and type of questions were:

- Educational value of the game, 1 – 5 rating
- Entertainment value of the game, 1 – 5 rating
- "What did you like about the game?', short answer
- "What did you not like about the game?", short answer

Out of 232 students that participated in the survey, 155 students (response rate of 66.8%) completed the online questionnaire due to the lack of access to electronic devices and time (see Table 6).

4.2 Pilot Test #2: Quiz-Quiz-Trade

The Quiz-Quiz-Trade format was piloted with a class of lower-progressing Primary Six students (Grade 6, ages 11 – 12, n=25; 16 boys, 9 girls). The science teacher curated age-appropriate Info cards based on students' reading capabilities and facilitated both the gameplay session and subsequent discussion. Student feedback was collected through verbal responses during the post-game discussion period.

5. Results and Discussion

5.1 Role-Playing, Team Challenger and Presenter Challenger

Our hypothesis predicted that Role-Playing would yield the highest entertainment value but lowest educational impact, while Team Challenger and Presenter Challenger gameplays demonstrating higher educational outcomes. However, the data presented in Table 5 contradicted these expectations: Role-Playing achieved the highest educational rating (4.45), while Team Challenger and Presenter Challenger formats received comparatively lower ratings (3.80 and 3.81 respectively).

Students' responses to questions (3) and (4) were grouped into three broad categories: (1) content knowledge, (2) affective aspect, and (3) game mechanism. For the purpose of this article, only responses pertaining to content knowledge were analysed. Nonetheless, the feedback from students were used to further refine the gameplays.

Table 5: Observations and results from students' survey

	Role-Playing	Team Challenger	Presenter Challenger
Venue	Students were in their home classroom	A combination of two classes of students in a multi-purpose room.	Students were in their home classroom
Grouping	7 to 8 students, 5 groups per class	3 or 4 students, 20 teams	3 or 4 students, 10 groups
Observation	One student from each group was assigned as moderator. Students who had not played Mafia before required assistance from the teacher.	The room was noisy as many teams of students were talking simultaneously. To facilitate transition after each round, only the even numbered teams move	Groups took turns to present at the front. The teacher in-charge moderated the discussion and voting rounds after the group had presented.
Educational rating	4.45 / 5	3.80 / 5	3.81 / 5
Entertainment rating	4.76 / 5	4.22 / 5	3.70 / 5

Analysis of student feedback across all three gameplay formats revealed consistent themes regarding content engagement (see Appendix). Role-Playing and Team Challenger generated positive content-related comments from 28.6% and 26.0% of participants respectively (Table 6). Presenter Challenger received both the highest percentage of positive content comments (38.1%) and negative content comments (30.2%), suggesting this format heightened students' awareness of both their content learning and knowledge gaps in renewable energy concepts. Role-Playing received notably low negative content comments (4.8%) suggesting that its higher entertainment value may have masked knowledge gaps, potentially inflating perceived educational value.

While both Team Challenger and Presenter Challenger formats facilitated in-depth content discussions, Team Challenger achieved a notably higher entertainment rating (4.22 compared to Presenter Challenger's 3.70). This difference may be attributed to Team Challenger's kinaesthetic elements, where students could physically move between teams, and therefore create more opportunities to engage in strategic discussions. In contrast, Presenter Challenger's structure limited each group to a single presentation opportunity, potentially reducing engagement during non-presenting periods when students were passive listeners.

Table 6: This table shows the a) the total numbers of students who participated in the pilot test, b) number of students who participated in the survey and c) the number and percentages of students' who provided positive and negative feedback regarding content across three gameplays

	Role Playing	Team Challenger	Presenter Challenger
Number of students that participated in game	77	77	78
Number of students that participated in the survey	42	50	63
Number of participants who provided positive remarks on content, derived from question (3)	12 (28.6%)	13 (26.0%)	24 (38.1%)
Number of participants who provided negative feedback on content, derived from question (4)	2 (4.8%)	6 (12.0%)	19 (30.2%)

Teachers' feedback from the pilot study emphasised the importance of post-game discussions in consolidating students' learning outcomes and meeting the game's learning objectives. In addition, science teachers were identified to be ideal facilitators of the game sessions as they have the subject expertise and ability to guide content-specific discussions effectively.

In conclusion, the Role-Playing gameplay achieved the highest entertainment rating while enhancing students' perceived educational value. This aligns with research showing that student enjoyment significantly influences

their self-efficacy in learning (Lu & Lien, 2019). Team Challenger gameplay achieved a balance between engagement and learning, despite students encountering some challenges with content complexity. While Presenter Challenger gameplay was praised for its knowledge gained, students noted difficulties with content comprehension and fact verification. These results suggest that although Presenter Challenger gameplay may promote deeper learning, Role Playing's engaging nature potentially led to better overall student engagement and perceived educational value. This insight underscores the critical balance between educational content and gameplay mechanics in educational game design, which informed our subsequent iterations and game improvements.

5.2 Quiz-Quiz-Trade

The teacher who conducted the trial provided feedback on the QQT format:

> *"For the Lower Progress group, they can use the cards to test partners - Quiz and Response followed by gain/lose a token. Then move on to another partner, quiz the next partner with the same card or a different card. For my class, each student was given an info and 5 tokens. The students liked guessing Fact or Fiction and then win a token."*

The QQT format had demonstrated as an engaging cooperative learning strategy that combines student movement and interaction with knowledge synthesis. Students work with multiple partners in a short period of time, and the tactile and kinesthetics aspects of this strategy support and engage a variety of learning styles (Wong, 2022). The gameplay structure facilitated students to develop academic language and encourage peer to peer interactions. Given its effectiveness, particularly with lower-progress students, QQT was incorporated as an additional gameplay option in the final product of the educational card game.

6. Conclusion

6.1 Limitations

The first Pilot test for Role-Playing, Team Challenger and Presenter Challenger were conducted exclusively at an all-girls secondary school. This presented limitations in a good demographic representation of local schools that significantly impacts the generalisability of our findings. The absence of primary schools, mixed-gender secondary schools, and students with diverse ability levels restricts the applicability of our results to broader educational contexts. This narrow focus may have introduced gender bias and overlooked challenges that could arise in different education environments. The lack of diversity in the test population limits our ability to assess how the game might perform across varied educational settings and student demographics, potentially missing important insights that could emerge from a more heterogenous sample.

The value of QQT is to promote peer-to-peer teaching, incorporates discussion and practice, and provides students with physical movement. Even though QQT is a well-established learning strategy and formative assessment for classroom (Wong, 2022), the second pilot test was conducted at a single class of lower-progressing Primary Six students. There is no comparison between the effectiveness of QQT and other gameplays.

6.2 Future Plans

The team plans to expand this research work and broaden the range of participating schools and student populations to enhance the robustness and applicability of the findings. Each school will be offered two to three gameplays (Role-Playing, Team Challenger, Presenter Challenger and QQT) that meets the learning needs of students' profile. We plan to analyse students' discussions to answer the following questions:

- Were the learning goals achieved through students playing the FoF card game?
- How does the FoF card game promote communication and collaboration among students?

This would provide a more comprehensive evaluation of the game effectiveness in promoting renewable energy education across varied educational contexts.

Notes

Refer to the website, https://for.edu.sg/factorfiction, for a) the moderator guide and video instructions for Role-Playing gameplay; b) the infographic for Team Challenger gameplay; and c) references for *Fact*.

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Appendix

Table 1: Selected responses about the educational value retrieved from the questions (3) "What you like about the game"; 4) "What you not like about the game"

Game mode	Selected positive responses retrieved from question (3) "What you like about the game?"
Role-Playing	I liked how I was able to learn new information and clear up doubts like when I thought a fact was right but it's actually fiction. I got to learn many interesting facts about science The way it relates to real life situations knowing the different knowledges while playing the game

Game mode	**Selected positive responses retrieved from question (3) "What you like about the game?"**
Team Challenger	We got to know about STEM related things through a fun game I liked that I learned facts about this game and it was also fun. We can learn fun facts about science. We get to learn a lot about our environment
Presenter Challenger	It was very educational and we learnt a lot of new things. It was very interesting and we learned a lot of new things while it being fun. I could learn more about the use of technology in different parts of the world We also are able to gain some general knowledge while playing the game
	Selected negative responses retrieved from question (4) "What you did not like about the game?"
Role-Playing	Add in some simpler facts about science The topics were a bit difficult to comprehend, so it was hard to defend yourself in game too, but that somewhat made the game more intense, forcing you to reason with the fact and explain it. Some facts and fiction were common knowledge so everyone knew the correct answer
Team Challenger	The terminology of the cards are confusing Some of the cards had complicated terminology, so we didn't understand and our guesses were made entirely off assumptions. Having zero idea on what the card is talking about. (Too complex terminology.) I don't understand some of the facts
Presenter Challenger	The statements were a bit hard There's no speck is however I wish that there would be more topics such as; Cells, Biology, Atoms etc. I did not understand some of the information told to me so it was hard to tell whether it was a fact or fiction Some of the facts are hard to guess and my group had to do wild guesses, which meant that we didn't actually know what it meant

Innovative Game-Based Teaching of Entrepreneurship for Secondary Education: The Little Business Leader

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Abstract: In response to the evolving demands of the digital era, this study proposes a game-based pedagogical framework designed to cultivate entrepreneurial skills, financial literacy, and technological competencies among secondary school students. Drawing inspiration from the business reality show *The Apprentice*, the model incorporates experiential learning through simulation-based company creation, investment competitions, and formal summit presentations. This program uses a game-based, experiential learning approach to enhance participants' entrepreneurial thinking, investment literacy, public speaking skills, and assertiveness. Through a series of sessions, which include startup creation with AI tools, simulated investment competitions, and a high-impact business summit, participants will develop practical skills in innovation, management, and strategic presentation. With the methodologies of Bloom's taxonomy, Self-regulated Learning (SRL) theory, and Kolb's Experiential Learning Theory, the game-based teaching approach not only aligns with the syllabus for secondary business education but also equips students with essential skills for navigating the modern world. Additionally, it offers benefits that will aid them in their future endeavours, including asset management, career planning, and more. The author has already implemented this program in real educational practice and still feels it is being underestimated. Furthermore, the author believes more elements can be incorporated, such as self-created currencies and a simulated United Nations. The "Little Business Leader" concept could even evolve into "Little Economist," "Little Diplomat," and so on. Additionally, the game-based and role-based teaching methods will inspire more teachers and students in future pedagogical approaches.

Keywords: Entrepreneurship education, Business strategy simulation, Financial literacy, Game-Based learning, Secondary education

1. Introduction

The new era demands that the younger generation and future citizens acquire advanced technological skills and competencies. Generation Z, some of whom are already students, are familiar with basic concepts such as coding, the application of artificial intelligence (China, 2022), asset management (Bado & Basri and Hasan, 2023), and critical thinking from an early age.

In this contest, the author's preferred approach to Self-regulated learning (SRL) is a game-based teaching method. Unlike conventional and monotonous course teaching, this approach also addresses some outdated theories, such as Porter's Five Forces model, particularly considering that the founder has since gone bankrupt (Denning, 2021). The game-based activity can provide students with a more immersive experience in business learning.

In response to the evolving demands of the digital era, this study proposes a game-based pedagogical framework designed to cultivate entrepreneurial skills, financial literacy, and technological competencies among secondary school students. In this regard, the model get inspiration from the business reality show The Apprentice (Keef, 2018). In this framework, each student selects a company and formulates a strategy or business idea, which they then present to the class. For instance, a student interested in psychology can conduct in-depth research within that field, while a student passionate about aviation could launch their own self-driving airplane company.

In Session One, participants create their own startup companies by finalizing their business name, field, organizational culture, and visual identity, with AI tools assisting in generating logos, 3D product models, and office layouts. Session Two introduces an investment competition using simulation trading software to develop practical asset management and investment skills. In Session Three, the curriculum will be held as a simulated summit where students dressed in formal business attire as "Little Business Leaders" will present their business plan, operational arrangement, and finally receive simulated offer letters from global prestigious institutions such as Google, Tesla, Toyota, Dassault, and Oxford University, etc.

This game-based teaching approach not only cultivates students' independence, innovation, and managerial ability, but also enhances students' confidence and assertiveness in their chosen fields, which range from video games and aerospace to sports, psychology, and beyond.

Overall, the program combines experiential learning with hands-on activities, including creating simulated companies, participating in investment competitions, and delivering formal, summit-style presentations. It

encourages students to think critically about entrepreneurship, leadership, and the adaptability required to develop original business ideas. Designed as an immersive, game-based approach to teaching entrepreneurship at the secondary level, the program integrates traditional simulations, AI tools, and project-based learning. This combination provides students with a practical and engaging way to build financial literacy, develop an entrepreneurial mindset, and pursue a study path aligned with their personal interests—skills that are essential in today's rapidly changing world.

2. Teaching Note and Syllabus

2.1 Game-Based Teaching Objectives and Target Audience

This case is designed for discussion on entrepreneurship encouragement and financial literacy education for secondary school students, which caters to the advanced development of each.

To closely align with the undergraduate business teaching structures and syllabus, the author has thoroughly examined each chapter of the Business subject and the Global Perspectives & Research subject. The intention is to develop this case study as a teaching plan rooted in the A-Level Curriculum.

Table 1: A-level syllabus and course content

Subject	Chapter	Cover in Little Business Man
Business - 9609	1.1 Enterprise 1.2 Business structure 4.1 The nature of operations 5.1 Business finance 6.2 Business strategy 7.3 Leadership	- Understand the basic elements of a company - Based on the simulated investment, cultivate students' understanding of IPOs, financing methods, financial ratios, etc. - According to the company's initiative, the Simulated Summit aims to build confidence, improve public speaking skills, and enhance leadership capacity.
Global Perspectives & Research – 9239	Component 1. Become effective researchers, using appropriate sources to support judgements and understanding of research processes. Component 3. Candidates work in teams to identify a local problem that has global relevance. Each team member researches the problem from a distinct perspective and suggests a solution based on their research findings. Component 4. Undertake independent research on a topic of their own choice	- Identify the target business industry. - Analyse the market and take reference from the benchmark company in the world - Independent research ability on a business plan and business idea

Source: data collected from the official website of Cambridge International AS & A Level subjects

2.2 Teaching Target

This teaching case is designed to associate with the following teaching outcomes, which are coordinated with the Cambridge A-Level Business (9609) and Global Perspectives & Research (9239) curricula, as well as business subjects of IGCSE, IB, etc:

- Demonstrate an understanding of enterprise formation, basic enterprise elements
- Analyse the specific segmentation and how realize the commercialization
- Enhance self-regulated learning (SRL) for students, with a particular focus on fostering autonomy and competency.
- Use the theoretical concepts in real-world business decision-making
- Acquire the capacity to estimate the investment value of part of the securities.
- Build confidence, innovative insight, and foster the students' ability in public speaking, critical thinking, and career planning.

2.3 Theoretical Frame

The program was rooted in the theories of Bloom's taxonomy, Self-regulated Learning (SRL) theory, and Kolb's Experiential Learning Theory. These educational foundational theories, respectively, support the design of the three-phase teaching model, which cultivates both cognitive development and practical business capacity

among secondary school students. Kolb's standpoint outlines the foundational theory of experiential learning, emphasizing that learning is a process rooted in experience rather than merely a transmission of information. This focuses on practice-based learning, which is highly relevant to scenario-based learning. (Kolb, 2014) Additionally, the study examines the role of self-regulated learning (SRL) in helping students develop more sophisticated mental models for further learning and complex science topics. (Azevedo & Guthrie, 2004) By integrating progressive levels with active learning, critical thinking, backward design, and a flipped classroom approach, based on Bloom's taxonomy, we can achieve significant participation and recognition for all students, including those who are typically quiet in class. (Mulcare & Shwedel, 2017)

Through the support of the three Step by Step module sessions, students are encouraged to progress and develop greater application skills, critical thinking, and independent judgment.

3. Game-Based Teaching Structure

3.1 Session One: Entrepreneur and Startup

Guide the students in creating their own startup companies. They should finalize the name, industry, logo, organizational culture, and other essential elements. Students can use AI tools to generate rendering images for their business profiles, create company logos, and design 3D models of products and office layouts. (As shown in the Appendix 1)

The purpose of allowing students to use AI is to help them build their own understanding of business concepts. Therefore, AI serves solely as an auxiliary tool to assist them in completing the task.

Table 1: Agenda for Session One of The Little Business Leader Programme

Module	Session Length	Teaching Unit Title	Teaching Content	Learning Objectives
1.1	2 hours	Introduction to Entrepreneurship	- Introduce the basic information of famous companies worldwide. - Teach the basic process for registering a company	- Understand the basic structure and process of setting up a business (such as business naming, organizational structure, and licenses) - Develop entrepreneurial awareness and self-positioning skills
1.2	2 hours	Group Formation & AI Tools Using for Business Design	- Form student teams - Choose a business structure - Register the company name - Identify required licenses and the employment system - Use AI tools to assist in business planning	- Enhance effectively in teamwork - Apply learning and practical knowledge in designing a business - Utilize AI tools for creative business development - Understand AI is the tool for assisting in commercial activities, which enhances the efficiency rather than wheel and deal
1.3	2 days (home-based)	Reflection & Peer Feedback	- Reflect on group work and idea formation - Provide and receive constructive peer feedback	- Strengthen self-reflection and critical thinking skills - Understand the challenges and achievements of the entrepreneurial process
1.4	2 hours	Finalization of the Business idea	- Refine the core business idea based on feedback - Finalize company profile, structure, and concept pitch	- Merge the team's ideas into a complete business concept - Prepare for presentation and investor simulation

3.2 Session Two: Financing and Investment

Setting an investment competition, ask students to use the simulation trading software to invest and assess their final performance in the final session (As shown in the Appendix 4). In this second session, the lecturers will instruct students to learn the fundamental literacy of financing, which includes the domains of venture capital (VC), private equity (PE), and Initial Public Offerings (IPO). Based on the comprehensive interpretations and

interactions during this session, students can develop their own consciousness and common sense of financial literacy, as well as acquire the capacity to learn how a startup can raise capital and effectively manage its financing.

At the same time, invite students to present their investment portfolios, highlighting each of their acquisitions and losses. For profitable investments, the lecturer encourages them to share the strong points and potential they identified in the companies they chose. For those who incurred losses, provide appeasement and guidance to help them analyze their weaknesses or missteps and suggest strategies for future investment decisions.

Table 2: Agenda for Session Two of The Little Business Leader Programme

Module	Session Length	Teaching Unit Title	Teaching Content	Learning Objectives
2.1	2 hours	Introduction to Finance & Capital Markets	- Explain the basic concepts of stock, bond, fund, and securities. - Teach the basic process for enterprise financing as VC, PE, IPO, etc.	- Understand the structure and role of capital markets - Acquire basic knowledge of investment action
2.2	2 hours	Simulation: Investment Strategy	- Guide students through mock investments using simplified trading tools - Introduce investment strategies and risk awareness	- Understand the logic behind investment behaviour - Build up the consciousness for asset management
2.3	1 week	Practice for investment in simulation software and self-learning	- Ask students build their own portfolio and practice the investment	- Strengthen participants' ability in investment software using - Enhance the self-learning and investment analysis capacity
2.4	2 hours	Portfolio Review & Risk Reflection	- Review individual and group investment outcomes - Reflect on gains and losses, identify strengths and areas for improvement - Provide peer and instructor feedback	- Strengthen risk awareness and critical thinking - Learn from both success and failure in investment - Encourage a growth mindset and responsible risk-taking

3.3 Session Three: Simulated Summit

The summit meeting is referred to as an international meeting of heads of state or government. The benefits of a Summit, within the Diplomatic and commercial domains, are not only that it fosters interpersonal trust between leaders but also reinforces systemic trust in the state-as-person construct, which is identified as the implicit glue holding the international system together. (Ku & Mitzen, 2022) Furthermore, the formal attire and demeanor during the summit will help a person maintain their mental and physical well-being. Moreover, Self-confidence and a professional appearance are of vital importance for a worker. (A.O., 2021)The initiative to provide formal attire and well-prepared facilities can create a formal atmosphere for secondary students, many of whom rarely experience social conferences and meetings. A foundational understanding of business can instill the essence of a commercial environment.

Ask each "Little Business Leader" in formal attire to present their idea. They will be granted a simulation offer letter from eminent companies such as Google, Tesla, Toyota, Dassault, and Oxford University (As shown in Appendix 3). The purpose in this phase is to recognize them as the best and to gain recognition from the world's top enterprises, allowing them to continue pursuing their interests and dreams.

Table 3: Agenda for Session Three of The Little Business Leader Programme

Module	Session Length	Teaching Unit Title	Teaching Content	Learning Objectives

3.1	1 hours	Business Presenting	- Students formally present their business ideas and company profiles to other candidates and the audience	- Practice business communication and presentation skills - Build confidence in public speaking within the context of IPOs or other commercial presentation scenarios.
3.2	1 hours	Completion & Voting	- Each student receives a token representing a simulated startup capital - Teams pitch their businesses to attract investment votes - Voting process conducted based on presentations *Refer to Appendix 2: Voting Token*	- Understand investor perspectives, and acquire the ability navigating in capital market - Enhance persuasive communication and teamwork under pressure
3.3	1 hours	Instruction and review	- The instructor provides feedback on student ideas, teamwork, and presentations - Encourage students to offer constructive suggestions to one another and learn through other contemporary. - Encourage reflection and areas for improvement	- Provide constructive feedback and full consideration for growth Reflect on learning progress and group collaboration
3.4	30 minutes	Prize-giving & Ceremony	- Announce the most-voted company and ask to present their inspiration - Grant the offer letter from prestigious global companies (As shown in Appendix 3) - Celebrate participation and effort	- Enhance the sense of ceremony and students' professional belonging - Cement students' confidence in study and life

Note: Note in the offer letter that it is for events and educational purposes only, and not for commercial use.

4. Further Thinking and Business Insight

The purpose of motivating students to participate in this game-based program is to cultivate their initial awareness of entrepreneurial spirit, financial literacy, innovative thinking, and resilience in business operations. The game and awards are not the end goal, but rather a starting point for their future development, encouraging deeper engagement in postgraduate studies, career planning, business insight, and the ability to withstand pressure in real-life challenges.

4.1 The practice for Pedagogy Theory

The practice for Pedagogy theory coherently correlates with the content in 2.3 Theoretical Frame, and can be exhibited as the following aspects:

- Self-directed learning and practical business skills development: Rooted in Self-Regulated Learning (SRL) theory, this module aims to foster student motivation by creating an engaging and participatory learning environment. It encourages the development of students' autonomy, a sense of relatedness, and competence through hands-on business activities. (Niemiec, 2009)
- Concretization in business subject and conception: Drawing on Kolb's Experiential Learning Theory, the programme guides students through all four stages of the learning cycle: concrete experience, reflective observation, abstract conceptualization, and active experimentation. (Kolb, 2014) These stages are embedded in practical activities to help students connect theory with real-world business practice.
- Gradually enhance students' cognitive abilities to think deeply and critically. There's analysis indicates that implementing case-based learning effectively enhances the application of knowledge, which in turn fosters higher-order thinking. This advanced thinking ability positively influences learners' capacity to evaluate practice. The teaching approach uses case studies in teaching an undergraduate course on the Internet for Business in class, based on the revised Bloom's taxonomy. (Nkhoma & Lam, 2017)

This programme takes reference from Nkhoma's case study, and extends the topic to the finance and entrepreneurship field. In this regard, the author believes that this case has covered the three main pedagogical theories and effectively integrated educational theory with learning practice.

4.2 Lessons Learned and Application in Further Education

This game-based teaching approach not only aligns with the syllabus for secondary business education but also equips students with essential skills for navigating the modern world. Additionally, it offers benefits that will aid them in their future endeavours, including asset management, career planning, and more.

Aiming to foster creativity, resilience, and business acumen, the "Little Business Leader" program offers a unique teaching model for entrepreneurship education and the development of comprehensive skills.

Compared to postgraduate business education, secondary-level business education integrates more interactive elements and encourages greater participant engagement.

The author has already implemented this program in real educational practice and still feels it is being underestimated. Furthermore, the author believes more elements can be incorporated, such as self-created currencies and a simulated United Nations. The "Little Business Leader" concept could even evolve into "Little Economist," "Little Diplomat," and so on. Additionally, the game-based and role-based teaching methods will inspire more teachers and students in future pedagogical approaches.

5. Conclusion, Implementation and Impact Evaluation

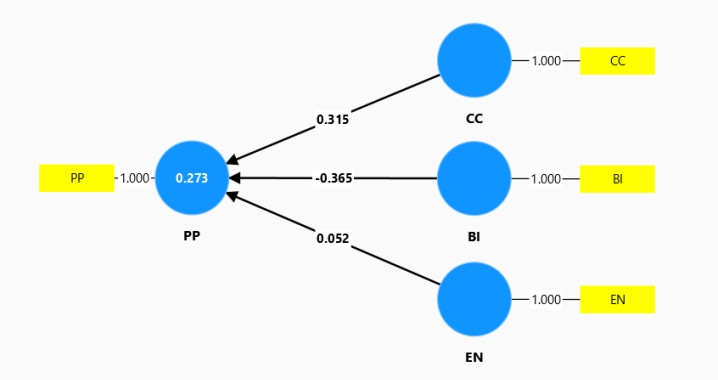
The author is honoured to implement this teaching plan for students from Hanyang University – Raya team. Following a two-week immersion program involving 24 participants, the students consistently expressed in their compositions and feedback that they had gained greater confidence.

The Impact Evaluation was estimated with both quantitative and qualitative methods. For the quantitative aspect, we distribute the questionnaires, as the question is shown as follows:

- The simulation summit and company offer enhance my confidence
- The Little Business Leader programme builds up my business insight
- The summit meeting presentation enhances my English-speaking skills
- I get progression in this programme

According to the SmartPLS results using the basic PLS-SEM algorithm to examine the questionnaires, the correlation is presented in the figure below. Despite the limited number of observations, the results indicate that confidence enrichment, with the coefficient 0.315, has the most significant impact on students' self-progression.

Table 4: The results for correlation with confidence, business insight, English-speaking skills, and self-progression



Nevertheless, due to the scarcity of the observation sample, the author conducted a supplementary assessment with qualitative feedback:

> *"I learned about confident attitude and critical thinking. Marshal taught us that we can do anything, and we should be more confident."*

> *"I could learn the mind and mental of speaking English. Thanks to Marshall and Daniel, I could learn confidence and courage."*

The comments above represent some of the students' key reflections. In this regard, our teaching team has come to realize how subtle influence, encouragement, and patience can effectively support and reshape students' mindsets. The following table is a summary by Hanyang University – Raya team 24 students' composition and feedback.

Table 5: Domains of Student Growth Reflected in Feedback

	Confidence Enrichment	Critical Thinking	English Skill	Business and Economic Literacy
Volume of Students	17	6	9	1

Source: Data collected from Hanyang University – Raya team students' composition and feedback

Most participants highlighted the emphasis on thinking and noted that the relaxed atmosphere helped build their confidence. They felt more comfortable using English as a tool for communication and self-expression, and were encouraged to apply their language skills in practical contexts.

Moreover, the implementation process and impact evaluation coincidentally align with the three core psychological components of self-regulated learning: autonomy, competence, and relatedness. These elements have been shown to effectively enhance and support students' engagement and performance in comprehensive learning environments.

Acknowledgement

I would like to express my heartfelt gratitude to all members of the UCSI Consulting Group, Graduate Business School (GBS), and to the teachers and students of Hanyang University. The staff at Consulting Group and GBS have provided solid and powerful support for the study and tour programs for Korean students from Hanyang University. Additionally, the students have played a crucial role in coordinating and enrolling in the course, which has allowed all authors to practice implementing this game-based teaching plan. Their diverse talents, innovative business ideas, and warm, sincere expressions continually inspire me.

In this spirit, I hope this paper serves not only as a meaningful academic outcome but also as a fruit of inspiration that motivates my excellent Korean students to pursue their aspirations and explore vibrant career pathways ahead.

Statements and Ethics declaration: This study involved 24 students from Hengyang University in Korea, who participated as members of the Raya team. All necessary ethical reviews were conducted, and informed consent was obtained from all participants. The authors declare no conflicts of interest, and no funding was received for this study. All images, logos, and renderings used—whether processed or generated by AI—were authorized by the author, who retains the publication rights. The datasets used in this study were collected from publicly accessible sources, including official industry websites, news reports, media agency information, as well as students' compositions and feedback. Code availability is not applicable. The first author, Chen JianYuan, served as the lead researcher and principal writer of the teaching plan. The second author, Han Qisheng, was the primary lecturer responsible for implementing and delivering the module.

I hereby declare that the manuscript with the title *"Innovative Game-Based Teaching of Entrepreneurship for Secondary Education: The Little Business Leader"* is my original work and has not been published previously, in whole or in part, in any journal, book, or other academic outlets.

Furthermore, I affirm that this manuscript is not under consideration for publication elsewhere and will not be submitted to another journal while under review by your publication.

All authors have read and approved the manuscript and have agreed to its submission to your journal.

Declaration of AI: This paper employed an AI tool (ChatGPT by OpenAI) to assist in matching A-level business subjects, refining language, checking grammar, generating example posters and symbols, and enhancing the clarity and structure in certain tables and paragraphs. The author developed the ideas, structure, analysis, and academic content entirely and originally. The AI-generated suggestions were only served as a reference and edited to ensure alignment with the intended meaning and academic integrity of the paper.

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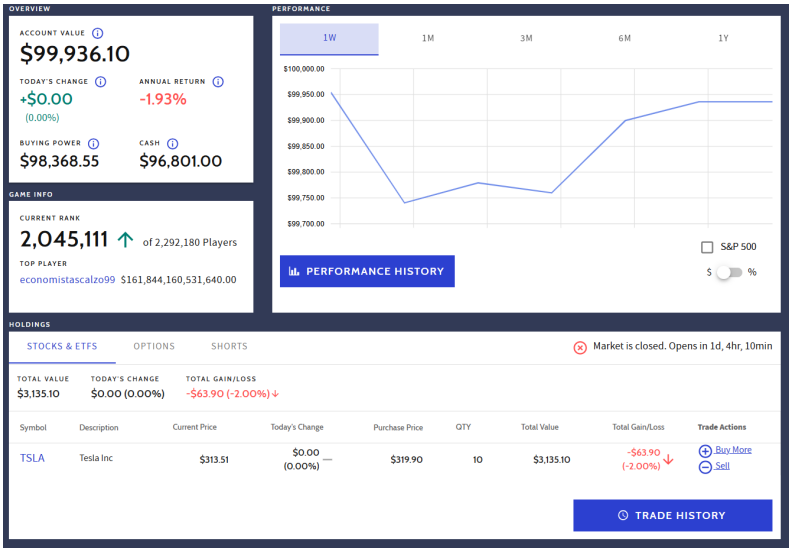
Appendix 1: Example of Student Startup Plan

Appendix 2: Mock Token for Startup Voting Activity

Appendix 3: Sample Offer Letter from Prominent Enterprises

Appendix 4: Example of the Simulated Investment Platform



Work in Progress Papers

A Co-Design Protocol for a Serious Game Supporting Emotion Regulation in Children

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Abstract: Technological advancements have led to the development of serious games (SGs), which are now widely used in mental healthcare. These digital interventions are used for education and treatment and are effective in supporting emotion regulation (ER) in young people. Their engaging nature and accessibility make them a promising solution to gaps in traditional mental health services. This work presents a protocol for the development of a SG designed to promote emotional knowledge and ER skills in school-aged children in both school and clinical settings. The SG's development will be based on a co-design methodology involving the active participation of children, parents, teachers, and healthcare professionals throughout three phases: 1) conceptual design, 2) prototype testing, and 3) usability testing. The outcomes of SG will be assessed based on user experience and satisfaction, as well as system usability and clinical measures. Pre- and post-test assessments will be used to measure improvements in emotion recognition and ER skills. The final SG is expected to fulfill real-world needs and ensure that it is educational and enjoyable. This protocol provides a replicable framework for co-designed digital interventions in mental health, emphasizing user-centered design to enhance both effectiveness and involvement.

Keywords: Serious game, Emotion regulation, Children, Co-Design, User-Centered

1. Introduction

Serious games (SGs) are digital games designed for purposes beyond entertainment, with usage since the early 1970s to support learning and skill development. SGs are being explored as engaging tools to complement traditional therapy, particularly for younger audiences (Fleming et al, 2017). One key area of focus is ER, defined as the ability to influence one's emotions, when and how they are experienced and expressed (Gross, 2015). Children's difficulties in ER are often predictors of psychological problems in adulthood (e.g., anxiety, depression), making early intervention crucial (Crowell, Puzia and Yaptangco, 2015).

The research team conducted a systematic review to identify existing solutions and design strategies of SGs supporting ER development in children. We found that few SGs address ER as a standalone skill, instead embedding it within broader socio-emotional learning or focusing primarily on emotion recognition. Notable examples include *ReThink*, a SG to support emotional health of young people aged 10 to 16, with studies showing its improvements in ER skills (David, Magurean, and Tomoiagă, 2022). *Emodiscovery* is another relevant SG that presents emotional dilemmas to older children (8-11), who must select from pre-defined regulation strategies (Pacella and López-Pérez, 2018). Both games were designed only by researchers and target older age groups, limiting their developmental and contextual applicability for younger children.

In contrast, this work presents a protocol for developing an SG to help school-aged children (6-9) acquire emotional knowledge and ER skills. The game will be created following a co-design approach with direct involvement of multiple stakeholders, ensuring all relevant voices are considered, making the final game more likely to be accepted and attractive to users (Vargas et al, 2022).

1.1 Proposed SG

The proposed SG is expected to be a multiplatform narrative game in which players navigate through real-life emotional situations. Gameplay activities will involve identifying emotions and selecting from adaptive and maladaptive ER strategies. These elements integrate theoretical concepts, particularly Gross's Process Model of ER (Gross, 2015) and Paul Ekman's framework of basic and complex emotions (Ekman, 2004), to support both emotional awareness and adaptive response in gameplay. The co-design process will further refine these elements and guide the game's direction.

2. Method

2.1 Procedure

The key stakeholders are children, parents/guardians, teachers, and healthcare professionals. Children, as primary end-users, will provide insights into what they find fun and understandable, guiding the design of narratives, characters, and challenges. The game targets typically developing and at-risk children aged 6 to 9, recruited from both school and clinical settings. At this stage, children with diagnosed developmental or psychiatric disorders will be excluded, as the intervention focuses primarily on prevention and psychoeducation. Parents can clarify their child's emotional difficulties and effective strategies used in everyday life. Teachers bring expertise on integrating ER tools into school environments. Healthcare professionals can validate the game's alignment with best therapeutic practices in child development and emotional health.

The co-design process will consist of three phases, with at least 10 participants each and 25 for the usability evaluation phase (Borsci et al, 2014). Sessions with adults will be held online or in person, whereas children's sessions take place in educational and clinical settings. In educational contexts, the research team will conduct data collection directly with children, while in clinical settings, sessions will be facilitated by a healthcare professional.

2.1.1 First phase of co-design

Parents, teachers, and healthcare professionals will participate in semi-structured interviews to discuss emotional challenges observed in children and suggest game elements to address these challenges. These interviews will help to identify recurring emotional difficulties and the everyday situations in which children experience emotional challenges. Children's sessions include creative exploration activities to create an age-appropriate and relatable concept. These sessions will begin with playful, imaginative exercises to ease children into the topic. Through storytelling, drawing, and brainstorming, children will help design fun characters and scenarios, such as one character assisting another in managing an emotional situation.

These contributions will serve as the foundation for the game's narrative, visual style of characters, and emotionally resonant interactions. While the research team leads the technical development, input from co-design participants, particularly teachers and healthcare professionals, contributes directly to shaping core mechanics such as challenges, feedback, and rewards. Their expertise ensures that gameplay elements are developmentally appropriate, engaging, and pedagogically meaningful.

2.1.2 Second phase of co-design

Parents, teachers and healthcare professionals will test a prototype through an open-ended online questionnaire covering gameplay mechanics, character design, engagement and educational relevance. While playing the SG, children will be asked open-ended questions to capture real-time feedback and identify any challenges. After gameplay, they will participate in interactive feedback activities where they will be invited to describe or illustrate their ideas for improvement.

2.1.3 Third Phase of co-design

The completed SG will undergo usability testing to assess acceptance, feasibility, and potential impact on children's ER skills. Children will begin with a guided session introducing the game's concepts and mechanics, with opportunities to ask questions and explore freely. The research team will observe behaviour and reactions to identify any areas that may need further refinement, asking simple, open-ended questions to understand how the child feels about the game and whether they find it engaging and easy to play. Afterward, children will take the game home for a week, playing at their own pace, with the freedom to stop at any time. Parents may contact the research team for support if needed during the week. Following the play period, a follow-up session will be held where children complete a paper-based usability questionnaire and participate in an easy-going conversation to share their experiences and suggestions. Parents, teachers, and healthcare professionals will also test the final game and complete self-report questionnaires and open-ended questions covering usability, engagement, and educational value. Parents will be asked to complete a questionnaire about their child's emotional skills both before and after the week of gameplay, to assess any observable changes.

2.2 Data Collection

To summarize, data collection will involve the components in Table 1. Regarding the third phase of co-design, child-reported data will be collected using smiley face Likert scales, and parents may assist children during

questionnaire completion to ensure comprehension, following standardized instructions to minimize bias and preserve data integrity.

Table 1: Data Collection Methods

Method	Participants	Phase(s)	Purpose
Semi-structured interviews	Parents, Teachers, Healthcare Professionals	Phase 1	Gather opinions on emotional challenges and game design
Open-ended questionnaires	Parents, Teachers, Healthcare Professionals	Phase 2 & 3	Collect feedback on game usability, content, and engagement
Hetero-report questionnaire (e.g., Emotion Regulation Questionnaire, ERQ (Fernandes et al, 1997))	Parents	Phase 3	Assess changes in children's ER before and after gameplay
Self-report questionnaires (e.g., System Usability Scale, SUS (Martins et al, 2015); User Satisfaction Evaluation Questionnaire, USEQ (Domingos et al, 2021))	Children, Parents, Teachers, Healthcare Professionals	Phase 3	Evaluate game experience and usability
Observations and notes	Children	All Phases	Qualitative insights from behaviour, reactions, and drawings during sessions
Gameplay data	N/A	During gameplay	Analyse duration and completion

3. Expected Results

The co-design process is expected to provide insights for improvement, including refining gameplay or expanding scenarios, for future iterations. The SG is expected to be perceived as enjoyable, relatable, and educationally effective, possibly fostering emotional connections between children and the characters and scenarios. In terms of clinical effectiveness, success will also be measured by feedback from parents, highlighting improvements in their children's emotional abilities, particularly the application of learned strategies to real-world situations. Ultimately, the protocol aims to demonstrate that well-designed SGs can serve as accessible, engaging tools for promoting emotional development in children.

4. In Conclusion

Emotional learning plays a crucial role in childhood development, having a lasting impact on social functioning and life outcomes. SGs offer promising digital solutions that capture children's attention while bridging resource gaps. This paper presents a co-design protocol for developing an SG that targets children's ER and makes learning both meaningful and enjoyable. The protocol integrates the perspectives of the target audience and relevant stakeholders as equal partners throughout development. This means that feedback continuously shapes the game's design, ensuring it aligns with user needs and preferences. This protocol makes a significant contribution to the growing literature on user-centred digital interventions by combining co-design with a robust theoretical foundation in developmental psychology. Despite potential challenges in implementation, such as recruitment or technological constraints, the protocol demonstrates how SGs can serve as engaging, scalable tools for mental health interventions. In addition to guiding the development of the proposed SG, this framework provides a practical, replicable model for designing future child-centred games that focus on emotional learning and mental health promotion.

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Ethics Declaration: The project is being evaluated by the Ethics Committee of FEUP.

AI Declaration: No AI tool was used.

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Serious Games in a Graduate-Level Human Physiology Course

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Abstract: Healthcare, like most industry sectors, is facing the transformative implications of Artificial Intelligence (AI). We do not yet fully understand the benefits and pitfalls of AI, so it is critical that training in healthcare-related fields includes opportunities to learn how to leverage the former while being alert to the latter. We aim to evaluate the integration of serious games, as scenario-based teaching strategies, into a graduate-level human physiology course. Students use a publicly available large language model to diagnose a series of tailored medical case studies that have been carefully crafted to highlight the utility of AI while revealing its limitations. The course modality is online, alternating between asynchronous and synchronous instruction. Asynchronous course material includes video presentations and group discussions of peer-reviewed medical case studies, which serve to prepare the students for a tailored case study with a similar or related condition. Synchronous course meetings include an individual readiness assurance test, which covers the preparation materials, to incentivise students to develop a robust understanding of the relevant pathophysiology prior to meeting. Individuals are then grouped into randomised teams, using AI to interpret a case within a serious game framework. Teams are prompted with questions and respond using a scratch ticket-style scoring sheet that allows partial credit in a point-based game. Teams navigate hallucinated responses, apply prior knowledge, and prompt AI toward correct diagnoses. Evaluation of course participants' attitudes and opinions of the course methods will be conducted by survey. In addition to the course, the process for developing effective case studies that fit into this model is described, and the potential for extending this strategy to an undergraduate human anatomy and physiology curriculum is also explored. Moreover, opportunities for raising ethical considerations with the use of AI in healthcare are considered. Together, this study is an effort to respond to the rapid changes AI is bringing to healthcare education and may serve as a model for highlighting the utility and pitfalls of AI in other fields.

Keywords: Physiology, Healthcare, Games-Based learning, Serious games, Artificial intelligence, Generative AI

1. Introduction

Serious games are scenario-based instructional activities that have been shown to improve student motivation and engagement (Al-Awadai, 2024). These activities, using elements of game design such as challenges, goals, cooperation, and feedback, represent an emerging area of educational research focused on identifying which features are most successful in improving student learning (Silva, 2020). Serious games have been successfully implemented in courses across a range of disciplines, including those related to anatomy, physiology, and medicine, (Gorbanev et al, 2018; Moro, Phelps and Stromberga, 2020). The aim of the present study is to serve as a proof of principle for integrating serious games into a graduate-level human physiology course using tailored medical case studies, and student assistance from generative AI, as the situational context.

2. Game Context and Design

2.1 Course Context

Serious games will be integrated into Human Physiology (BIOL 0570; Westfield State University), a graduate-level course for students in healthcare-related programmes or high school science teachers meeting licensure requirements. The online course blends asynchronous and synchronous modality. Asynchronous course material provides students with the knowledge they apply during the synchronous meetings, when student teams engage with a tailored medical case that focuses on a medical condition. The first three cases are designed by the course instructor, who also serves as a guide through the exercise. The rationale for the instructor presenting the first three cases is to model serious games elements. The roles are reversed later in the course, students develop a case and guide their peers through it.

Case studies must align with the course learning objectives, incorporate key serious game attributes, including scaffolding, rules and gameplay, rewards, feedback, and reflection (Silva, 2020; Al-Awadai, 2024), and include this progression of activities:

- Individual Readiness Assurance Test
- Team Readiness Assurance Test
- Team-Based Case Study

2.2 Individual Readiness Assurance Test

Students are required to read and comment on assigned peer-reviewed case studies related to a specific condition to prepare for each synchronous Zoom meeting. At this meeting students answer five multiple-choice questions related to the preparation materials. This individual Readiness Assurance Test (iRAT) is mediated via Google Forms. The iRAT, and the next activity, the team Readiness Assurance Test (tRAT), are modelled after the Team Based Learning (TBL) technique introduced by Michaelsen and colleagues (2002).

2.3 Team Readiness Assurance Test

Following the iRAT, students are organised into teams of three or four students that are randomised, which reduces social barriers and increases the mobility of knowledge between students (Liljedahl, Zager and Wheeler, 2021). Teams are assigned to Zoom breakout rooms to complete the tRAT, which is the same quiz as the iRAT, but each team responds on an Immediate Feedback Assessment Technique (IF-AT) form (Epstein Educational Enterprises, Cincinnati, OH). IF-AT forms are multiple choice (A-E) answer sheets with each choice covered by a metallic film that can be scratched off (similar to some lottery tickets). Teams can continue to discuss and scratch response options until they identify the correct response; 1 point for the first scratch, 0.5 points for the second scratch, or 0.25 points for a third (and last chance) scratch.

2.4 Team-Based Case Study

For the final activity, teams work through a tailored case related to the preparation material and tests. The case unfolds as a presentation (e.g. Google Slides), and can include a simple narrative, images of the patient, medical images, and lab values. Five questions are interspersed throughout the case, which may focus on telling clues, additional tests or information that may be required, or to determine a diagnosis. Teams respond on the IF-AT form, providing immediate feedback and determining the winning team of the serious game.

3. Generative AI

Generative AI has been shown to be prone to hallucinations and errors in accurately citing research (Alkaissi and McFarlane, 2022) and has been trained on data that reflect societal and cultural biases, compromising efficacy as a medical diagnostic tool (Cirillo et al, 2020). Recent studies have shown that when ChatGPT is challenged with medical case studies, it has a misdiagnosis rate of 51% with ChatGPT-3.5 (Hadi et al, 2024), 72% using paediatric cases with ChatGPT-3.5 (Barile et al, 2024), and 61% in complex cases with ChatGPT-4 (Kanjee, Crowe and Rodman, 2024).

The instructor-designed cases for the Human Physiology course have been tailored to exploit mismatches in how well the materials used to train large language models reflect a given clinical context. When cases omit terms that are typically paired with a condition, emphasize unrelated systems, or include signs that masquerade as another condition, ChatGPT is more likely to misdiagnose. ChatGPT was employed to create these “distractors”, or exploit known biases, to lead to a misdiagnosis. Students prepare for a case study by reading relevant peer-reviewed cases, then work in teams to navigate a case that is likely to lead ChatGPT to a misdiagnosis (Table 1). The case development offers an opportunity for participants designing cases to think deeply about what guides AI to a correct or incorrect diagnosis, and moreover, participants in the serious game must consider how they might shepherd ChatGPT in the right direction.

The following prompt was used to create the signs and symptoms that would be included in a case study that would likely lead ChatGPT to misdiagnose a condition:

> *Prompt 1: I am creating case studies as a teaching tool in a human physiology course. One of the course learning objectives is to demonstrate that ChatGPT can be a useful tool for interpreting patient signs and symptoms but requires human oversight because ChatGPT has been shown to misdiagnose cases and introduce bias and misinformation. Create a set of signs and symptoms for a patient with _____ that would lead ChatGPT to misdiagnose the condition.*

In all cases, ChatGPT came to a correct diagnosis with the first iteration despite distractor signs. ChatGPT was prompted to revise the signs and symptoms until they led to a misdiagnosis with the following prompt:

> *Revision Prompt: The signs and symptoms are leading ChatGPT to a correct diagnosis, modify the case signs and symptoms to increase the likelihood of a misdiagnosis.*

Table 1: Conditions used for tailored cases with the distractors that mislead ChatGPT

Condition (Sample student reading)	ChatGPT distractors	ChatGPT misdiagnoses (Required number of revisions)
Rhabdomyolysis **(Al Badi, Rasbi and Alalawi 2020).**	De-emphasize muscle involvement Remove trigger signs (e.g., brown urine) and excessive exercise	Viral myocarditis Early heart failure (Third revision)
Tetrodotoxin **(Almeida et al, 2019)**	Do not include seafood ingestion Highlight neurological presentations	Ischemic stroke (Second revision)
Endometriosis **(Hudson, 2021)**	Do not include menstrual cycle timing Add psychological symptoms	Irritable bowel syndrome Celiac disease (Second revision)

4. Evaluation

The evaluation of the project will be performed via a participant survey to measure respondents' attitudes and opinions of TBL, serious game elements, and inclusion of generative AI. The elements of serious games, and AI integration, that are successful will be trialled in our Human Anatomy and Physiology undergraduate-level courses. These courses have large enrolments that can be leveraged for quantitative evaluation of the methods.

Acknowledgements

Simon Holdaway was involved in many discussions about the use of AI as a learning tool and these discussions helped guide how this project would integrate AI. Westfield State University provided support for this project.

Ethics Declaration: Ethics clearance was not needed for this paper.

AI Declaration: ChatGPT-4o was used to proof for spelling and grammar errors and generate signs and symptoms leading to AI misdiagnosis.

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Developing ACT-R Model for Key Concept Recall in a Multilayered K-12 Educational Game

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Abstract: Educational games, while widely used to enhance engagement and motivation, often struggle to balance instructional content with compelling gameplay. Although integrating learning and gameplay within a unified structure is theoretically effective, it presents practical challenges in achieving both high engagement and instructional impact. To address this, the current study introduces an intertwined Multilayered Educational Game – Computer-based Framework (iMEG C-Framework) and an ACT-R cognitive model to simulate the recall process. These models will be evaluated across three instructional conditions (Traditional Learning, Classic Educational Game, and iMEG) targeting K–12 students in both short- and long-term memory tasks. Cognitive modeling is particularly valuable in K–12 contexts where large-scale studies are often difficult. The iMEG framework separates game mechanics, instructional content, and feedback to create a more adaptive and organized learning experience. ACT-R modeling supports analysis of how students encode, store, and retrieve key concepts, enabling real-time adaptive feedback and instructional refinement. A within-subjects experiment will be conducted with 39 seventh-grade students across three counterbalanced conditions, each involving a 75-minute session on board game design, followed by retention assessments one and seven days later. By combining experimental data with ACT-R modeling, this study explores predictive capabilities and the impact of different game-based learning structures on student trajectories, contributing to the design of motivation-driven learning environments in K–12 education.

Keywords: ACT-R modelling, Game-Based learning, Motivation-Based learning, K-12 learning environments

1. Introduction

Over the past two decades, game-based learning has gained recognition as a strategy to enhance motivation, engagement, and learning outcomes in K–12 education (Boyle et al., 2016). Well-designed games can foster deeper understanding and persistence, especially among students who struggle in traditional settings (Plass et al., 2015). However, many still fail to produce measurable academic gains. A key issue is the blending of entertainment and instructional goals, which can lead to cognitive overload or superficial engagement (Parthasarathy & Mittal, 2023). This is further complicated by a disconnect between educators and designers. Educators may lack technical skills to build interactive systems, while developers may lack pedagogical knowledge (Roungas, 2015). As a result, many games remain ineffective or impractical for classroom use.

To be more specific about the learning processes involved in game-based learning, it is important to recognize that understanding how games influence memory requires more than a surface-level examination of engagement or enjoyment; it involves analysing the structural elements that shape cognitive processing (Mayer, 2019). From educational games designed to enhance learning outcomes (Clark et al., 2016), to non-educational games that foster incidental memory gains (Bavelier & Green, 2019), and gamified systems that overlay game-like features onto instruction (Deterding et al., 2011), each environment engages memory through distinct mechanisms. Research shows that memory-based educational games support vocabulary learning and retention using techniques like visual cues, mnemonics, and pattern recognition. Evidence includes improved recall through card games (Razali et al., 2017), long-term memory gains from digital mnemonic tasks (Heidari et al., 2023), and vocabulary development through games like Scrabble and memory grids (Halpern & Wai, 2007; Sivakumar, 2022). Collectively, these findings highlight the potential of such games to strengthen encoding, retrieval, and long-term retention (Fung & Oyibo, 2024).

While these games offer strong learning potential, merging gameplay with instructional content remains challenging. According to Self-Determination Theory, this integration can increase intrinsic motivation and engagement (Cook & Artino, 2016), but developing unified games often demands significant time and resources, limiting scalability (Christopoulos, 2023). Moreover, such games are typically designed for specific subjects, restricting their broader applicability despite demonstrated effectiveness (Young et al., 2012).

Building on these insights, this study introduces an ACT-R modeling approach within the iMEG C-Framework to examine how separating gameplay, instruction, and feedback into distinct layers affects learning. The framework can enhance instructional clarity and cognitive efficiency, while the ACT-R model simulates

encoding, retrieval, and decay to provide real-time insights into memory. Together, they enable dynamic personalization and promote collaboration across education, design, and learning science.

This study addresses two central research questions:

RQ1- How does the iMEG C-Framework compare to traditional and classic game-based designs in supporting memory encoding and retrieval?

RQ2- To what extent can the ACT-R model accurately predict learners' memory performance across different educational game structures?

2. Theoretical Background: ACT-R Model

ACT-R modeling (Anderson & Lebiere, 2014) forms the core theoretical framework of this study, simulating key cognitive processes such as memory encoding, retrieval, and decision-making. Using real-time learner data, it enables adaptive feedback and iterative refinement of instructional strategies to better match individual learning trajectories. The model tracks how memory strength changes with repeated exposure and how retrieval probability varies over time. Each game mechanic and its examples are represented as memory chunks, with activation levels computed using ACT-R's standard equations.

$$m = \ln\left(\sum_{i=1}^{n}(t_i^{-d_i})\right) \quad (1)$$

where m is the memory activation, t_i represents the time since the *i*-th encoding event, and d_i denotes the decay rate specific to each encoding. The decay rate following each encoding is modeled dynamically as a function of prior activation, following the equation:

$$d_i = a + c \times m_{i-1} \quad (2)$$

where *a* is a baseline decay constant, *c* is a scaling parameter controlling how decay changes with prior memory strength, and m_{i-1} represents the activation before the *i*-th exposure. The probability of successful retrieval at any testing point is modeled using a logistic retrieval function:

$$p_r = \frac{1}{1 + e^{\frac{\tau - m}{s}}} \quad (3)$$

where P_r is the probability of retrieval, τ is the retrieval threshold, and *s* is the noise parameter reflecting individual variability in retrieval success. Currently, the model is theoretical, with no simulations or fitted parameters. After the experiment, it will be implemented in ACT-R to calibrate based on data and assess how different instructional conditions impact short- and long-term memory retention, as well as how the model can capture these effects.

3. Experiment Design

All instructional content and game-based materials in this study were developed using Articulate Storyline (version 3.20) to ensure consistency and interactivity across conditions. Each learning condition—Traditional, Classic Educational Game, and iMEG—was implemented as a standalone module. The study includes 39 seventh-grade students (balanced by gender) from private middle schools, randomly assigned to one of the three conditions using a between-subjects design. The experiment consists of three main phases: a pretest phase, a learning (encoding) phase, and a posttest (retrieval) phase. In the pretest phase, all participants complete a 15-item multiple-choice test to assess prior knowledge of board game mechanics. In the learning phase, each group receives a different instructional intervention based on their assigned condition. Finally, in the retrieval phase, participants complete two post-tests: one 15-item test administered 24 hours after the learning session to measure short-term retention, and another identical test given seven days later to assess long-term memory. This design enables comparisons of learning effectiveness across instructional formats and time intervals.

3.1 Traditional Condition Design

In the traditional learning condition, participants begin with an initial study phase (Exposure 1) by reviewing slides that define ten game mechanics, each paired with three illustrated examples, spending one minute per

slide to support encoding. In the second phase (Exposure 2), they complete a 15-item multiple-choice quiz within 10 minutes, receiving 10-second corrective feedback for incorrect answers and retaining access to definitions throughout. This is followed by two more sets of 8 multiple-choice questions (3 minutes each), during which no definitions are available, encouraging retrieval practice without support. After each quiz, unresolved questions and correct answers are shown for feedback.

Figure 1: Sample image from Exposure 1, used across all three conditions

3.2 Classic Educational Game Condition Design

In the classic educational game condition, participants begin with the same initial study phase (Exposure 1) as in the traditional condition, reviewing slides on ten game mechanics and examples for one minute each. In Exposure 2, they complete three rounds of a memory-based matching game. The first round (Blitz Race) is a 10-minute 5×6 Match Pairs game with access to definitions and examples (Figure 2, left) with retaining access to definitions throughout. The second and third rounds (Bullet Races) use a 4×4 grid with 3-minute limits and no access to definitions, promoting retrieval-based learning. After each round, unresolved pairs and correct answers are shown for feedback.

3.3 iMEG Condition Design

In the iMEG condition, participants begin with the same initial study phase (Exposure 1) as the other groups, reviewing slides on ten board game mechanics with three examples each, spending one minute per slide. In the second phase (Exposure 2), participants will engage in three rounds of memory-based matching games, like the classic design (Section 3.2), but using a neutral theme, matching animals to their corresponding foods, instead of board game mechanics (Figure 2, right). At the start of each round, participants will be given three initial attempt opportunities to match pairs. To earn additional attempt opportunities, two for each correct answer, participants must answer a multiple-choice question (timer will pause during responding) similar to those used in the traditional condition. If a participant answers incorrectly, the correct answer will be displayed for five seconds before they return to the matching task. This structure is designed to separate the gameplay experience from the instructional content.

Figure 2: Blitz section of Classic Game Design (left) and Bullet section of iMEG Framework Design (Right)

3.4 Mapping Experimental Design to ACT-R Model

To bridge the experimental design with computational modeling, Figure 3 presents the conceptual flow of the ACT-R based memory model underlying this study. The diagram maps how participants move from initial study exposure to multiple phases of practice, with corresponding updates in memory activation after each learning event. Following the learning phases, memory decay is applied over one- and seven-day intervals to simulate the natural forgetting process, and retrieval probability is predicted based on the resulting activation values.

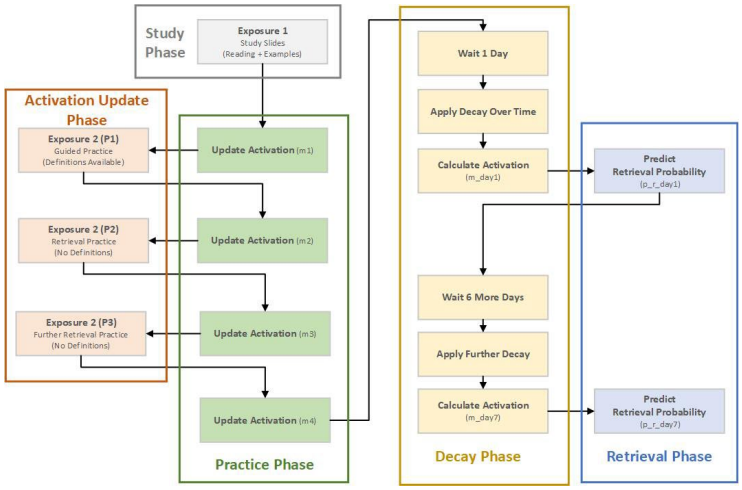

Figure 3: Conceptual flow of the ACT-R memory model showing exposure, activation updates, decay over time, and retrieval prediction

4. Conclusion

This study introduces a novel approach to understanding memory processes in educational game environments by integrating the ACT-R cognitive architecture with the iMEG C-Framework. By structurally separating gameplay, instruction, and feedback, the iMEG framework aims to reduce cognitive load and promote more effective memory encoding and retrieval. The use of ACT-R modeling enables simulation and prediction of learners' cognitive performance, offering a foundation for adaptive learning design. Together, these contributions represent a step toward more theoretically grounded and scalable educational game development for K–12 learners.

5. Future Work and Limitations

While the proposed framework and model are promising, this study remains in the implementation and validation phase. No formal simulation results are currently available, and model parameters have not yet been empirically calibrated. Future work will involve analyzing the experimental data from the three instructional conditions to fit and validate the ACT-R model. Additionally, the generalizability of findings is

limited by the specific subject matter and grade level (seventh-grade students). Expanding the framework to different content areas and learner populations, as well as exploring affective and motivational variables through extended modeling, are important directions for future research.

Ethics Declaration: This study involved the design and evaluation of instructional materials for seventh-grade students using de-identified, anonymized procedures and did not collect any personal or sensitive data. As such, formal ethical clearance was not required. The research was conducted in accordance with institutional guidelines for educational research with minors.

AI Declaration: During the preparation of this manuscript, the authors used GPT-4 for grammar and clarity checks. No content was generated by the AI tool beyond surface-level editorial suggestions. All substantive content, analysis, and interpretations were developed by the authors, who take full responsibility for the final work.

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Game-Based Learning for Autism: A Tabletop Approach to Theory of Mind

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Abstract: Theory of Mind (ToM) is the cognitive ability to recognize that others have thoughts, beliefs, and emotions different from one's own. It is essential for effective social interaction and communication. Children diagnosed with autism spectrum disorder (ASD) often experience significant difficulties with ToM, especially in perspective-taking and interpreting false beliefs, negatively impacting their social relationships and academic performance. Structured, game-based interventions have demonstrated promising results in enhancing social-emotional cognitive abilities in autistic children. This article explores the prototype design of a tabletop game titled "*Guess the Animal*," which aims to promote ToM skills in autistic children aged 7 (seven) to 12 (twelve) years old.

Keywords: Theory of mind, Autism spectrum disorder, Game-Based learning, Perspective-Taking, Universal design for learning, Tabletop games

1. Introduction

Understanding that what others think, feel, or believe is different from our own experience is a skill often taken for granted in everyday social interaction. Yet for many autistic children, this kind of perspective-taking, known as Theory of Mind (ToM), can present significant challenges. Difficulties in interpreting false beliefs or predicting others' actions may lead to breakdowns in communication, social withdrawal, or academic misunderstandings. In a foundational study, Baron-Cohen, Leslie and Frith (1985) found that only 20% of autistic children answered a classic false-belief task correctly, compared to 85% of their non-autistic peers—a striking illustration of this developmental gap.

However, such challenges are not insurmountable. Research consistently shows that ToM skills can be strengthened through targeted interventions and repeated practice. Programs designed around structured social reasoning tasks and video modeling have led to notable improvements in children's ability to understand others' perspectives (Begeer *et al.*, 2010; Dhadwal *et al.*, 2021). These findings underscore the importance of creating opportunities where autistic learners can engage in perspective-taking in safe, supported, and enjoyable contexts.

Tabletop games offer precisely this kind of environment. Their clear rules and turn-based structure align well with the preferences of many autistic children, who often thrive in predictable, low-stress settings (Atherton *et al.*, 2024).

Currently, digital serious games are increasingly used to support social cognition and ToM in autistic children. Digital tools like Tom Tom and Deusto-e-motion 1.0 have shown effectiveness in training emotion recognition and belief inference through structured, screen-based tasks (Monteiro and Pires, 2022; Lázaro *et al.*, 2020). However, these tools often lack role-playing elements and tangible, collaborative interaction, limiting engagement and real-time perspective-taking practice.

This paper introduces *Guess the Animal*, a tabletop game designed to foster ToM in children aged 7 to 12. Drawing on Game-Based Learning (GBL), Universal Design for Learning (UDL), and the Understanding by Design (UbD) framework, the project aims to offer an inclusive, engaging approach to social-cognitive growth through playful interaction.

This prototype aims to address the gaps of transference by enabling players to adopt character roles, receive asymmetric clues, and reason about others' mental states in a live, turn-based setting. This format reflects naturalistic false-belief situations and supports applied ToM practice through social play (Hofmann *et al.*, 2016).

Furthermore, tangible user interfaces (TUIs) have been shown to enhance engagement, embodiment, and collaborative learning, especially among neurodiverse learners (Li *et al.*, 2022). By incorporating TUIs into gameplay, this prototype aims to increase accessibility and real-world skill transfer compared to screen-based games.

2. Design Rationale and Theoretical Frameworks

Designing a game for inclusive social learning requires more than engaging mechanics—it calls for intentional alignment between educational goals, accessibility principles, and the diverse ways learners experience the world. This design is intended for diverse learners, including but not limited to autistic children, and is structured to align instructional goals with inclusive participation. The project integrates insights from three complementary frameworks that shape both its pedagogical structure and inclusive design: game-based learning, Understanding by Design, and Universal Design for Learning.

At the foundation is game-based learning, which emphasizes active participation, collaboration, and systems thinking. Well-designed games can foster cognitive engagement, emotional investment, and authentic social interaction—key conditions for supporting Theory of Mind development (Gee, 2007; Dishon and Kafai, 2020; Plass, Homer and Kinzer, 2015). These features are especially impactful for autistic learners when gameplay offers predictability and scaffolds peer interaction (Kangas, 2010; Mukund *et al.*, 2022; Toh and Kirschner, 2020).

Building on this, Understanding by Design provides a curricular structure that begins with end goals and works backward: identifying what learners should understand, defining how that understanding can be demonstrated, and designing experiences that lead toward those outcomes (Wiggins and McTighe, 2005). In *Guess the Animal*, mechanics such as clue interpretation and cooperative deduction are explicitly designed to elicit behaviors linked to perspective-taking and empathy.

To ensure all learners can access and express these skills, Universal Design for Learning offers an additional layer. The game incorporates visual cues, simplified prompts, and nonverbal participation options that reflect inclusive design principles (CAST, 2018; Bray *et al.*, 2024; Ismailov and Chiu, 2022), treating learner variability not as a challenge to accommodate but as a central design asset.

3. Game Design Process

The game *Guess the Animal* was developed to support two foundational social-cognitive competencies associated with Theory of Mind (ToM): cognitive perspective-taking and affective empathy. These goals were identified early in the design process and guided the development through the Understanding by Design (UbD) backward planning model. This structured approach ensured that every game element—from clue construction to player interaction—was intentionally aligned with the targeted learning outcomes.

At the heart of the gameplay is the mechanism of asymmetric clue interpretation. Each player adopts an animal character and receives a personalized clue card describing the hidden target animal (the “culprit”) in relation to their own character’s features. Because clues are contextual and comparative (e.g., “The culprit is larger than me”), players must interpret them from their character’s point of view. This mechanic cultivates cognitive perspective-taking, requiring learners to reason beyond their own knowledge—a process analogous to false-belief understanding, a core construct in ToM development.

In addition to perspective-taking, the game embeds affective empathy through naturalistic social interactions. Players are rewarded with tokens when they demonstrate prosocial behaviors such as offering help, yielding a turn, or affirming another player's contribution. These actions are not explicitly scripted but emerge organically, fostering spontaneous emotional responsiveness. Turn-taking and shared deduction further reinforce recursive reasoning (i.e., second-order ToM) by prompting players to monitor others’ thought processes and adjust their own strategies accordingly. The table 1 below illustrates how specific game mechanics correspond to subcomponents of Theory of Mind.

Table 1: Mapping of Game Mechanics to Theory of Mind Subskills

Game Mechanic	Targeted ToM Subskill	Description
Clue interpretation from character's perspective	Cognitive perspective-taking	Requires players to assess clues relative to their animal’s traits, simulating false-belief reasoning.
Turn-taking and shared deduction	Understanding of others’ mental states	Players infer peers’ knowledge and intentions during collaborative decision-making.

Game Mechanic	Targeted ToM Subskill	Description
Token rewards for prosocial behaviors	Affective perspective-taking/ empathy	Reinforces emotionally responsive behavior through social reinforcement mechanisms.
Collaborative guessing with partial information	Recursive reasoning (second-order ToM)	Encourages meta-cognition (e.g., "I think they think…") in joint problem-solving.

By translating abstract ToM constructs into concrete, interactive experiences, these mechanics offer repeated, low-pressure opportunities for autistic learners to practice essential social reasoning skills. Importantly, these skills are not taught through direct instruction but are enacted and reinforced through play.

To ensure equitable access for diverse learners, the game is also grounded in Universal Design for Learning (UDL)principles. Visual supports, simplified instructions, and multimodal options for participation (e.g., speech, gestures, pointing, visual aids) ensure that players with different communication styles and sensory preferences can engage meaningfully. These inclusive design features position neurodiversity not as a constraint, but as a foundational value of the learning environment.

In sum, *Guess the Animal* transforms complex Theory of Mind objectives into engaging, developmentally appropriate gameplay, offering a flexible and inclusive platform for practicing social cognition in autistic learners.

4. Gameplay

The following section provides a detailed breakdown of player roles, components, setup, and gameplay flow.

4.1 Players and Moderators

The game accommodates two to nine players and is facilitated by an adult moderator. The moderator, typically an educator or therapist familiar with autistic learners, does not participate as a player but oversees the session. Their responsibilities include selecting the target animal ("culprit"), distributing clue cards, and guiding turn-taking and interpretation throughout the game.

The players are children diagnosed with Autistic Spectrum Disorder that has understanding of verbal and visual instructions.

4.2 Game Components

4.2.1 Animal cards

A set of ten distinct animals, each defined by three visual traits: body size (small, medium, large), clothing color (e.g., red, blue, green), and tail length (short, medium, long).

4.2.2 Clue cards

Personalized clues distributed to each player based on their character. Each clue compares the culprit's features to the player's animal. For instance, if the culprit is a mouse, a clue might say, "This animal is bigger than me," depending on the player's character.

4.2.3 "Guess Who" boards

Each player receives a board displaying all ten animals. Players flip down animals that do not match the clues they interpret each round.

4.2.4 Reward tokens

Sensory items are awarded to players who correctly identify the culprit at the end of the game.

4.3 Setup and Play

At the start of each session, the moderator secretly selects one animal as the culprit. Each player then selects or draws a character card and places it face up, making all character traits visible to others.

The game unfolds over three rounds. In each round, the moderator distributes a clue card related to one trait category (e.g., body size). Players read their personalized clues aloud and interpret them from their character's perspective, then eliminate animals on their boards that do not match their reasoning. To support diverse communication needs, and in alignment with UDL principles, players may express their thinking verbally or nonverbally using gestures, pointing, or visual aids provided. After all three rounds, players make a final guess as to the culprit's identity. The moderator reveals the correct animal, and reward tokens are given to players who made accurate deductions—reinforcing both reasoning skills and collaborative engagement.

5. Assessment and Testing

Evaluating whether *Guess the Animal* meets its intended goals involves assessing both learning outcomes and usability. Specifically, the design targets two core dimensions: improvements in ToM, especially perspective-taking, and the game's effectiveness and accessibility for autistic learners.

To assess gains in ToM, several methods can be employed. Standardised false-belief tasks (e.g. the Sally-Anne test) can be administered before and after gameplay to measure changes in children's ability to reason about others' beliefs. In addition, the Theory of Mind Inventory (ToMI), a caregiver-report measure, provides insight into how children apply perspective-taking in real-life situations (Peters and Thompson, 2018). These tools are complemented by behavioural observations during gameplay. Facilitators may document how players interpret clues, engage in turn-taking, or collaborate with peers—behaviours that indicate growing social-cognitive flexibility (Atherton and Cross, 2021). Semi-structured surveys and observation protocols can further capture these interactions systematically.

Evaluating educational effectiveness also involves examining whether skills developed in the game transfer to broader social contexts. Observing how children use game-learned strategies outside the session can reveal real-world impact (Whalen et al., 2010). For example, when players have learned to interpret clues that can be ambiguous, the moderator can assess whether the ambiguity is understood with other commands by intentionally removing subjects in commands and observing if the player understands that such ambiguous commands are the same concept with the ambiguous rules in the game.

Feedback from children and caregivers also plays a critical role. Using simple Likert scales or emotive rating systems tailored to autistic users, facilitators can gather input on enjoyment, challenge level, and perceived relevance (Xavier et al., 2022). These responses, combined with behavioural data, help identify strengths and areas for refinement.

Finally, engagement metrics such as how often children choose to play and how long they remain involved provide additional insight into the game's motivational impact. When paired with ToM assessments and usability observations, these measures form a well-rounded understanding of how the game supports both social learning and inclusive participation.

6. Conclusion

Guess the Animal was designed to support social-cognitive learning in an inclusive, engaging format. By centering perspective-taking and empathy as its guiding goals and aligning them with structured gameplay, the project offers a model for translating complex Theory of Mind objectives into practice. Rather than teaching these skills through isolated instruction, the game situates them within peer interaction and shared reasoning, allowing players to experience and demonstrate social understanding as it unfolds in real time.

Importantly, the game also reflects a commitment to accessibility. Through multimodal input and expression, scaffolded interactions, and opportunities for flexible participation, *Guess the Animal* embraces learner variability as a foundation for design. These UDL-informed choices help ensure that autistic learners and others with diverse communication profiles can meaningfully participate—not in spite of their differences, but in ways that value and draw upon them.

While the current prototype has shown strong potential as a classroom-friendly tool for building social cognition, further research is needed to explore its adaptability, long-term impact, and integration across instructional contexts. In particular, future iterations may expand the range of social reasoning it supports, offer additional sensory accommodations, or reduce facilitator dependence to increase scalability.

Ultimately, *Guess the Animal* is more than a learning game; it is an attempt to rethink how we structure participation, belonging, and shared meaning-making. Its design suggests that with the right alignment of goals,

mechanics, and inclusive intent, playful learning can open space for every student to be seen, heard, and understood—one interaction at a time.

7. Limitations

Guess the Animal is currently a conceptual prototype informed by established Theory of Mind frameworks. While the design aligns with evidence-based principles, no empirical testing has yet been conducted. As such, claims regarding effectiveness remain preliminary.

We acknowledge this limitation and plan a small-scale pilot study with autistic learners to assess usability, engagement, and early indicators of ToM development. These findings will inform further refinement and validation of the game design.

Ethics Declaration: While no human participants were involved in the current stage of development, future testing is planned to evaluate the educational effectiveness and usability of the game. Recruitment will involve autistic children aged 7–12 through partnerships with local clinics and schools, following informed consent procedures from parents or legal guardians. Ethical approval will be obtained from an institutional review board (IRB) prior to implementation. Testing sessions will be designed to prioritize participant comfort, minimize anxiety, and allow for withdrawal at any time without consequence. Observations, surveys, and pre/post assessments will be used to ensure low-risk, developmentally appropriate data collection.

AI Declaration: Artificial intelligence (AI) tools, specifically OpenAI's ChatGPT, were used during the preparation of this manuscript to assist with proofreading, language refinement, and preliminary literature searches. All final content and interpretations are the responsibility of the author.

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VAFUG: A Model for Designing Educational Activities Grounded in Game Studies and Aesthetics

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Abstract: This paper introduces VAFUG, a model for designing learning activities that draw on the expressive and affective dimensions of commercial video games. Developed through a Design-Based Research process (DBR), VAFUG offers a set of indicators organized into three analytical components —Visual and Auditory Environment, Fictional Universe, and Core Gameplay— that guide educators through a descriptive phase and a subsequent process of identifying relevant educational questions. The model aims to support the design of dialogical activities that are both sensitive to the emotional and symbolic depth of games and adaptable to diverse classroom settings. This first design cycle covers the initial DBR phases, namely: 1) analysis of practical problems (the lack of analytical models available to educators for examining video games and designing meaningful educational activities); 2) development of solutions (our proposed model, influenced by both Game Studies and Aesthetics); and 3) testing and refinement (through an application of the model to the game *Neva* (Nomada Studio, 2024), a visually and emotionally rich indie title). The application enabled a preliminary validation of the model's descriptive and heuristic dimensions and allowed for the formulation of early design principles to guide future educational interventions. Preliminary results suggest that VAFUG can facilitate a more deliberate and context-aware incorporation of video games into educational contexts, particularly in relation to civic and socioemotional competences. Moreover, the model encourages a form of pedagogical engagement that recognizes the cultural, artistic, and affective potential of video games as meaningful learning objects. In this sense, VAFUG also contributes to the broader dialogue on how Game Studies and Aesthetics can inform educational innovation.

Keywords: Video games, Education, Game studies, Art, Design-Based research

1. Introduction

This paper presents the design and initial testing of VAFUG, an acronym derived from the three proposed categories: Visual and Auditory Environment, Fictional Universe, and Core Gameplay). VAFUG is a practical analytical model developed through Design-Based Research (DBR), aimed at helping educators critically examine commercial video games and create meaningful educational activities.

Video games offer significant potential to create learning opportunities. Pedagogical efforts have delved into the design of serious games specifically focused on providing valuable educational outcomes. On the other hand, there is a comparatively limited body of research on the educational application of Commercial Off-the-Shelf Games (COTS). As noted in the literature review by Oceja *et al.*, there is a "historical lack of research focusing on these games in comparison with educational games" (2022: 420). The aim of this research is to provide a tool to support educators in evaluating independent commercial video games for use in their pedagogical strategies.

Previous research has focused on establishing connections between the enjoyment and engagement of serious games and the achievement of valuable educational outcomes. One notable example is the LM-GM model developed by Arnab *et al*. Their tool focuses on serious games, identifying numerous learning-relevant mechanics as well as general video game features. Its aim is to identify Serious Game Mechanics, that is, "the game components that translate a pedagogical practice/pattern into concrete game mechanics directly perceivable by a player's actions" (Arnab *et al.*, 2015: 6). Our model can be considered a complementary work to this tool for two main reasons. First, we explore independent commercial video games that are not necessarily designed for educational use. In addition, we focus on video game components that support the development of Key Competences 5 (Personal, Social and Learning to Learn Competence) and 6 (Citizenship Competence).

VAFUG is also influenced by previous approaches to game analysis synthesized by Kłosiński's (2022), and stems from theories developed within Game Studies and Aesthetics. For instance, Fernández-Vara's (2015) textual analysis includes a substantial discussion of the formal elements that structure video games, distinguishing between the rules governing ludic design and the fictional world as related but separate dimensions—a distinction also found in other frameworks (Juul, 2005; Mäyrä, 2008; Navarro-Remesal, 2016). Proceduralist research has also shaped our model. Following Ian Bogost, procedures are, in general terms, "entrenched ways of doing things" (2007: 3). Playing a video game involves using the procedures established by the developers to

"explore the possibility space its rules afford by manipulating the game's controls" (43). In our proposal, we use a broad concept of the aesthetic qualities of a video game and consider that the "ways of doing things" during gameplay shape emotional experience—for example, the possibility of controlling two characters in the world of ICO (Team ICO, 2001). Recent work also treats specific features of video games, such as difficulty systems (Terrasa, 2021) repetition (Tosca, 2023), and waiting (Lozano, 2022), as aesthetic components, expanding reception studies into domains unique or distinctive to video games. This expanded view is also echoed in the MDA framework (Hunicke *et al*., 2004), which connects developers' creative intent with the player's experience, structured around several aesthetic perceptions. For his part, Pérez Latorre *et al*. (2017) combine proceduralist and semiotic approaches to develop a vocabulary of "semiotic resources" for game analysis. This vocabulary, which operates on multiple levels, also contributes to our model as it may help teachers to propose meaningful conversations.

Thus, the model has two objectives: (1) to assist teachers— who frequently are not specialists in Game Studies— in analyzing video games with rigor and depth; and (2) to create sets of questions that foster meaningful conversations with their students.

Central to this project is bridging theoretical depth and practical applicability. Rather than offering educators abstract analytical tools, the model encourages teachers to create their own questions and activities, particularly for leveraging the emotional and aesthetic potential of video games. This approach is informed not only by the aforementioned theoretical approaches but also by the authors' prior experience in designing classroom activities, especially focused on socioemotional and civic competences through projects such as *Playing Emotions* (https://www.educacionresponsable.org/recursos/playing-emotions/), *Ecoindie* (https://ecoindiegames.upf.edu/) and, currently being implemented, *PLAYCOMP* (https://playcomp.es/).

This proposal represents the first design cycle within a DBR process, namely 1) analysis of practical problems (lack of analytical models available to educators for examining video games and designing meaningful educational activities), 2) development of solutions (our proposed model which is influenced both by analysis models from game studies and aesthetics), and 3) testing and refinement (through and application of the model to the game *Neva* (Nomada Studio, 2024).

Although the project remains ongoing, initial findings suggest the model is effective, adaptable, and valuable for educators seeking to rigorously and creatively integrate commercial video games into their teaching practices.

2. Methods

Rooted in the principles of DBR, the development of this model follows an iterative process to generate actionable design principles and improve educational practice (Hoadley & Campos, 2022; McKenney & Reeves, 2018).

According to McKenney and Reeves, DBR consists of four iterative phases. First, analyzing practical problems, which involves identifying an educational challenge based on prior research and collaboration with stakeholders. Second, developing theory-informed solutions, including models, frameworks, or tools to address the problem. Third, iteratively evaluating and refining the solution through implementation and empirical feedback. Finally, producing design principles to inform future innovations. Currently, we have completed the first three phases, and the model still needs to be implemented and evaluated in real settings before generating design principles and beginning a new cycle.

The following lines summarize the steps taken to create the initial version of the model and to test it with the video game *Neva*:

- *Problem definition.* Lack of analytical models available to educators for examining video games and designing meaningful educational activities. Teachers need support to critically integrate commercial video games into the classroom, addressing the gap between academic theory and teaching practice.
- *Development of theoretically informed solutions.* The model structures the analysis of video games into three components (audiovisual, fictional, and procedural), drawing on established Game Studies frameworks and Aesthetics.
- *Evaluation and testing of the model.* The research team is currently discussing the model's suitability and testing it through the analysis of selected video games. It will next be implemented in educational settings to gather teacher feedback.
- *Design principles.* Insights from researchers and teachers will be used to generate design principles, guiding further refinements and initiating the next DBR cycle.

3. Results

3.1 General Model

The model presents three components (visual and auditory environment, fictional universe, and core gameplay) and two indicators for each. First, we want teachers to reflect on each of the components, describing how it applies to a particular game; then, the aim is to help them design questions and activities to work with their students.

We provide the following indicators as suggestions to help educators focus the design of learning activities:

- Artistic Style: aesthetic features that define the visual and audio composition of the game. Examples: the cartoon-style imitation in *Cuphead* (Studio MDHR, 2017); HD-2D graphics resembling a diorama in *Octopath Traveler* (Square Enix/Acquire, 2018); the dynamic soundscape of *Hellblade: Senua's Sacrifice* (Ninja Theory, 2017), which uses binaural audio and inner voices to convey the protagonist's psychosis and intensify the player's emotional immersion.
- Symbolic Elements / Allegorical Motifs: objects, characters, or props that play a prominent expressive role and can be associated with special symbolic meanings. Examples: Bowser's castle at the end of *Super Mario Bros*. (Nintendo, 1985) levels, or the mountain that marks the path in *Journey* (Thatgamecompany, 2012).
- Narrative World: fictional elements that give depth and internal coherence to the game's universe, such as the background lore in RPG-style video games.
- Plot: the sequence of events emerging from the narrative world in which the player takes an active part, and which result in significant changes to the game's fictional consistency. Example: the adventures of Link in the *Legend of Zelda* franchise (Nintendo, 1986–present).
- Procedural Mechanics: gameplay characteristics that shape the player's experience. Examples: in *Papers, Please* (3909 LCC, 2013), the daily addition of arbitrary rules intensifies the player's sense of stress or frustration; in *Braid* (Number None, 2008), the ability to rewind time to undo actions reconfigures the flow of gameplay.
- Platform-Related Features: limitations of the platform on which the game is played. Examples: hardware or engine constraints—such as the fog used in the first *Silent Hill* (Konami, 1999); differences when playing on mobile, handheld, or desktop systems; use of peripherals.

This model provides a structured two-step method for designing educational activities. First, the suggested indicators should be described to single out those expressive elements in a particular video game. The aim is not necessarily to provide an exhaustive description of each indicator (for instance, one might question whether a game like Tetris has a plot), but rather to focus attention on layers of meaning related to the game's aesthetic and emotional impact and to explore their potential educational relevance and applications. The content generated during that stage can be then used to formulate guiding questions to promote dialogical learnings.

3.2 Application to *Neva*

The following table shows the application of the model to *Neva*.

Table 1: VAFUG Model applied to *Neva*

	Visual and Auditory Environment	
Indicator	Artistic Style	Symbolic Elements/ Allegorical motifs
Description	A highly expressive artistic proposal that employs a combination of visual and auditory elements to create an emotionally engaging environment. The hand-drawn, watercolor-style settings are meticulous in their depiction of natural landscapes, conveying a strong sense of atmosphere. Fluid animations enhance the visual experience. The soundtrack is seamlessly integrated into the game's atmosphere, contributing to the pacing and emphasizing both dramatic tension and the overcoming of challenges.	The relationship between Alma and Neva (and later Bruma) symbolizes growth and the overcoming of obstacles through mutual care and resilience. It serves as a metaphor for the destruction of nature and its potential for regeneration.
Guiding Questions for teachers/students debates	How do the visuals and music work together to create an emotional atmosphere? In what ways do color and sound help	What do you think Neva represents for Alma? Do you find any similarities between Neva's story and your own personal

	Fictional Universe	
Indicator	Storyworld	Storyline
Description	The settings are primarily focused on natural environments, though they feature decayed architectural elements that may conceal mechanisms essential for progression. Dark, shadowy tones are used to symbolize malevolent forces and the degradation of the natural world. Upon defeating opponents, the landscape regains its lost color, symbolizing life and hope. This contrast is employed to emphasize the tension between destruction and vitality.	The story follows the journey of a young woman, Alma, after the death of a companion—a wolf-like creature—whose cub, Neva, she must adopt. The narrative unfolds without dialogue, focusing on the emotional growth and development of the characters as they cope with loss and navigate a world in constant decline.
Guiding Questions for teachers/students debates	How do the game's environments reflect the characters' emotional states? Can you identify any parallels between the world depicted in the game and current environmental issues?	What decisions does the protagonist make that demonstrate personal growth? How does the relationship between Alma and Neva evolve throughout the story? Is there a moment in the narrative that made you reflect on your own emotions?

	Core Gameplay	
Indicator	Procedural Mechanics	Hardware Constraints
Description	2D platforming environment. Fluid character movement. Simple mechanics. Progression requires solving puzzles or overcoming obstacles. Players must manage the secondary character (Neva) to overcome certain challenges. The challenges presented may include the completion of combat sequences.	Its graphic style requires substantial processing capacity to maintain visual fluidity and sharpness. However, its artistic design allows it to adapt to different resolutions without losing its expressive quality.
Guiding Questions for teachers/students debates	How did it make you feel to have to care for and collaborate with another character in order to progress? What personal skills do you think are engaged through these game mechanics?	Why is visual sharpness important in a game like Neva, and how does the artistic style help maintain expressiveness even at different resolutions?

4. Discussion and Conclusions

The preliminary testing of the VAFUG model demonstrates its potential as a bridge between analytical frameworks in Game Studies and Aesthetics and the practical demands of educational design. By proposing a model based in the visual and auditory environment, the fictional universe and the core gameplay, it enables educators to generate meaningful questions for critically reflecting on games. This dual emphasis—on theoretical richness and classroom feasibility—responds to a longstanding gap in game-based learning. The use of *Neva* as a test case seems to indicate the model's adaptability for designing activities aligned with socioemotional and civic competences.

The model should be considered a foundational prototype. While the first phases indicate promise, future cycles of implementation in diverse educational contexts are essential to validate its robustness. The model's success hinges on its capacity to evolve through sustained collaboration with educators and students, generating insights that will refine both the analytical framework and its pedagogical applications. In this regard, the VAFUG model not only contributes to the design of educational activities but also proposes a methodological pathway for integrating Game Studies and Aesthetics into the broader discourse of educational innovation.

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Designing a Gamified Learning Tool for Enhancing Project Monitoring Skills in Technical Engineering Projects: An Interdisciplinary Approach Integrating Project Management and Systems Engineering.

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Abstract: Within project management and systems engineering there are five process groups. While the theory related to these groups is covered well in higher education, there is limited room to explore challenges that mimic the execution and monitoring of real-world engineering projects. The main reason this step is usually left behind, is the high variability during the execution. This gap in education limits the student's ability to grasp the dynamic nature of project execution, where progress must be tracked, risks mitigated, and baselines for scope, time, and cost frequently adjusted. Since various studies in recent years have described the benefits of gamification in education, a gamified learning tool to enhance project monitoring skills could help in the teaching of the execution process group of a project. The aim of this study is to create a boardgame that uses the best project management and systems engineering practices from the execution and monitoring process groups. In this way, students can use the safe environment provided by the game to gain experience. The boardgame will be based on the best practices and challenges of project management and systems engineering, as well as the best practices of gamification and the interdisciplinary approach. The review also covers a look into previously developed serious games and the best ways to track learning outcomes. The game aims to be customizable to simulate different real-world scenarios to allow for diverse projects in the technical engineering field.

Keywords: project management, systems engineering, gamification, game-based learning

1. Introduction

Project management and systems engineering are two important aspects of real-world engineering projects, which is why they are thought at various universities. Most of these studies focus heavily on the initiation and planning process groups. However, to fully grasp the extend of the theoretical instructions, experiential learning is required. It allows students to understand and appreciate the dynamic nature of project execution, and teaches them to track progress, mitigate risk, and adjust baselines for scope, time and costs. (Project Management Institute (PMI), 2022)

A lack of knowledge in this regard can lead to problems such as missed deadlines, compromised quality, and overrun costs. It is therefore important that these skills are thought to students through innovative teaching methods. One such solution lies with gamification principles. By simulating a realistic project scenario, using adaptive dashboards, students can have an engaging learning experience where they participate in a practical project management scenario.

The goal of this project is to incorporate challenges and best practices from project management and systems engineering into a game that allows students to develop the skills necessary to properly react in the monitoring process group of a real-world project. The game should be adaptive and thereby simulate multiple real-world scenarios.

2. Approach

To create a gamified learning tool that helps students to understand the monitoring process group of project management and systems engineering, one must first understand the challenges and best practices from that monitoring process group. To achieve this, an in-depth literature review has been conducted, covering topics such as: project monitoring in project management and systems engineering; dashboards in project management; project management education; systems engineering education; gamification in education; serious games and learning outcomes; and interdisciplinary approaches to education in technical fields. In these topics different search quarries were created to answer certain questions. The quarries were then sorted both on the number of citations and on the most recent publications. The papers that seemed relevant, based on the content in their abstracts and conclusion, were then analysed in greater detail to answer the questions at hand. After this analysis the game will be created incorporating the above-mentioned challenges and best practices.

3. Learning Goals

The aim of this project is to give students the opportunity to practice with the execution of a project, without having to spend a lot of real resources on set project. However, to actually learn useful project management and systems engineering skills, there should be more defined learning goals to strive for.

Olechowski, Oehmen, Seering, & Ben-Dava (2016) provided one such source of proper learning goals that can be derived from the ISO 31000:2009 on risk management. In those principles it is states that risk management should create value; be an integral part of organizational processes; be part of decision making; explicitly address uncertainty; be systematic, structured and timely; be based on the best available information; be tailored; take human and cultural factors into account; be transparent and inclusive; be dynamic, iterative and responsive to change; and facilitate continual improvement. While there is a reasonable chance that not all of the above listed principles will be reached, the players should be able to incorporate the ISO principles in future projects after playing the gamified learning tool.

4. Octalysis

A good way to create a gamified learning tool is by the principles of Octalysis. (Chou, 2015) The Octalysis framework has eight core drives, including epic meaning; accomplishment; empowerment; ownership; social influence; scarcity; unpredictability; and avoidance. The principle in Octalysis is that these core drives are the drives people experience to do anything. By filling out the Octalysis tool and creating different ways to motivate students, the game should help to keep students engaged in the Project Monitoring Game (PMG).

Figure 1: Octalysis chart of the Project Monitoring Game

The eight core drives each help in a different way to keep someone engaged. Epic meaning gives the player the feeling like they were chosen for a greater purpose. It accounts for things that are greater than the player themselves. In the PMG this core drive will be achieved with story telling aspects, as the players will be in charge of the monitoring of a project that would suggest a life-saving situation. This will cause the players to feel a 'bigger than themselves' responsibility.

Accomplishment is all about the internal drive to make progress and overcoming challenges. The PMG will pursue this core drive by creating challenging aspects in the game and rewarding the players with checkpoints.

Additionally, in learning environments with multiple groups, there will be a leaderboard which will motivate the players to achieve better results.

Empowerment drives players by giving them creative freedom and feedback on their choices. In the PMG the players will attain this core drive by gaining more options as the game progresses. Each of these options will have a certain risk and reward. By having a game with many solutions, the players get to feel that their choices matter. An example could be the use of a special card, after a certain threshold is reached.

Ownership is the drive someone has to accumulate wealth and is accomplished when the player owns something and has the ability to make what they own better or get more of it. In the PMG, the players will be the owners of their projects, and have visual resources, such as tokens for money, various valuable assets that are needed for the project and cards they are able to play or obtain. By playing certain cards, the players will be able to gather more resources, while other cards might prevent them from loosing resources.

Social influence as a core drive accounts for all social elements that drive people. For the PMG this will mostly incorporate the team effort that the players will have, as they will all work together to reach a positive end state of the PMG.

The core drive scarcity regards wanting things but not being able to have them. The PMG will incorporate this core drive by having limited amounts of certain resources, which can only be obtained once during the game. This could include special onetime cards, or an exclusive bonus where the players have to pick one of three options.

By not knowing what will happen next, the unpredictability core drive will be achieved. It is all about the curiosity of the unknown. The PMG will incorporate this with the many variabilities that can be encountered in the game. The cards the players have access to will be distributed and drawn at random, and events that can occur during the game will also be determined with a certain randomness.

The last core drive is avoidance. Which is the drive to do something in order to avoid negative consequences. This core drive has not been fully analysed and incorporated for the PMG. When creating an actual game, this core drive is often not what creators want to incorporate, as it generally has negative connotations. However, it could be incorporated with a story aspect, at which point it ties in closely to the epic meaning core drive.

5. Game prospect

The game should consist of a dashboard, that clearly indicates various aspects of real-world aspects of project management. Among the aspects included should be scope, time, and cost. There should also be a clear indication of what risks are taken, and which are avoided. This will be done by visual indicators, such as tokens on trackers, cards on certain areas, and pawns on certain fields.

The game will generally be set in three stages. The first stages will in learning environments be set by a teacher or supervisor. This will include the timeframe in which the project should be finished, what requirements should be met at the end, and what limitations the project has. Overall, phase one will try to mimic the planning process group of a real project. For a version of this project that is more of a game, the first stage could include more of a play-style similar to phase two, but this still has to be figured out.

In the second phase of the game, the players will be able to play cards to act as preventative measures. At certain intervals the players will encounter events, which will influence the dashboard. Certain events could be countered by certain preventative measures, while other events can only be handled after the fact. These steps of encountering events, and reacting to those events, as well as trying to prevent upcoming events will be the core of the second phase of the game. The details of playing cards and events still have to be determined.

In the third phase of the game, the players will be able to reap their rewards. Effort that was put in could be converted into points, while preventative measures that were needless could be seen as losses. The exact detail of this pointing system is still to be sorted out.

Ethics declaration

There were no participants involved in the creation of the initial PMG. This research and proposed testing will be reviewed by the Natural Sciences and Engineering Sciences (NES) ethics committee, before any testing with human participants will be conducted.

AI declaration

No artificial intelligence has been used in the creation of this paper.

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Divergent Design: Disrupting Systems Through Game Experiences

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Abstract: This interdisciplinary research project investigates how divergent design choices in video games could have the potential to influence player thinking and challenge oppressive societal systems. Through play, including play in video game simulations, we shape our cultural norms and societal structures (Huizinga, 1955). Baudrillard's (1994) theories of simulacra and the hyperreal demonstrate how designed media experiences reflect, distort, and ultimately influence societies. Grounded in systems thinking (Meadows, 2008) and Creative Game Studies (Ruffino, 2018; Chess, 2020), this research explores the connections between virtual and real-world systems through an intersectional feminist lens. Using gender representation in character design as an example of a divergent design choice in video game media, the study highlights opportunities for research in digital ethnography and digital sociology to analyze the impact of design decisions on societal structures. The project treats video games as both cultural simulations and pedagogical spaces for questioning patriarchal systems. Drawing from literature on cognitive effects in games—such as creativity, problem-solving, flow, and learning—it positions video games as immersive media uniquely suited for generating player investment and reflective engagement, beyond the passive consumption of traditional media. A pair of case studies includes game titles *Satisfactory* and *Outer Wilds*, representing divergent design choices that counter gender norms. These titles serve as sites of inquiry for understanding the connections between divergent video game design choices and experiences that invite player reflection on social systems. These game systems function as experiential learning environments, fostering player metacognition and ethical reasoning. The project explores how informal, incidental learning emerges when players engage with transgressive designs that disrupt social norms. This work bridges disciplines in critical game studies and learning sciences and encourages instilling ethical design principles in game designers of the future. It proposes prospective research pathways using methodologies from mass media studies to further examine the potential implications of game design choices.

Keywords: Game design, Player experience, Design thinking, Systems thinking, Sociology, Interdisciplinary

1. Introduction

Video games are more popular and far-reaching than ever, with immersive experiences that deeply shape psychological and emotional understandings of the world (Chess, 2020; Ruffino, 2018; Bogost, 2015; Flanagan & Nissenbaum, 2014; Green, Garo, & Kaufman, 2015; Hodent, 2021; Isbister, 2016; Klopfer et al., 2018). We have the power to create new systems—or to reinforce existing, problematic ones by replicating them in digital simulations. Video game design frequently mirrors dominant social norms, yet it holds the potential to subvert or question these norms. The role of play and simulation in shaping social structures is underexplored, particularly through the lenses of systems thinking and intersectionality.

Play, including digital play through video games, contributes to the construction of cultural norms and societal systems (Huizinga, 1955). Baudrillard's (1994) concept of simulacra and the hyperreal illustrates how designed media reflects, distorts, and ultimately shapes societal perception. This project is grounded in systems thinking (Meadows, 2008) and Creative Game Studies (Ruffino, 2018; Chess, 2020), and it approaches the relationship between virtual and real-world systems through an intersectional feminist framework.

Design is a powerful, systemic act— each design decision influences many users. If, as the scholarship suggests, design significantly impacts perception and behavior, then its power must be wielded with care. This project addresses the gap in research that considers the intersection of systemic design, identity, and social structure, with a focus on how video game design can challenge patriarchal systems.

This study asks—how do divergent design choices in video games provoke player responses, as reflected in the rhetoric and debates within online game communities? Two case studies examine recent games with non-normative design choices, alongside a review of player discourse in online communities. Early observations suggest digital ethnography and sociology may reveal deeper connections between design, player experience, and cultural patterns. The following sections will outline theoretical frameworks, present case studies, explore online player responses, and propose pathways for future research. This work aims to contribute to game studies, design ethics, and conversations about media's power to shape society, by building on current conceptual frameworks, sharing initial observations, and outlining planned research in these areas.

2. Theoretical and Methodological Framework

As humans, we replicate systems through simulations in media (Baudrillard, 1994). Video games represent the most immersive form of media yet, with simulations growing hyperreal through advancements like virtual and augmented reality. They offer a prime platform for experimenting with systems and observing player responses.

Donella Meadows (2008) describes systems through stocks, flows, and feedback loops, noting how unchecked systems perpetuate themselves—and how targeted interventions can shift outcomes. The video game industry has a history of profiting from games designed by, marketed to, and played by a largely male audience (Chess, 2020; Ruffino, 2018). Misogynistic and violent content becomes the "stock" that flows from designer to player. Young players grow up to be the next generation of game designers, and the system continues. Feedback loops of capitalist profit and gamer culture propel the system forward, solidifying social systems that privilege cisgender men as core structures of the game design industry. There is opportunity to diverge from this status quo, by inserting design choices that counter patriarchal norms.

The loosely defined rise of 'indie' game development shows promise for smaller developers to challenge these norms through designing new simulated systems. Indie developers are generally under fewer restrictions and can explore new ideas over popular themes. Additionally, it is more accessible than ever for players to become designers using free development platforms. Ruffino (2018) sees indie development as a revival of early game-making eras, when small teams built games as research experiments. The definition of game developer has widened, and games have the potential to represent a broader range of voices. There is opportunity in the game design industry to support this diversity and foster the creation of divergent systems.

Creative Game Studies (Ruffino, 2018; Chess, 2020) offers a framework for engaging with video games as surprising, engaging media experiences. It is in this space I ask about the potential for interactive experiences in video games to impact the real-world systems we live within. By approaching this inquiry in a critical and performative way (Ruffino, 2018), this work serves as exploratory research in which I aim to spark conversation about the responsibility of game designers in shaping the world through their creations. Additionally, this work aligns with Chess's (2020) vision of a playful feminism, and through this lens examines design choices that subvert heteronormative structures in traditional games. Building on systems thinking, games futurism, and feminism, the following case studies support the critical examination of divergent design choices in current games.

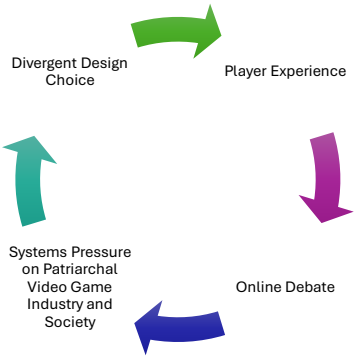
3. Case Studies

The planet of MASSAGE-2(A-B)b holds a wealth of resources, flora, and fauna for the lonely pioneer who inhabits it. In this open-world building game of production and efficiency, the pioneer faces hostile creatures, harsh landscapes, and the cold indifference of their employer, FICSIT. The open-world game *Satisfactory* provides a system in which players can exercise their creative thinking and problem-solving muscles, leading to increased brain plasticity (Ganter-Argast et al., 2024). This game induces a flow state for players—some report spending hundreds or thousands of hours playing (Reddit r/SatisfactoryGame).

The player character in Satisfactory is rendered as a space pioneer, with facial features obscured by a full-face oxygen mask but a body shape showing curved hips and chest in a full-length jumpsuit. There are no customization options aside from changing the colors and textures of the jumpsuit and accessories. The game is primarily viewed from a first-person perspective, with only gloved hands visible as players rotate through tools. This design—featuring a woman as the sole protagonist and engineer—challenges gender norms in STEM fields. The Society of Women Engineers reports that women represent only 16.7% of careers in architecture and engineering (Society of Women Engineers, 2024). An initial review of the vocal Reddit community, r/SatisfactoryGame, suggests that some players are significantly bothered by having to play as a female character—an ironic reaction given the history of male-dominated game design where women often have no choice but to play as male characters. While there are a wide range of player reactions and many potential factors for these reactions, some vocal and argumentative comments about the woman engineer protagonist clearly suggest that the representation resonates as a divergent, disruptive, norm-challenging choice for their worldview.

In contrast, traveling the *Outer Wilds* solar system as a Hearthian in a spaceship pieced together with wood, rope, and natural materials, the player presents as genderless and is referred to with they/them pronouns, while the long-lost Nomai characters use gendered pronouns. These deliberate design choices spark discussion by

drawing attention to specific societal systems. Like *Satisfactory*, *Outer Wilds* features non-normative gender presentation that provokes discussion. The key difference is that the player is not a woman, but genderless. An initial review of online conversations reveals less misogynistic rhetoric and more introspection—some players question why they notice gender at all or default to binary roles.



As these cases demonstrate, divergent design choices shape the player's experience with the game system and provoke reflection, which are visible in online conversations where players process and discuss these disruptions.

4. Future Research Direction

The current methodology presented here involves critical ludological analysis, but future directions include social listening and content analysis of Reddit discourse to assess ethnographic and sociological implications of divergent design choices. Reddit is identified as a key site for metacognitive insight, where user-generated content—comments, upvotes, downvotes, and moderator deletions—offers a rich source of rhetorical and behavioral data. Additional sites of inquiry could include Steam game forums. The research plan currently includes implementing an API script to pull data in the form of post comments, upvotes, and downvotes to facilitate a thematic analysis. A thematic analysis will serve as a foundation for understanding various player reactions, and comparing expressed sentiments with the number of upvotes and downvotes will demonstrate relationships between sentiments and popularity of those sentiments. Indicators such as misogynistic language and body shaming point to negative sentiments, while positive descriptions of the design choice or player character point to positive, neutral, or accepting sentiments. While not intended to be generalizable to all players or all game experiences, these conversations reveal how some players process disruptive design and reflect on their experiences in virtual systems, then use online game communities to discuss and debate their views on social systems. This player discourse provides a window into the metacognitive experience of gameplay and the negotiation of social norms.

Ultimately, this research bridges critical game studies and game-based learning, highlighting how divergent design choices can support divergent thinking, ethical reflection, and creative learning outcomes with broader social implications. This work contributes to scholarship that treats video games not only as entertainment but as cultural texts with pedagogical potential. Future research will apply digital ethnographic methods and thematic analysis to explore how online player communities engage with non-normative design. Additional research is needed across games with various presentations of player representation, or other divergent design choices in mechanics or gameplay. These methods will support a deeper understanding of how players interpret or internalize messages embedded in games.

By interrogating the intersection of design, identity, and player experience, this project underscores the transformative potential of intentional game design to question—and reimagine—the systems we live within.

Ethics declaration: This research did not involve human subjects or personal data collection and therefore did not require formal ethical clearance. All analysis is based on publicly available content and theoretical frameworks.

AI declaration: AI tools (ChatGPT, Grammarly) assisted with the process of organization and editing of the original thoughts and inquiries presented here. All ideas are the author's own based on a multitude of influences. The pre-writing, draft, and final paper are original works.

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Emotional-Driven Gameplay: Exploring Gesture-Based Interactions in XR Environments

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Abstract: This research dives into the fascinating world of virtual reality (VR) and how gestures can evoke a sense of human-like behaviour, enriching emotional and immersive experiences while fostering empathy. By analysing both subtle and broad body language, the goal is to create a system where gestures can shape our physical and emotional reactions, allowing for more natural and intuitive non-verbal communication. Ultimately, the study aims to enhance empathy through expressive virtual interactions, helping to connect the digital realm with our physical presence.

Keywords: Virtual reality, Hand gestures, Emotional responses, Empathy building, Spatial environment, Game technologies

1. Introduction

Virtual reality (VR) has completely changed the way we interact online by creating immersive environments that really pull users in. This study takes a closer look at how spatial design and nonverbal communication, especially hand gestures, affect user experiences in VR.

By utilizing the Meta Quest 3 VR headset's built-in camera for gesture recognition and a Rokoko motion capture suit to give the character better feedback gesture like human behaviour, the research dives into how familiar gestures can evoke emotions in various virtual settings. Nonverbal communication, like body language and hand gestures, is essential for creating natural and intuitive interactions in digital spaces.

Previous research on nonverbal emotional expression and gesture-based human-computer dialogue lays a solid groundwork for understanding how movement impacts user engagement. This study zeroes in on how different spatial environments shape these interactions, particularly in both enclosed and open areas. The findings indicate that personal interactions in enclosed spaces tend to elicit stronger emotional responses because they offer a controlled, distraction free environment. In contrast to another special environment designed with more characters and elements introduce outside stimuli that can muddle gesture-based communication. While open spaces, allow for more freedom of engagement, the absence of clear focal points might result in less deliberate gestures.

These design principles resonate with earlier research that emphasizes how spatial distance can influence emotional reactions. By exploring these dynamics, this study underscores the potential of VR and motion capture technologies to create immersive, emotionally engaging virtual interactions. The insights gained here could pave the way for advancements in educational applications, interactive storytelling, and the future of gesture-driven VR experiences.

Overall, the study shows the exciting potential of VR and motion capture technologies in crafting immersive, gesture-driven experiences that push the boundaries of educational and interactive design in virtual reality.

2. Literature Survey

Recent studies have extensively explored VR and nonverbal communication. Research has demonstrated the importance of nonverbal expressions in conveying positive emotions, highlighting how gestures and facial cues effectively communicate different emotional states [4]. This aligns with the use of hand gestures as controllers in VR environments, such as the Meta Quest, where natural movements enhance immersion and emotional connection.

A critical review on nonverbal communication in immersive VR examines how VR transmits nonverbal cues, such as gestures, gaze, and proxemics, which are crucial for presence and social interaction in virtual spaces [5]. This is particularly relevant for educational and training applications, such as scuba diving or space station simulations, where gestures serve as intuitive controls and communication tools.

Studies have also investigated VR as an interview technique, showcasing its potential to assess communication skills and emotional responses in con-trolled settings [6]. This method can further explore how spatial

environments and gestures impact emotional content, providing insights into human behavior and nonverbal communication.

The cognitive and communicative advantages of gestures have been highlighted, emphasizing their role in improving understanding and memory [7]. This has implications for using VR to assist individuals with autism or those learning sign language, as gestures help bridge the gap between verbal and nonverbal communication.

Much of the current VR research focuses on creating more natural and immersive user interfaces through motion capture and advanced computing techniques that replicate natural body movements and facial expressions [8]. Studies suggest that adding detailed gesture recognition and body language capture can significantly improve user engagement in visceral environments.

However, there are still some significant gaps in the area. While virtual reality (VR) is becoming more popular for educational purposes, many existing studies tend to focus on things like interacting mechanics, learning outcomes, and how effective gesture-based controls are. It hasn't been explored enough is how gestures contribute to emotional engagement in educational virtual reality experiences, especially in terms of how emotional responses are triggered and captured through nonverbal interactions. Most of the current systems prioritize usability and understanding, but they fall short when it comes to systematically capturing and analyzing the emotional reactions tied to gesture-driven interactions.[9] This presents a valuable research opportunity: integrating emotional feedback mechanisms could really deepen engagement in educational virtual reality applications. By addressing this gap, we can gain a more comprehensive understanding of how gestures impact both learning and emotional connections in virtual environments.

3. Methodology

This study takes a mixed-method research approach to create and evaluate a gesture-based interaction system in virtual reality (VR).[1] By blending qualitative and quantitative methods, the goal is to deliver a thorough assessment of the system's architecture, gesture recognition accuracy, and interaction fidelity within virtual reality environments, specifically using the Meta Quest 3 framework and Unity's mixed reality development support.[7][8]

3.1 Research Design

The research follows a well-structured framework that merges technical validation, user experience analysis, and game design principles to evaluate gesture-driven interactions in VR. It employs three distinct methodological strategies [2][3]:

- **Embedded Design**: The focus was on assessing system performance. However, insights gained from real-time gesture responses were also integrated into the analysis to enhance the interaction framework, game design principles, and overall usability. This approach ensured that the technical aspects of gesture tracking were in sync with user behavior and emotional engagement.
- **Explanatory Sequential Design:** Initially, a quantitative analysis of gesture recognition accuracy and latency was conducted to establish a baseline for system performance. Next, qualitative assessments were carried out to explore interaction dynamics and user responses, ensuring that the findings were interpreted in context and directly linked to improvements in user experience. This sequence facilitated data-driven enhancements, fine tuning the system's responsiveness based on real user feedback.
- **Exploratory Sequential Design:** A preliminary qualitative review of gesture-driven VR interactions was performed. This helped inform early adjustments to recognition modeling and game design elements. Following these initial refinements, quantitative testing was conducted to validate the enhancements in interaction efficiency.

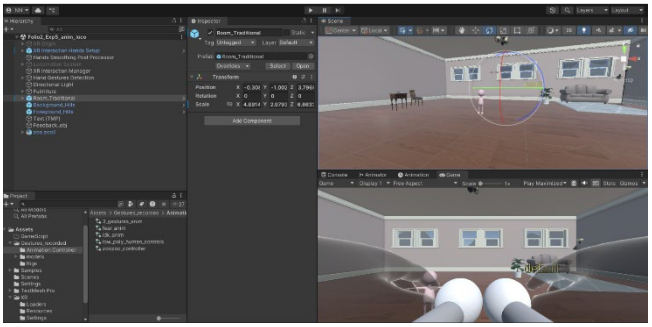

Figure 1: VR setup in unity

3.2 System Architecture and Gesture Processing

3.2.1 Gesture recognition pipeline

The system employed computer vision-based tracking and machine learning classification within the Meta framework to identify both macro- gestures and micro-gestures. Hand tracking data from the Meta Quest and a motion capture suit were processed in Unity engine. The mixed reality (XR) supported package was used to distinguish between static and dynamic gestures.

3.2.2 Environment and Interaction Modeling

The 3-dimensional environment to support virtual reality was crafted using Unity, dynamically adjusted to recognized gestures, triggering real-time changes in lighting, spatial audio, and object interactions. These enhancements created a more immersive experience for users.

4. Tools and Techniques

4.1 Important Considerations

The gesture recognizer supports static poses only, meaning dynamic gestures (e.g., swiping or throwing motions) are not recognized.

A Static Hand Gesture component was added to the scene, configured to reference Hand Shape or Hand Pose assets along with an XR Hand Tracking Events object that is supported by mixed-reality headset. This component triggers Unity Events upon detecting or ceasing a gesture.

4.2 Gesture Mapping and Emotional Correlation

The following custom gestures were designed and mapped to specific emotions:

- **High Five:** Represents happiness.
- **Thumbs Up:** Indicates approval or joy.
- **Fist:** Reflects anger or frustration.
- **Thumbs Down:** Denotes disapproval or dissatisfaction.
- **Pointing Finger:** Expresses confusion or focus.

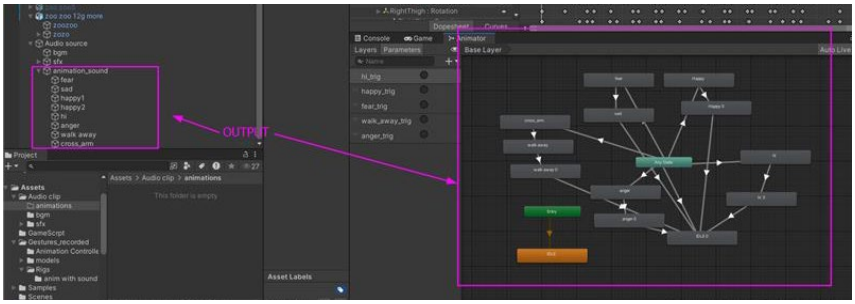

Figure 2: Mapping of gestures with character behavior

4.3 Environment Design

To highlight body language instead of facial expressions, the environment was carefully crafted with low-poly designs and featured a non-human character that lacked any facial features. This intentional choice allowed

researchers to zero in on macro-level body language and gestures without the distractions of facial expressions. Low-poly models were implemented to reduce the graphical processing, to minimize the rendering load on the headset providing a smoother performance.

The study took place in two different settings: a cozy living room and an open park with simple elements, offering diverse contexts for thorough analysis. However, the open-space environment faced performance issues due to its high rendering demands and too many graphical elements, which made it unmanageable within the current system. Consequently, the study shifted to the closed-room VR environment for further development. This smaller space allowed for optimized rendering, cutting down on computational strain while still facilitating meaningful interaction studies.

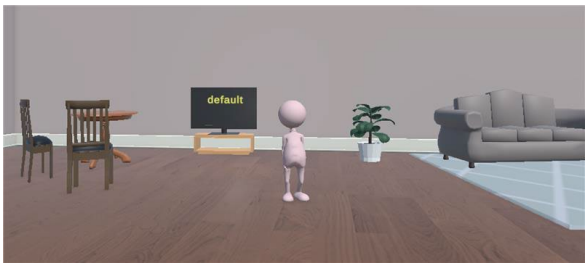

Figure 3: Character places in living room environment and character places in open space

A feedback system was created, using gestures, sounds, and lights to express various moods and emotional states to the player. Bright lights signaled positive responses, creating a cheerful vibe, while shadows represented negative responses, adding a touch of unease. This system was designed to provoke strong emotional reactions and boost player engagement with the character. The virtual reality environment enabled players to view the character and its surroundings from different angles, promoting the players to feel a strong sense of fun, immersion, and emotional connection to the character.

5. Result

The interactive simulation was launched on the Meta Quest 3 VR headset, which participants donned during the testing phase. They were instructed to use specific gestures that had been mapped out beforehand, each intended to provoke responses in the virtual environment. Throughout the sessions, the participants responses and reactions were closely monitored and documented, with a focus on gesture accuracy, caterer interaction, emotional engagement, and behavioral patterns.

a) b)

Figure 4: (a) and (b) Gameplay testing with hand gestures

This table shows how certain gestures connect with emotional reactions and user behaviour, providing useful insights for crafting more engaging and meaningful VR experiences.

Table 1: Gestures and Emotional correlation

Gesture	Emotional Response	Player Behaviour	Observations
Fist	Negative emotions, heightened empathy	Players tended to back out of interactions	Elicited strong empathetic responses despite being perceived as hostile gestures.
Thumbs Up	Positive emotions such as happiness and approval	Frequently used by players	This gesture was among the most preferred and encouraged positive interaction.
Wave	Positive and welcoming emotions	Frequently used by players	Triggered friendly interactions and was widely adopted for initial engagement.

Gesture	Emotional Response	Player Behaviour	Observations
Thumbs Down	Negative emotions such as disapproval or frustration	Mixed reactions: some players disengaged	Clearly communicated dissatisfaction or criticism.
Open-Hand Swipe	Neutral or exploratory emotions	Encouraged playful exploration in open spaces	Often associated with testing boundaries or exploring responses.
First (Punch)	Cathartic release of negative emotions, stress relief	Some players expressed satisfaction through repetition	Gestures allow a constructive outlet for stress within the virtual environment.
Point finger	Confused, but neutral	Most of the player were neural	Generated confusion or a sense of humour with the players

6. Conclusion

This study highlights how using simple, universal gestures in character interactions within virtual reality can really evoke a wide range of emotions from happy, sad, angry and empathy, which can significantly enhance user engagement with the system. The results indicate that participants felt a stronger connection in environments that mimicked enclosed spaces, where interacting with a non-human character through gestures was more responsive and impactful, no spoken dialogue needed. These findings pave the way for exciting applications in nonverbal communication training and emotionally rich interactive storytelling. Looking forward, by improving gesture recognition accuracy and enhancing the emotional feedback system, we can create more intuitive, human-centred virtual reality experiences, especially in areas like education, therapy, and inclusive design. Incorporating universal gestures into different VR settings could truly elevate learning, communication, and immersive storytelling experiences.

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Ethics Declaration: All user testing has been carried out with their clear consent to uphold ethical standards of research.

AI Declaration: No artificial intelligence was used to create the project.

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IMPACT: An Unplugged Board Game to Introduce Programming Concepts in Primary Education

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Abstract: Fundamental programming concepts and Computational Thinking (CT) are not sufficiently covered in early primary education in Switzerland, particularly in grades 3 and 4. This gap makes it challenging for students to grasp programming when first introduced in grade 5, as they lack foundational knowledge in sequences, loops, conditions, and events. Without structured exposure to these concepts at an earlier stage, students often struggle with understanding programming logic and syntax when transitioning to coding environments. The IMPACT project addresses this issue by developing an unplugged board game that introduces key programming principles in an engaging and age-appropriate way. Following the Educational Design Research (EDR) approach, the game was developed in an iterative process that involved structured literature review, expert interviews with teachers, and feedback from didactic specialists. The first prototype was evaluated with didactic experts before testing in primary school settings to ensure its pedagogical suitability. The game is designed to be both intuitive and scalable, allowing students to progress through different levels—starting with simple movement commands and advancing towards more complex programming structures such as nested loops, conditional statements, and event-based actions. In the initial qualitative research phase, four teachers participated in semi-structured interviews to explore their expectations, challenges in teaching computational concepts, and potential classroom applications of the game. Their insights were instrumental in refining the game mechanics, ensuring alignment with curriculum goals, and improving usability for both teachers and students. Findings from the second interview (after the game had been played in class) indicate that teachers appreciate the game's accessibility, adaptability, and effectiveness in preparing students for future programming lessons. Future research will focus on quantitative analysis, extended classroom testing, and further iterations of the game. Additionally, teaching materials and training modules for educators will be developed to support broader implementation. The findings contribute to discussions on game-based learning approaches in computational education, offering practical insights into how unplugged activities can be effectively integrated into the early curriculum.

Keywords: Unplugged learning, Programming concepts, Computational thinking, Game-Based learning, Educational design research

1. Introduction

In Swiss primary education, there is a significant gap in the systematic introduction of fundamental programming concepts, particularly in grades 3 and 4. While cycle 1 focuses on basic cognitive and procedural skills such as sorting objects and following rules, many students face challenges when transitioning to formal programming in grade 5, as key concepts like loops, sequences, and conditions are not introduced early enough. This often leads to difficulties in understanding programming logic, a lack of confidence, and decreased motivation (Curzon et al., 2019; Huang & Looi, 2021).

Targeted preparation during grades 3 and 4 could lay a stronger foundation for successful programming instruction. Especially effective are unplugged and game-based approaches, which introduce programming principles in age-appropriate and motivating ways (Huang & Looi, 2021; Curzon et al., 2019). The IMPACT project addresses this gap by offering a playful and age-appropriate learning environment that builds computational foundations through an unplugged board game. It targets students in grades 3 and 4 and aims to prepare them for more complex programming instruction by engaging them in problem-solving, planning, and reasoning activities. The project situates itself at the intersection of informatics education, Educational Design Research (EDR), and game-based learning, with a distinct focus on equity, accessibility, and scalable classroom integration. Unplugged approaches were chosen deliberately to ensure broad access without reliance on hardware or digital infrastructure. Unplugged activities have emerged as an effective approach to teaching computational thinking and programming concepts in primary schools, especially where digital resources are limited (Brackmann et al., 2017; Caldwell & Smith, 2017). This educational intervention not only introduces fundamental programming concepts (sequences, loops, conditions, and events), but also supports early cognitive structuring of programming logic, fosters computational thinking, and scaffolds learning before the introduction of syntax-based environments such as Scratch. The initial phase (June–December 2024) resulted in the development and classroom testing of a board game prototype, showing high engagement and

positive learning potential. A next phase will build on this work, with specific emphasis on optimizing the game and preparing it for broader dissemination and evaluation in diverse school settings.

In this paper, we introduce IMPACT+, an unplugged board game designed to teach core programming concepts to grade 4 students. The paper is structured as follows: Section 2 outlines the pedagogical background and design rationale. Section 3 describes the methodology, including the Educational Design Research approach and classroom implementation. Section 4 presents initial findings from the classroom pilot. Section 5 discusses future development steps, including refinement, hybrid extension, and planned transfer studies. Section 6 concludes with reflections on educational impact and scalability.

2. Background

The IMPACT+ game provides a scaffolded, analogue introduction to core programming concepts before learners actually begin coding. This approach is expected to reduce cognitive load, support mental representation of programming structures, and increase problem-solving efficiency.

The project developed a board game in which two to four players control avatars across a game board using command cards (see Fig. 2). The objective is to collect coins placed at the corners of the board and score as many points as possible. In each round, players first plan their moves using the game board (see Fig. 1), then execute their sequence of actions. The game ends when the golden key is revealed. The game includes several levels, starting with simple movements and advancing to conditions and complex loops, thereby covering programming concepts such as loops, conditions, sequences, and events.

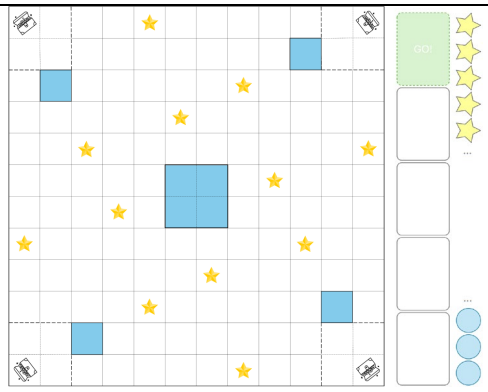


Figure 1: Game board

Figure 2: Game cards

The game is structured into progressive levels that gradually introduce core programming concepts. Table 1 summarises the content and function of each level, including available command cards, loop mechanisms, and conditional logic elements.

Table 1: Gaming Levels

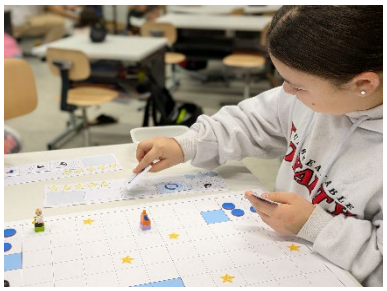
Level 0	**Command cards:** Turn 90° left Turn 90° right Move forward 1 field Back of all cards: GO + Collect objects
Level 1	**New gaming cards:** 1-step loop (repeat 2x / 3x / 4x): use template and place it over the card to be repeated.
Level 2	**New loop templates:** 2-step loops (2x / 3x / 4x): same principle, templates have space for 2 cards Loops can also be nested **New gaming card:** Trun 180°
Level 3	**New loop templates:** 3-step loop (2x / 3x / 4x): same, templates hold 3 cards

Level 4	Use portals (conditions/variables): If two stars, then you may use the portal
Level 5	**New gaming cards:** Repeat until edge / obstacle / treasure chest: same principle
Pro level	**Pro Level – New game cards and loop templates:** 4-step loop (2x / 3x / 4x): same (for advanced players), templates hold 4 cards

3. Methodology

The game was developed and evaluated in two phases using an Educational Design Research (EDR) approach (Plomp, 2013). A structured literature review included analysis of existing games (e.g., Tsarava et al., 2019). Expert interviews were conducted with four teachers who later participated in the classroom pilot. Their feedback was incorporated into the subsequent development phase. The prototype was then tested by two didactics experts. Their feedback led to further refinement of the game prior to the intervention phase. Before testing in the classroom, participating teachers submitted demographic data on their students via Excel. The Educational Design Research (EDR) approach chosen (Plomp, 2013) is particularly suitable for the practical development and testing of educational innovations. Combining literature research, expert interviews, subject-specific didactic assessment and classroom testing enables an iterative development process.

The intervention in class lasted three lessons and took place directly at schools. In the first two lessons, students played the prototype version (see Figs. 3–5). In the third session, focus group interviews with students were conducted. Teachers also participated in a guided post-interview. Additionally, students completed an online questionnaire based on the Game Experience Questionnaire (GEQ; Poels et al., 2007), administered shortly after the intervention with teacher support.



Figures 3-5: Classroom experiences

3.1 Sample

A total of 161 grade 4 students from eight classes in the cantons of Zurich and Schwyz participated. Recruitment took place via flyers in teacher networks and oral invitations during continuing education events. Parental consent was obtained prior to participation.

3.2 Data Collection Instruments

The expert interviews followed a guide (Helfferich, 2022) that gathered teacher expectations, requirements, and classroom context for the didactic game. Teachers also described their students' play behaviour and discussed possible classroom integration of the unplugged game.

The focus group interviews with students also followed a structured guide. Students were divided into groups of four and asked about their learning, game incidents, challenges, strategies, improvement suggestions, and visual design ideas. One group was interviewed directly by the research team.

The student survey was conducted online using Microsoft Forms and based on the GEQ (Poels et al., 2007) to assess game experience.

The teacher post-interviews focused on game observation, mechanics, clarity, design, learning effect, feasibility (e.g., prep time, organisation), and suggestions for revision or expansion.

4. Results

Several data sets were collected from the prototype evaluation:

- Qualitative data from audio recordings of student focus group interviews

- Quantitative survey data on game experience
- Qualitative data from teacher post-interview recordings

Initial insights: While final data analysis is still pending, several initial findings can be reported:

Implementation was successful in all classes. Students understood the rules and could play independently or with minor support. The physical design—coins, cards—was appealing. Game mechanics functioned well, e.g., the balance of card types, board size, and coin quantity supported progress and achievements. Three out of six levels were tested during the pilot.

Teachers gave consistently positive feedback in interviews. They found the game age-appropriate and noted observable learning effects. All participating classes kept a prototype and all teachers expressed interest in using the game again.

5. Future Work

Building on the positive feedback and initial evaluation results, several follow-up initiatives are planned to further develop and scale the project. A comprehensive analysis of the rich dataset, collected through classroom observations, interviews, and surveys, will be conducted using both qualitative and quantitative methods. These findings will guide targeted revisions. The analog prototype will continue to undergo iterative development. Game mechanics, level structures, and the visual design will be refined, and additional programming concepts such as variables or event chains may be introduced to broaden the learning potential (Tsarava et al., 2018; Chen et al., 2023). A hybrid version of the game is also in development. This will include a narrative-driven digital layer, offering contextual support without being essential to gameplay. Elements such as onboarding sequences, explanatory prompts, and a timer will enhance user guidance (Metwally et al., 2021; Poels et al., 2007; Nishida et al., 2009). To support broad implementation, printable game components and editable templates will be made available as Open Educational Resources (OER). These will be complemented by teacher guides, optional challenges, and lesson ideas to enable flexible use in different classroom settings. This aligns with current calls for accessible and curriculum-aligned resources in informatics education (Huang & Looi, 2021; Grover & Pea, 2013). The next classroom study will involve 2–4 classes to test the hybrid version's usability, clarity of narrative elements, and pedagogical effectiveness. Insights from this phase will inform the next design iteration. Finally, a future research phase (phase 3) will explore how unplugged learning with the game facilitates the transition to visual programming environments such as Scratch. A comparative study will evaluate the learning gains of students with and without prior unplugged experience.

6. Conclusion

IMPACT demonstrates how unplugged, game-based learning can effectively introduce core programming concepts at an early stage, addressing a critical gap in primary education. By combining structured gameplay with progressive challenges, the board game fosters computational thinking and supports cognitive readiness for later programming instruction. The strong engagement observed during the classroom pilot, along with positive teacher feedback, confirms the game's relevance and age-appropriateness. With its low-threshold, scalable design and upcoming hybrid extension, IMPACT contributes not only to more equitable access to informatics education but also to current research on early computing and educational game design. Future work will build on these results through systematic evaluation, iterative development, and empirical studies on learning transfer.

Ethics Declaration: All participation was voluntary and conducted with parental consent.

AI Declaration: This paper is based on a previously written German-language interim report from the IMPACT+ project. AI tools (specifically DeepL and ChatGPT) were used to support the translation and linguistic refinement of the English version. All content, structure, and academic arguments were developed by the authors.

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Meta-Analyzing Experiential Game-Based Learning in Entrepreneurship Education

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Abstract: This paper presents a meta-analysis grounded on a previously conducted systematic literature review on game-based learning (GBL) in Entrepreneurship Education (EE), with a particular focus on comparing the design principles, pedagogical value, and learning outcomes of experiential versus non-experiential game-like methodologies. While existing literature provides rich taxonomies of GBL tools and learning intentions, there is a gap in understanding how differing instructional approaches shape entrepreneurial competence development—particularly in terms of depth, engagement, and transferability of knowledge and skills. Experiential GBL approaches — such as role-playing scenarios, makerspace projects, entrepreneurial challenges, and serious games — immerse learners in problem-centered, often collaborative environments that mirror real-life entrepreneurial dynamics. These formats emphasize learning through doing, reflection, and iteration, and are deeply rooted in constructivist and transformative learning theories. In contrast, non-experiential approaches — such as gamified quizzes, flashcards, point systems, and digital badges — aim to increase engagement and motivation through extrinsic rewards, but often limit the learner's active agency and emotional investment in the process. Our analysis indicates that experiential methodologies consistently show stronger results in fostering higher-order entrepreneurial competencies, such as creativity, opportunity recognition, resilience, and decision-making under uncertainty. These formats promote not only cognitive learning but also personal growth, self-efficacy, and teamwork. However, their implementation requires greater time, instructor preparation, and contextual adaptability. Non-experiential formats offer scalability, consistency, and ease of assessment, making them suitable for foundational knowledge acquisition or large-scale learning environments, yet may lack the depth needed for transformational outcomes. The paper concludes with implications for course and curriculum design in higher education, drawing on an applied example from a university-level entrepreneurship course that embodies experiential GBL principles. This serves as a case study for translating meta-analytic insights into actionable educational practice and provides a roadmap for educators and institutions seeking to enhance EE through game-based strategies tailored to their specific goals and constraints.

Keywords: Entrepreneurship education, Game-Based learning, Experiential learning, EntreComp, Transversal competences

1. Introduction

In today's volatile, complex, and knowledge-driven global economy, entrepreneurship is widely regarded as a key driver of innovation, competitiveness, and societal transformation. While its precise definition remains debated (Hessels & Naudé, 2019), most perspectives agree that entrepreneurship involves recognizing and acting on opportunities to create economic, social, or cultural value. The European Commission's EntreComp framework translates this concept into a structured model of entrepreneurial competence, offering a practical guide for educators and policymakers (Bacigalupo et al., 2016). Consequently, Entrepreneurship Education (EE) has gained momentum in higher education—not just to promote startups, but also to equip graduates with transversal competences for thriving in diverse careers (Hynes & Richardson, 2007; Boldureanu et al., 2020).

Despite this growing emphasis, higher education often struggles to effectively develop entrepreneurial competence. Traditional lecture-based methods frequently fall short in fostering the integrated skillset—such as opportunity recognition, creativity, and teamwork—required for entrepreneurial action. In response, experiential and game-based approaches to EE have gained traction (Neck & Corbett, 2018; Haneberg et al., 2022). Among these, game-based learning (GBL) stands out for its ability to engage cognitive, emotional, and behavioral aspects of learning through interactive experiences.

A recent systematic literature review (Casau et al., 2023) synthesizes research at the intersection of GBL and EE, identifying several effective pedagogical strategies—such as simulations, serious games, and collaborative projects—that enhance learners' motivation, entrepreneurial attitudes, and problem-solving skills. Yet, it also

highlights persistent challenges, including inconsistent competence alignment with frameworks like EntreComp, and issues of cost, scalability, and access. Building on these findings, this paper explores how the Game It Away! International Entrepreneurship Training Programme (ETP) applies GBL to operationalize EntreComp in higher education. The programme incorporates hands-on game design, collaborative ideation, and makerspace environments to engage students while developing key competences. It goes further by mapping learning activities to EntreComp's three dimensions—Ideas and Opportunities, Resources, and Into Action—ensuring a structured, scaffolded approach to entrepreneurial learning.

The programme's use of hands-on game design, collaborative ideation, and makerspace environments mirrors many of the high-impact practices identified in the literature. However, *Game It Away!* extends these practices by mapping specific learning activities to the EntreComp dimensions—*Ideas and Opportunities*, *Resources*, and *Into Action*—in a deliberate effort to scaffold competence development. This integration supports the cultivation of transversal skills such as creative thinking, initiative-taking, ethical reasoning, and teamwork, thereby addressing the interdependent nature of entrepreneurial competences.

The paper is organized as follows: Section 2 reviews key insights from the literature; Section 3 outlines the Game It Away! programme; Section 4 examines its alignment with EntreComp. The conclusion discusses implications for curriculum design, scalability, and future research in EE.

2. Game-Based Learning in Entrepreneurship Education Framework

Recent studies highlight the shift in higher education toward active methodologies, particularly in EE, where students become active learners. Lee and Yu (2025) advocate for Game-Based Learning (GBL) in business education, integrating flow theory and intrinsic motivation to foster complex skills through immersive, engaging simulations, outperforming extrinsic reward-based gamification. Scroccaro, Engzell, & Norrman (2025) compared cases in Italy and Sweden, emphasizing coaching, constructive feedback, formative assessment, the Entrepreneurship Competences model, and tailored assessment tools for individual and team skills.

A study by León et al. (2025) shows that GBL, via structured board games, enhances communication and socialization of children with ASD in regular classrooms, promoting inclusive collaboration through clear, consistent game structures.

2.1 Summary of Previous Systematic Review: The 7 Categories

A systematic literature review (Casau et al., 2023) identified seven key categories through which gamification and GBL have been applied to EE. These reflect diverse approaches aligned with varying learning goals and skill development needs:

1. *Simulation-based environments* place students in realistic business scenarios, fostering strategic thinking and risk management through decision-making and problem-solving.
2. *Digital serious games* are designed for educational use, embedding entrepreneurship challenges in interactive formats to support practical, engaging learning.
3. *Role-play and narrative driven formats* involve students in story-driven business scenarios, helping them build social and emotional competences such as communication, empathy, and teamwork.
4. *Competitive game mechanics* like leaderboards and point systems boost motivation, though they may not always lead to deep learning.
5. *Makerspace and design thinking challenges* engage students in solving real problems through prototype creation and idea development, promoting creativity and innovation.
6. *Point-and-badge systems* track progress and encourage participation via rewards, commonly used in online or large-scale learning contexts.
7. *Blended models* combine multiple approaches, offering flexible, comprehensive learning experiences.

Together, these categories form a useful framework for analyzing GBL in EE and highlight critical questions about engagement and educational impact.

2.2 Meta-Analysis of Implementation Methods

Following the identification of the 7 main categories, this meta-analysis examines how they are implemented—focusing on common game mechanics, interaction types, and levels of experiential engagement.

Experiential methods like simulations, role-play, and makerspace challenges tend to use immersive mechanics—like complex problem-solving, storytelling, and feedback loops—that promote active participation and critical

reflection. These approaches help develop transversal skills like creativity, empathy, and strategic thinking by placing learners in realistic, decision-making scenarios.

In contrast, simpler models like point/badge systems or gamified quizzes rely on extrinsic motivators—scoring, levels, visual rewards—that capture attention but often lack depth. As noted by Deterding et al. (2011), these mechanics typically drive short-term behavior rather than transformative learning.

Interaction styles also vary. Collaborative formats, common in simulations and design thinking activities, foster interpersonal skills and collective knowledge-building. Individual approaches, often found in digital games or quizzes, provide less opportunity for social learning.

Delivery format also matters. Digital tools offer scalability and flexibility, while face-to-face formats—like board games or classroom role-play—deepen emotional and social engagement. Hybrid models combine both benefits.

In sum, while GBL is widely used, its effectiveness depends on aligning mechanics with sound pedagogy. Simpler, more scalable models remain common but often lack the depth needed to cultivate complex entrepreneurial competences.

2.3 Analysis of Experiential vs. Non-Experiential Nature

Tran (2024) conducted a systematic review on GBL, focusing on hotel management, including an empirical study with students at FPT University Danang. It contributes by grounding GBL on experiential learning theory, proposing a conceptual model for future research, and introducing a curriculum that progressively integrates experiential methods. It emphasizes the importance of linking theory to practice, enhancing engagement and teaching effectiveness.

A study at the Lebanese International University implemented GBL in the Pharmacy Practice Experience curriculum, addressing limited data on its role in pharmacy education. Conducted in July-September 2021, the study found that students exposed to GBL scored significantly higher on exams (MD=7.152; $p<0.001$). A validated motivation scale (ALMAS) also showed a strong correlation between motivation for GBL and academic performance, highlighting motivation as a key factor in learning outcomes (Dabbous et al, 2022).

Martina and Göksen (2022) explored educational escape rooms (EERs) as non-digital GBL tools. Though common in STEM and health education, EERs are underused in EE. Their study identifies 11 validated design elements for integrating EERs into experiential entrepreneurship programs.

The distinction between experiential and non-experiential GBL is based on the degree of immersion and practical applicability. Experiential GBL involves students in realistic and challenging contexts, promoting skills through action and reflection. Non-experiential GBL is limited to more superficial recreational activities, with less impact on meaningful learning. The literature shows that the experiential nature of CLB is decisive in increasing motivation, engagement, and pedagogical effectiveness.

2.4 Critical Discussion and Identification of the Gap

This analysis highlights the limitations of traditional teaching methods in EE, which often rely on passive content delivery and summative assessment. By emphasizing memorization and theoretical knowledge, these approaches overlook key entrepreneurial competences such as strategic thinking, creativity, decision-making under uncertainty, and teamwork (EntreComp).

In contrast, the reviewed studies demonstrate the benefits of GBL, particularly when applied experientially. These methods enhance intrinsic motivation, emotional and cognitive engagement, and knowledge retention—especially when students are actively solving real problems, taking on roles, and collaborating, as in simulations, serious games, or design thinking activities.

Despite this, traditional models remain widespread, even though they fail to support the transformative learning needed in EE. This gap has fueled interest in hybrid approaches that combine experiential learning with the motivational game dynamics, offering more immersive and effective pedagogical formats. The *Game It Away!* project arises from the need to update teaching methods through entrepreneurial skills such as communication, teamwork and creativity, among others. It aims to raise awareness and teach both teachers and students about teaching entrepreneurial skills through games, promoting GBL in EE.

3. The Game It Away! Approach

Transversal competences like creativity, collaboration, and resilience are increasingly seen as essential outcomes of formal education. However, a gap persists between abstract frameworks and their practical implementation. While models such as EntreComp provide structured pathways for competence development, translating them into measurable, student-centered learning experiences remains a challenge.

The Game It Away! ETP addresses this gap by integrating experiential, game-based learning into educational practice. Grounded in the EntreComp framework, the programme uses it not just conceptually but as a practical scaffold for developing entrepreneurial skills, knowledge, and mindset. By combining theory with hands-on engagement, the ETP enables learners to embody entrepreneurial values and processes in meaningful, immersive ways. The following sections detail the programme's pedagogical foundations, structure, and learning environments.

Game it Away! - Entrepreneurship Education through Game Design & Maker-Centred Learning" is a project funded through the Erasmus+ programme of the European Union (Proj. No 2022-1-PT01-KA220-HED-000087026). Its main goal was to design an Entrepreurship Education Programme for higher education students, regardless of their cognitive and disciplinary background. It is founded on EntreComp and focuses on the cultivation of the corresponding competences.

3.1 The EntreComp Framework

Over the past decades, the entrepreneurship concept has evolved from a focus on innate traits—e.g. risk-taking and leadership—to a more inclusive view of entrepreneurship as a set of competences that can be learned and developed. This shift reframes entrepreneurship as a dynamic combination of knowledge, skills, and attitudes, accessible to a broader population through education and experience (Chouhan & Srivastava, 2014).

This reconceptualization has major implications for education policy and practice. As entrepreneurial learning is increasingly integrated into educational systems of all levels, one persistent challenge has been the lack of coherence across the existing frameworks. Without a common understanding of what entrepreneurial competence entails, efforts to assess or compare learning outcomes are often fragmented and inconsistent.

To address this, the European Commission introduced the EntreComp (Entrepreneurship Competence Framework) in 2016 (Bacigalupo et al., 2016). EntreComp provides a comprehensive model for developing and assessing entrepreneurial competence across formal, non-formal, and informal learning contexts. It supports educators, policymakers, employers, and learners by offering a shared language and flexible structure applicable to diverse educational and occupational settings.

At its core, EntreComp defines entrepreneurship as the ability to turn ideas and opportunities into value for others (economic, social, or cultural). The framework is organized into three interconnected competence areas:

- Ideas and Opportunities – including creativity, vision, and opportunity recognition
- Resources – encompassing self-awareness, motivation, and resource management
- Into Action – involving planning, initiative, teamwork, and implementation

Each area comprises five competences, totaling 15, with eight proficiency levels that describe progression from novice to expert. A user guide and adaptable learning outcomes accompany the framework, aiding in curriculum design and assessment.

Importantly, EntreComp promotes entrepreneurship as a transversal competence, relevant not only to business but also to civic engagement, social innovation, and personal development. It aligns with broader EU goals related to lifelong learning, innovation, and sustainability, and is compatible with other frameworks like DigComp and LifeComp (European Commission, 2018).

In sum, EntreComp offers a powerful, flexible tool to support entrepreneurial learning and mindset development, helping individuals take initiative and create value in an increasingly complex world.

3.2 Embedding Game-Based Learning in Entrepreneurship Education: The "Game It Away!" Approach

Transversal competences like creativity, collaboration, and resilience are increasingly seen as essential educational outcomes. However, a gap persists between abstract competence frameworks and their practical application. While frameworks such as EntreComp provide structured pathways, translating them into actionable, student-centered learning remains a challenge.

The *Game It Away!* ETP addresses this by integrating experiential, GBL into education. It uses EntreComp not just as a reference but as a scaffold for building practical skills, knowledge, and an entrepreneurial mindset.

By combining theory with immersive, hands-on experiences, the ETP helps learners internalize entrepreneurial values and processes. The following sections detail its pedagogical foundations, learning structure, and enabling environments.

3.3 Game Design as a Pedagogical Vehicle for Entrepreneurship

Game It Away! emphasizes learning-by-doing by using game design as both content and method in EE. This approach engages students in authentic tasks that simulate real entrepreneurial activities.

The programme views game design—through analog board games or escape rooms—as a way to foster entrepreneurial behavior by mirroring real innovation processes. It encourages learners to spot opportunities, create solutions, manage uncertainty, and iteratively develop ideas within a safe educational setting (Gatti Jr. & Kim, 2019; Fergusson, 2022). Students actively collaborate, make decisions, and solve problems, embodying key entrepreneurial competences (Daniel et al., 2024).

This experiential format promotes not only cognitive understanding but also emotional engagement and behavioral change. Aligned with EntreComp, it helps learners build initiative, teamwork, resilience, and resource management through hands-on, immersive experience (Yang et al., 2022).

3.4 Programme Design and Learning Trajectory

The "Game It Away!" programme is structured into six modular units, each corresponding to a particular stage in the entrepreneurial journey. This scaffolded design ensures that students progressively build competences in a coherent and integrated manner (Bratitsis et al., 2025). The six modules include:

- *Module I: Let's Game It!* . Introduces core principles of game design and entrepreneurial thinking, contextualized within the EntreComp framework (3 hours).
- *Module II: GameCraft – Elevate, Collaborate, Aim for Great!* . Focuses on collaborative creativity through brainstorming and user-centered design exercises (3 hours).
- *Module III: ProtoPlay – Master Prototypes, Budget Grooves, Creative Moves!* . Encourages the creation of game prototypes, highlighting resource management and sustainability through iterative practices (6 hours).
- *Module IV: TestCraft – Level Up Your Game, Learn, and Earn!* . Emphasizes testing, feedback collection, and redesign, promoting adaptability and resilience (3 hours).
- *Module V: PitchCraft – Rock the Show, Steal the Glow!* . Develops communication and presentation skills through persuasive pitching strategies (4 hours).
- *Module VI: Public Presentation and Reflection* . Culminates in a public event where students present their final game products, fostering leadership, reflection, and engagement with real-world audiences (3 hours).

This modular progression mirrors the lifecycle of an entrepreneurial project—from the identification of an opportunity through inspiration, the ideation and development to testing and market presentation. Each phase builds upon the previous, reinforcing knowledge and enabling iterative skill development. The programme thereby creates a flexible, yet logically sequenced, learning environment that enables deep engagement and authentic competence acquisition.

3.5 Makerspaces as Catalysts for Experiential and Entrepreneurial Learning

A key feature *Game It Away!* is the use of makerspaces —open, flexible environments equipped with tools and materials that foster creative, collaborative work. These spaces reflect constructivist and experiential learning principles, offering students hands-on access to rapid prototyping resources, experimentation, and teamwork.

Makerspaces embody the openness, tolerance for failure, and innovation typical of entrepreneurial ecosystems (Hui & Gerber, 2017), allowing students to learn by doing, failing, and iterating. They serve multiple educational roles by encouraging creativity and adaptation, enhancing collaboration through team problem-solving, supporting iterative feedback and redesign, and connecting theory with real-world practice.

Within this context, the makerspace serves multiple educational functions (Li et al., 2022; Soomro et al., 2023). It fosters creativity and innovation by encouraging divergent thinking and experimentation, but also adaptation to the available material. It enhances collaboration and communication through team-based problem-solving

and design/construction. It supports iterative learning, promoting feedback cycles and reflective redesign. It bridges theoretical frameworks and lived experience, enabling learners to enact the EntreComp competences in real-world-like contexts. Thus, the makerspace is more than just a backdrop for learning; it is an active driver of competence development. The convergence of experiential spaces, GBL, and structured frameworks such as EntreComp positions *Game It Away!* as a forward-thinking and impactful model for EE in higher education.

3.6 Aligning Game It Away! with EntreComp: A Framework for Transversal Competence Development

The *Game It Away!* ETP was designed as a dynamic interface between structured competence frameworks and experiential, learner-centered pedagogies. Central to this design is EntreComp, offering a holistic model for entrepreneurial competence development. By embedding EntreComp's dimensions into each stage of the ETP, the programme transforms abstract descriptors into tangible experiences that foster transversal competences across cognitive, social, and behavioral domains.

Early in the design process, EntreComp competences were mapped to phases of the Design Thinking approach, reflecting the lifecycle of real-world product development. This guided the creation of the ETP modules (section 3.4), ensuring that learning activities scaffold competence develop,ent through engagement, reflection, and iteration.

Initial modules—*Let's Game It!*, *GameCraft*—let students explore entrepreneurial thinking through collaborative game ideation. They correspond to *Ideas and Opportunities*, fostering competences like *creativity*, *spotting opportunities*, *valuing ideas*, and *vision*. Structured brainstorming and imaginative scenario-building allow learners develop divergent thinking and opportunity recognition skills, essential for entrepreneurship and innovation in any context.

Middle modules —*ProtoPlay, TestCraft*— deeply engage learners with *Resources*, as they work with limited materials/tools within makerspaces, manage time constraints, and engage in design and feedback loops. This fosters competences like *mobilizing resources*, *financial and material literacy*, and *self-awareness and self-efficacy*. Physical prototyping as learning strategy enhances understanding sustainability, constraint-based problem-solving, and resilience—key aspects of entrepreneurial learning.

Final stages—*PitchCraft*, *Public Presentation and Reflection*—map *Into Action*, focusing on strategic communication skills, persuasive narratives crafting, and engagement with audiences through pitching. They promote competences like *taking initiative*, *working with others*, and *learning through experience*, facilitating agency and critical reflection on both process and outcomes.

This progression mirrors the entrepreneurial learning journey—from guided ideation to independent, real-world action—promoting deep learning and competence transfer across life domains.

The programme also supports advancement across EntreComp proficiency levels—*Foundation*, *Intermediate*, *Advanced*—by increasing task complexity, learner autonomy, and stakeholder interaction. For instance, while initial tasks are scaffolded/supported by facilitators, later stages require independent planning, critical evaluation, and confident public presentation, reflecting learners' growing capacity to act entrepreneurially in uncertain/dynamic environments.

Crucially, this alignment enables the development of a broad set of transversal competences that extend beyond EE. These include:

- Creativity and Innovation: through open-ended design challenges and storytelling within game environments.
- Collaboration and Communication: via peer co-design processes, iterative team feedback, and audience engagement during pitches.
- Resilience and Adaptability: cultivated through trial-and-error prototyping cycles, encouraging learners to embrace failure as a learning opportunity.
- Critical Thinking and Ethical Judgement: embedded in the process of designing meaningful, inclusive, and socially aware game narratives.
- Strategic Thinking and Leadership: as learners plan, organize, and present their concepts, assuming roles of responsibility within their teams.

The physical and conceptual use of makerspaces as pedagogical environments amplifies the impact of the programme. These spaces provide the material conditions and collaborative culture necessary for hands-on, constructivist learning that is essential to the development of entrepreneurial mindset and transversal

competence (Hui & Gerber, 2017; Soomro et al., 2023). In this way, *Game It Away!* moves beyond the limitations of abstract instruction, offering a fully embodied learning experience that resonates with both the EntreComp framework and contemporary educational theory.

In sum, *Game It Away!* ETP exemplifies how structured frameworks like EntreComp can be effectively implemented through innovative pedagogical models that prioritize learner agency, creativity, and social engagement. By aligning each phase of the programme with specific EntreComp competences and progression levels, it ensures that transversal competences are not only addressed in theory but developed in practice—empowering learners to thrive as adaptive, responsible, and proactive citizens in an increasingly complex world.

4. Discussion

This paper reaffirms that experiential GBL represents a powerful pedagogical paradigm for the development of transversal competences within EE. By immersing learners in realistic, interactive, and often collaborative environments, experiential approaches—such as game design, role-playing, and makerspace projects—not only transmit entrepreneurial knowledge but also foster critical soft skills like creativity, resilience, collaboration, and strategic decision-making. These skills are increasingly valued across professional domains, underscoring the importance of embedding transversal competence development in higher education.

Contrasted with non-experiential, reward-based gamification models, experiential GBL emphasizes agency, reflection, and iteration—core principles of transformative learning. As illustrated in *Game It Away!*, such methods enable learners to enact entrepreneurial behaviors and mindsets in authentic contexts, closely aligned with the EntreComp framework. The deliberate scaffolding of competences, from ideation to public presentation, ensures a structured yet flexible learning trajectory that encourages deep engagement and meaningful learning outcomes.

In summation, the paper advocates for a shift in educational practice—from traditional, passive models toward active, experience-rich methodologies. Experiential GBL not only addresses the limitations of conventional instruction but also offers a vision for future-ready education. By integrating game-based strategies with robust competence frameworks, educators can cultivate learners who are not only knowledgeable, but also adaptive, innovative, and ethically grounded—capable of navigating the complexities of the 21st century with confidence and creativity, as described via the structured competence frameworks, evident in the literature.

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The Quest for Learning: Pedagogical and Interaction Design Perspectives on Quest Rooms

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Abstract: Educational Escape rooms (EERs) foster learning engagement, but have been criticized for promoting extrinsic motivation and shallow learning by overemphasizing game elements. To address this, it is essential to better align game mechanics with desired learning outcomes and consider the relationship between EER interaction design and pedagogical theories. This work combines educational and interaction design methods to improve escape rooms as a pedagogical format. We introduce an escape room design approach here named *the quest room,* adapted for informal learning at museums. Using a Research-through-Design methodology, we present three digiphysical quest rooms developed and implemented at museums. Further, we propose an edu-interaction framework that combines five lenses of analysis: playification, embodied aspects, sociality, game mechanics, and interactive storytelling, to analyse the quest room exemplars. The study offers insights for designing and evaluating future EERs.

Keywords: Educational escape rooms, Playification, Embodied learning, Interactive storytelling, Research through design

1. Introduction

Currently, there is a lack of knowledge on how educational escape rooms (EERs) can be systematically designed to support deep and meaningful learning, especially in informal settings such as museums. While EERs are increasingly used to foster engagement, collaboration, and creativity, their design often emphasizes gameistic elements —such as time pressure and competition— that may undermine educational goals. While there is an abundance of research on EERs, gamification, and game-based learning (e.g., Clarke et al., 2017; Plass et al., 2020; Arnab et al., 2015), they do not focus on how to align EER design with educational and interaction design theories to ensure that game mechanics support rather than distract from learning. This lack of integration has been highlighted in literature reviews on EERs, for instance by Vorderobermeier et al. (2024), Veldkamp et al. (2020), and Nicholson (2018), who emphasize the need for more theoretically grounded and pedagogically aligned design approaches.

This research aims to explore a new approach to educational escape rooms that better supports learning, particularly in informal learning settings such as museums. We approach this aim by asking how educational and interaction design principles can be integrated to create quest rooms that support informal learning in museums. We approach this aim by asking how educational and interaction design principles can be integrated to create quest rooms that support informal learning in museums?

The study follows a Research through Design approach, presenting three iterations of the Quest Room, a type of EER designs adapted for museal settings. An edu-interaction design framework is presented and utilized to analyse the designs.

2. Educational Escape Rooms

Escape rooms, initially developed as a leisure activity, are widely used in formal and informal education (Veldkamp et al., 2020; Vorderobermeier et al., 2024), including museums (Karageorgiou et al., 2021). EERs enhance collaborative and creative engagement, but elements such as time pressure and competition can distract from learning aspects (Fotaris and Mastoras, 2019; Warmelink et al., 2017), making the EERs too gamistic (Veldkamp et al., 2020; Vorderobermeier et al., 2024). While frameworks for analysing EERs exist, such as the Eduscape framework (Clarke et al., 2017), they offer a practical tool for designing EERs rather than theoretical analysis.

2.1 Educational Escape Rooms at Museums

EERs are used in multiple ways in museums (Karageorgiou et al., 2021), and is increasingly popular to implement. Desired outcomes in EERs at museums include authenticity, emotions, and immersion. (Nowacki and Stasiak, 2025; Pakhalov and Rozhkova, 2020). Design approaches vary from digital (Tzima et al., 2020) or VR (Valera Jr. et al., 2024) to built-up immersive ERs (Pakhalov and Rozhkova, 2020). Such as *Escape Extinction* at the Swedish

Museum of Natural History (Naturhistoriska riksmuseet, no date) and escape room projects at the Rijksmuseum in Amsterdam. Most museum EERs require active facilitators from the museum, even though this is resource-intensive and challenging (Richardson, 2024), but they can be designed as interactive exhibitions that operate without facilitators (Back et al., 2019).

2.2 Educational Theories for Escape Rooms

Positive learning outcomes from hands-on activities, learning by doing (Dewey, 1916), experiential learning (Kolb, 2014), and active learning (Bonwell and Eison, 1991) are well known in education theory. Numerous studies show that active, collaborative, and problem-based activities improve learning outcomes (Freeman et al., 2014; Prince, 2004), and EERs are a clear example of such an activity. Dale's cone of experience categorizes activities that enhance memory and long-term learning (Dale, 1946; Jackson, 2016), and EERs can be placed high on that scale.

EERs can foster collaborative learning (Vidergor, 2021), where students work together to solve problems. This aligns with Vygotsky's theory of development which emphasizes the importance of social interactions and scaffolding in learning (Doolittle, 1997; Vygotsky, 1962).

Challenge-based learning addresses real-world problems collaboratively. One such approach is Quest-based learning (Snelson, 2022), which provides students with different quests that offer a progression based on their current skills. This ties into the proximal zone of development (Doolittle, 1997; Vygotsky, 1962).

Embodied cognition holds that thinking and learning are grounded in the body's sensorimotor systems and environmental interactions (Varela et al., 1991; Shapiro, 2011). Embodied interaction enhances learning (Glenberg, 1997; Macedonia, 2019). This perspective is relevant when designing physical or digiphysical EERs where manipulating physical artifacts and spaces supports engagement and memory. And such EERs can offer multimodal, tangible, and sensory experiences (Bakk, 2024), tying into theories on deep multimodal learning (Ramachandram and Taylor, 2017), and research showing that bodily engagement enhances learning (Macedonia, 2019; Barsalou, 2008; Glenberg, 1997).

EERs can be seen as a form of game-based learning (Plass et al., 2020) and the concept of serious games (Arnab et al., 2015). Games has many strengths, but can trigger extrinsic motivation (Andrade et al., 2016; Mekler et al., 2017) and can be related to educational theories on shallow learning (Entwistle, 1983). In EERs, this is reinforced by time pressure and the escape narrative. A literature review from 2020 suggests that EER design should focus more on creating a relation between the game mechanics and the educational goals, to be an efficient tool in teaching (Veldkamp et al., 2020).

EER can be seen as a playful activity, related to playful learning approaches (Whitton, 2018; Veldkamp et al., 2021). Play enhances the brain's plasticity (Himmler, 2011), and within neurocognitive educational research, the effects of playfulness on the brain have received increasing interest (Siviy, 2016).

EER storytelling aligns with story-based learning (Diermyer et al., 2009), with stories creating meaningful learning situations (Diermyer et al., 2009). Interactive storytelling can promote cultural heritage awareness (Alinam et al., 2021), enhancing learning through storytelling and immersion (Bormann and Greitemeyer, 2015; Lordly, 2007).

2.3 Interaction Design for Escape Rooms

Embodied interaction (Dourish, 2004) becomes relevant in relation to physical escape rooms. Physical Hybrid installations allow engagement materials for rich experiences (Bannon et al., 2005), providing tangible interaction. Real-life EERs can be designed for multimodal and embodied experiences. EERs are multiuser, collaborative, and can be designed to enhance communication and sociality (Pan et al., 2017).

Interactive storytelling in design can create engaging experiences (Greene, 1996), for instance, in cultural heritage-related EERs (Paananen et al., 2024). Non-linear formats, such as in games, differ from linear storytelling (Zagalo, 2020), breaking up the narrative through player agency (Adams, 2013; Paulsen, 2021). Transmedial (Jenkins, 2012; Paulsen, 2021) and multimodal storytelling (Alinam et al., 2021) can also be incorporated in EER design.

EERs have game and play elements. Games and play are inherently different, even oppositional (Caillois, 1961). Play is characterized by more freedom and exploration, while games are more confined by rules, focusing on contests between powers (Salen and Zimmerman, 2003; Sutton-Smith, 1966). Designing for play gives a big design palette, as rule-based play, such as games, is just one play type in Hughes' taxonomy, that also includes

role play, explorative play and object play, among others (Hughes, 2006). The concept of ludic design has been implemented within an interaction design context, relating to playfulness rather than gameism (Christina, 2021; Gaver et al., 2004). EERs can draw on playfulness through role play and storytelling, to enhance learning (Veldkamp et al., 2021).

Gamification (Deterding et al. 2011) is effective to create engagement but risks promoting shallow reward-driven behaviours (Andrade et al., 2016). To mitigate the problems with gamification, playification has been proposed as an alternative approach (Carbone et al., 2021; van Turnhout, 2012; Márquez Segura et al., 2016), leveraging on playful behaviour such as curiosity, sociality, storytelling, and exploration (Davis, 2018). Playification can be utilized in museums to enhance cultural heritage awareness and for engaging hybrid play installation design (Back et al., 2023; Márquez Segura et al., 2016).

Game mechanics are the core rules and systems that define how a game is played. Broadly, it can be seen as the behaviors within a game that a game promotes (Salen and Zimmerman, 2003). Game mechanics can be designed to promote learning (Arnab et al, 2015). Escape rooms often in a problematic way utilize game mechanics superficial to the learning concepts (Nicholson, 2018).

3. Method

This study follows a Research through Design (RtD) approach where researchers generate knowledge by designing (Zimmerman et al., 2007). This study emphasizes designing and analysing conceptually rich artifacts rather than user studies (Pierce, 2014). The analysis draws inspiration from artifact analysis (Trausan-Matu and Slotta, 2021), with a design artifact analysis through educational and interaction design concepts and theories. The study uses annotated portfolios (Gaver and Bowers, 2012) to create intermediate-level knowledge (Höök and Löwgren, 2012). Thematic analysis is utilised for the analysis. The Interaction Design approaches were mainly pre-formulated, informing the design process based on previous research. The educational theories are identified retrospectively, building on the RtD concepts of emergence (Gaver et al., 2022) and reframing (Zimmerman et al., 2022). All three quest rooms are designed by the authors in close collaboration with museum design teams over several years.

4. Shared Design Traits of the Quest Rooms

The quest rooms are adapted to the museum informal learning context. They are digiphysical installations (Fiedler and Skorin-Kapov, 2025; Pysander et al., 2020), building on a hidden technology approach, non-intrusive to the physical experience of the room.

The format differs from ordinary escape rooms in that several groups can partake in the experience asynchronously and independently of each other. No time pressure is included; a slow and thorough exploration is encouraged. Instead of escape, users unravel mysteries, with non-linear quests tied together in an overarching narrative. The quest rooms are built to be self-instructive without facilitators. The main technology enhancement is a central panel (Figure 1), with quests mapped to buttons in the central panel. The buttons have ludic markers, with corresponding markers found around the room. When solving a quest, the user returns to the central panel, pushes the ludic symbol, and the answer button or code, getting light and sound feedback.

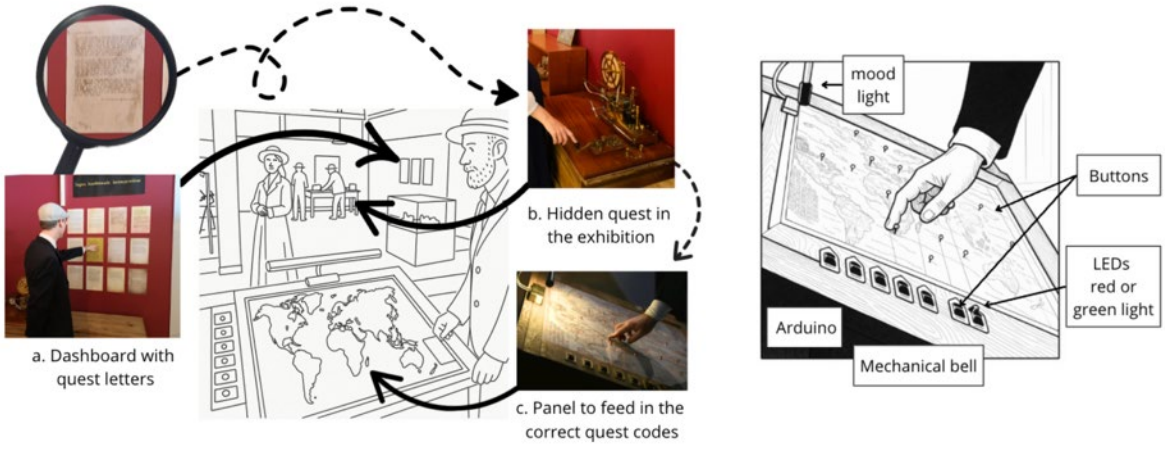

Figure 1: Annotation of quest room general design structure

Each quest contains its own game mechanics and knowledge content; they are free-standing and can be solved in any order. The quests can be modified and replaced without changing the functionality of the central panel, enabling the quest room to be remade with new designs over time.

5. Design Exemplars

5.1 Iteration 1: The Adventures of Ingrid Johansson

This design, shown in Figure 2, was developed in collaboration with the Swedish National Museum of Science and Technology and an artist group. The exhibition was presented in a non-public room, open only to invited groups.

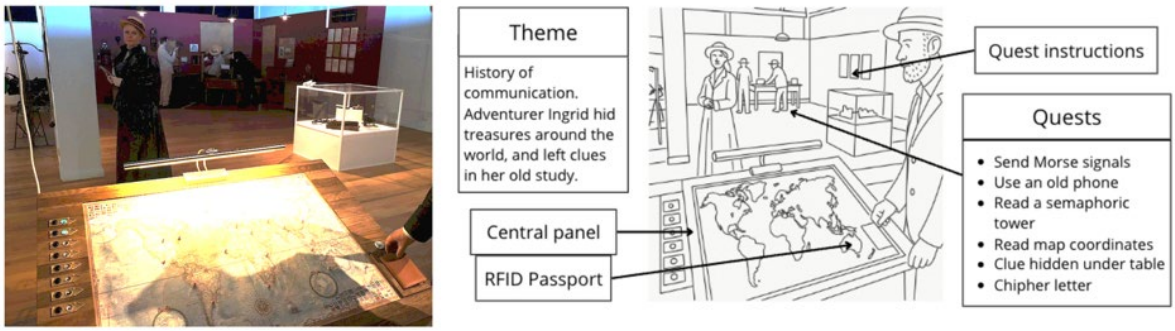

Figure 2: Overview of layout for the Adventures of Ingrid Johansson

It contained eight quests. As grandchildren of (fictitious) explorer Ingrid Johansson, players solved quest puzzles throughout the exhibition. Each visitor got a specially designed passport, containing an RFID chip. The quest was consolidated by placing the passport on a central panel, then pushing the corresponding quest symbol and the correct city on the world map. Progress was saved on the panel through the passport. Solving all quests resulted in the light blinking and the bell ringing, signalling that the quest room was completed.

The room was tested twice in 2019, with a total of around 30 invited participants. Combining observations, group interviews, and a survey, we found that most participants enjoyed the experience, especially the collaborative nature and aesthetics of the room. Most stayed for at least 30 minutes to an hour. The engagement of the participants and the desire to solve quests were strong in most groups.

The integration of puzzle solving in a sensation-rich environment that integrated museum objects, interactive exhibitions, and fictional and factual narratives created an interesting effect where users could interact in a range of ways. Problem-solving behavior emerges as the dominant form of engagement, but it did not come at the expense of more general exploration or learning dialogue.

Most participants reported gaining new knowledge, including a deeper understanding of technology and detailed information, such as how longitudes and latitudes on maps function. Participants skimmed text signs for clues, rather than deep reading. Quests involving physical actions, such as sending Morse code or using a map, seemed to spark the most learning conversations.

5.2 Iteration 2: The Quest - Subject Hello!

Based on the first iteration, this quest room is a part of a permanent museum exhibition. Due to COVID, tangible elements had to be removed, and the central panel was designed as an app. For an actual exhibition, the museum personnel did not want to include a fictional character explicitly, so while keeping the theme from iteration 1, it was toned down. The narrative centred on solving five quests to open a locked chest (Figure 3).

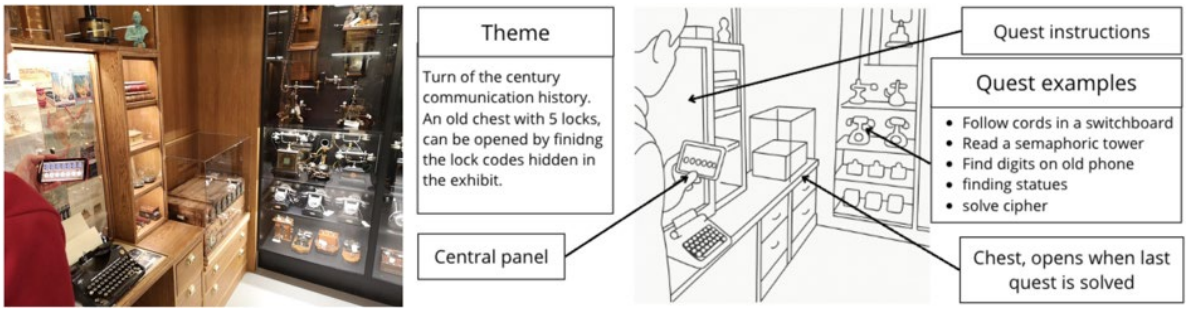

Figure 3: Interaction design overview of quest room iteration 2

The quest room was tested through in-the-wild observations after inaguration, app data, and a partcipant thick description of the user experience. This exhibition struggles with onboarding issues, but those who start playing show engagement, there are few app users per day (10-20), but those solving many quests. Observations showed that many did not initiate the game, but those who solved one or two quests got hooked; "I went back to the board, now determined, I want to solve the others now. I was now really engaged to the game." . The presence of other groups seem to work as an inspiration "The others in the room also really helped. They provided a slight hint, when I overheard their discussions, or saw the spots they were looking or sitting. It also helped to see them struggling, feeling not alone in my struggle."

5.3 Iteration 3: The Archive Quest

This quest room (Figure 4) was developed as part of the newely developed Uppsala Castle Museum. The narrative builds on Ingeborg, an authentic castle archivist who retired in 1978. Storywise, she left behind a messy desk of unsolved historical riddles connected to historical figures, and the players act as investigators. Each quest represents one method for getting knowledge of the past.

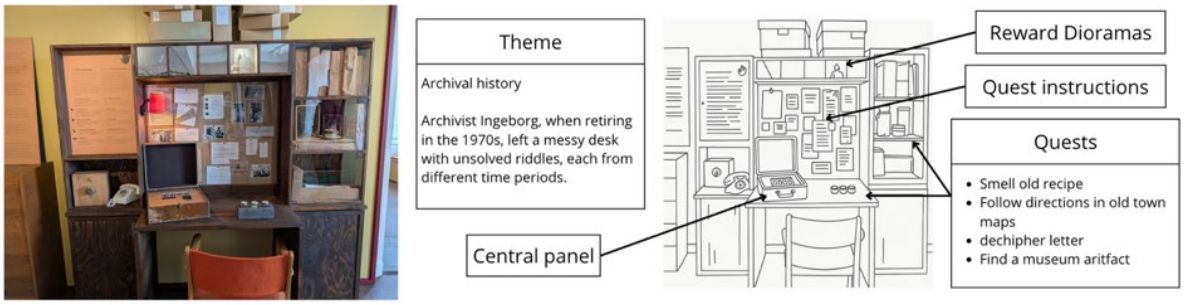

Figure 4: Overview of the layout for The Archive Quest

A master thesis project by Nandakumar (2025), on visitor engagement, included testing the quest room with invited groups. The data was analysed using self-determination theory, showcasing how it sparked curiosity, enhanced feeling of competence through well-balanced difficulty level, provided autonomy through self-directing exploration, and relatedness through collaboration. The participants stated that while the quests were not very difficult, they still sparked curiosity. Especially watching others seemed to give new perspectives and reinforce learning. Participants in the study expressed satisfaction in exploring hidden clues, cooperating to unravel mysteries, and felt intrigued by the archival narrative. (Nandakumar, 2025)

During the inauguration day in May 2025, with approximately 500 visitors, the quest room was observed using a protocol for engagement. Preliminary analysis shows engagement through problem-solving, discussions, and exploration of the room. Visitors referred to the quests, such as the one about 17th -century stomach medicine, rather than just discussing the smelling quest, indicating a connection between the activity and the learning content of the written texts. Museum personnel, a few weeks after the inauguration, describe the quest room as well-functioning, well-used, and with most visitors understanding and enjoying it.

6. Edu-Interaction Design Analysis Framework

In this section, the educational and interaction design concepts introduced in the background are combined into a joint framework, creating an edu-interaction design analysis framework for EER, and utilized on the design exemplars of the quest rooms (Figure 5).

Sociality. The quest rooms are designed as cooperative social activities that encourage collaborative learning. An interesting behaviour observed in all the quest rooms is that players tend to collaborate a lot within their group while actively ignoring what other groups do, creating collaborative learning in groups.

Embodied Aspects. Quest rooms encourage embodied interactions following principles from embodied cognition. Embedding the quest into the environment promotes movement, sensory engagement, and physical manipulation of objects, thereby integrating bodily engagement into the learning experience. Multisensory and tangible approaches include smell-based quests, turning an old telephone crank, and pushing Morse code buttons. Hidden technologies allow players to focus on tangible exploration and collaboration. Removing tangible aspects, as in the second interaction, reduced some of the potential for embodied learning.

Playification in the design exemplars includes the role-play layers, the removal of time pressure and competitive elements, and the promotion of exploratory and social play. Ludic markers and other scenography are designed to afford playfulness. The playification approach promotes intrinsic motivation, sociality, and exploration.

Interactive Storytelling. Each quest room can be seen as a form of embedded interactive storytelling. The story intercepts the whole experience ambiently through scenography, props, texts, and visuals and is integrated into the quest mechanics. Through multimodal storytelling, the users interact with and explore the story hands-on with several senses. Building more on this and having a stronger narrative focus could enhance those aspects of a quest room design.

Game mechanically driven learning. The learning experience could be strengthened if the quests' activity, or game mechanics, map to the learning goals, supporting meaningful engagement rather than superficial play. An example is how the quest of sending a Morse code across the room will make you learn Morse code in the process of solving the quest, while a generic quest, such as solving a cipher, is more detached from the intended cultural heritage learning.

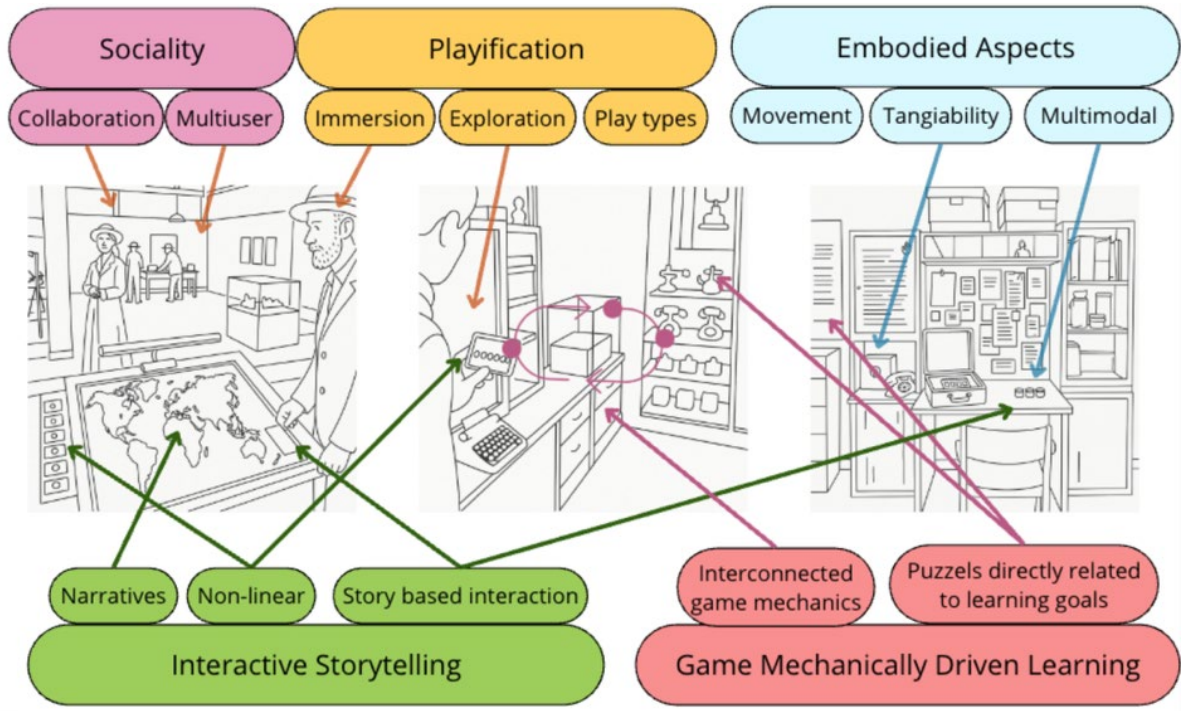

Figure 5: The edu-interaction design framework applied to the quest rooms

7. Conclusion

This study presents a design concept, the Quest Room, that adapts the EER approach to informal learning in museums. The Quest Room design approach is analysed through an edu-interaction design framework, combining educational and interaction design concepts and theories through five lenses of analysis: sociality, playification, embodied aspects, interactive storytelling and game mechanically driven learning. This study aims at opening up for combining interaction design and educational theories for designing and evaluating digiphysical educational installations such as EERs. This study can be seen as a first step. The paper presents a framework for analyzing educational escape rooms, but it is only applied to the three examples the authors

designed. To make the framework more reliable, it would help to test it in other learning contexts, such as formal education or science centers, as well as by involving other designers. Comparative studies, structured user evaluations and learning assesments could help validate and refine the framework. The quest room design can be further studied, tweaked and implemented for educational environments at museums and beyond.

Ethics declaration: As per standard procedure in its country of origin, the project was submitted to the national ethics committee, which found that it did not need ethical approval.

AI declaration: AI (ChatGPT 4.0) was used to convert photos into sketch-style outlines for figure annotations. Additionally, AI (ChatGPT 4.0 and Microsoft Copilot) was used editorially to correct grammar and language. The authors otherwise produced all content and results without AI assistance.

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Neuroplastic Reflective Game Design: A Framework Bridging Neuroscience and Game-Based Learning

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Abstract: This paper introduces Neuroplastic Reflective Game Design (NRGD), a theoretical framework that bridges neuroscience and game-based learning by linking reflective gameplay to underlying neuroplastic mechanisms. Neuroplasticity, the brain's capacity to reorganise neural connections, underpins learning, memory, and adaptability, yet its potential role in educational design remains underexplored. Reflection, defined as the deliberate evaluation of experience, engages prefrontal and cingulate regions, reinforcing executive functions and long-term retention. Digital games provide fertile ground for embedding structured reflection because they combine immersion, interactivity, and feedback, but their capacity to deliberately support neuroplasticity has not been systematically theorised. A structured literature review synthesised insights from neuroscience, education, and game design. The review revealed that while each domain offers valuable perspectives, such as neural mechanisms of plasticity, pedagogical models of reflection, and game-based scaffolds for metacognition, they remain siloed. Neuroscience often stops at describing mechanisms, education frames reflection as pedagogy without neural grounding, and games emphasise engagement without connecting to brain adaptability. To address this, the study investigates three guiding questions: (1) how reflective game design can be theoretically extended to support neuroplasticity within digital learning environments; (2) which cognitive and neural mechanisms may be activated through reflection in gameplay; and (3) what design principles can be derived to inform future interdisciplinary work. The NRGD framework responds through four cyclical phases (Gameplay, Assessing Conceptualisation, Active Experimentation in Level Up, and Reflective Feedback). Each one is mapped to cognitive functions and neural processes such as long-term potentiation, synaptogenesis, and error-driven adaptive rewiring. An illustrative example in music theory demonstrates how these phases can be operationalised in practice, and a summary table aligns design features with their associated neurocognitive outcomes. The framework offers practical value for educators and instructional designers seeking deeper learning, for game developers aiming to align mechanics with cognitive science, and for neuroscientists and clinicians exploring applications in neurorehabilitation, lifelong learning, and therapy. While conceptual in nature, the framework also identifies directions for empirical validation, methodological refinement, and adaptation across domains. By bridging pedagogy and neuroscience, NRGD establishes a novel theoretical foundation for designing digital games that are both pedagogically effective and biologically grounded.

Keywords: Neuroplasticity, Reflective learning, Game-Based learning, Reflective game design, Cognitive neuroscience, Educational technology

1. Introduction

Neuroplasticity, the brain's capacity to reorganise neural pathways in response to experience, underpins learning, memory, and adaptability, thus making it central to deep and transferable educational outcomes (Draganski et al., 2004; Kleim & Jones, 2008). Reflection is defined as the critical examination of one's experiences to generate insight and guide future action (Dewey, 1933; Schön, 1983). It strengthens the processes of metacognition and executive control that may also support neuroplastic change (Fleming & Dolan, 2012; Immordino-Yang & Damasio, 2007).

Digital games provide fertile ground for embedding such reflection. Their interactivity, feedback, and immersion allow learners to test strategies, reconsider decisions, and connect gameplay to broader knowledge, leading some to describe them as "reflection machines" (Khaled 2018; Gee, 2003; Squire, 2011). Reflective Game Design (RGD) builds on this potential by formalising how games can scaffold reflection through feedback loops, prompts, and social discourse (Shaheen & Fotaris, 2024b; Villareale et al., 2020). Yet, despite its adoption in game-based learning, the potential of reflective games to explicitly support neuroplasticity has not been systematically theorised.

Figure 1 presents the conceptual foundation of this study. It rests on three premises: (i) reflective learning supports neuroplasticity (Clark, 2016; Davis, 1997; Fleming & Dolan, 2012; Immordino-Yang & Damasio, 2007; Schön, 1983; Zeidner et al., 2009); (ii) digital games are effective vehicles for structured reflection (Khaled, 2018; Shaheen & Fotaris, 2024b; Villareale et al., 2020); and (iii) combining these strands suggests that reflective digital games may deliberately enhance neuroplasticity by aligning gameplay with reflection.

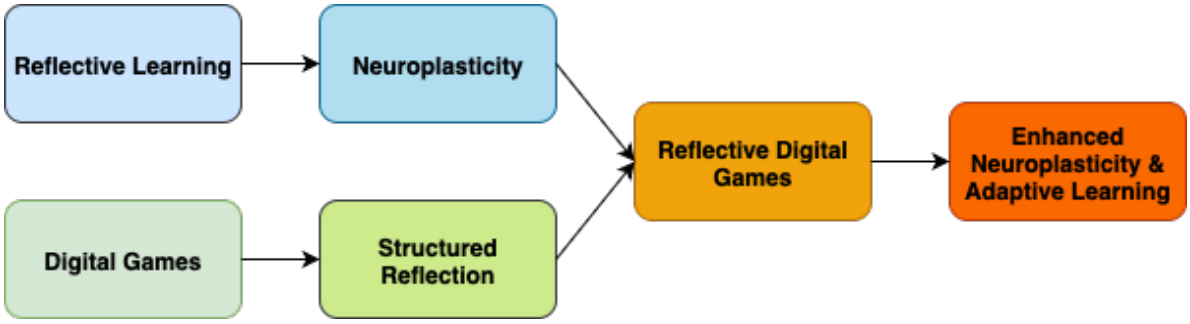


Figure 1: Conceptual framework of the study. Reflective learning supports neuroplasticity; digital games provide structured reflection; their integration (reflective digital games) is proposed to enhance neuroplasticity

Accordingly, this study is guided by the following research questions:

- *RQ1:* How can Reflective Game Design (RGD) be extended to incorporate neuroplastic mechanisms within digital learning environments?
- *RQ2:* Which cognitive and neural processes may be activated through reflective practices embedded in gameplay?
- *RQ3:* What design principles can be derived to guide educators, game designers, and neuroscientists in leveraging reflection to support neuroplasticity?

2. Literature Review

2.1 Neuroplasticity in Learning

While the introduction established neuroplasticity as a foundation for adaptive learning, this section expands on the specific mechanisms through which it operates. Neuroplasticity manifests in two primary forms: structural plasticity, involving physical changes such as neurogenesis and dendritic branching, and functional plasticity, where brain regions reorganise, roles following experience or trauma (Mateos-Aparicio & Rodríguez-Moreno, 2019). These changes are supported by processes including long-term potentiation (LTP), long-term depression (LTD), and spike-timing dependent plasticity (STDP), which regulate the strengthening or weakening of synaptic connections (Lynch, 2004).

Research has identified key brain regions implicated in these adaptive processes. The prefrontal cortex supports working memory and cognitive control, the anterior cingulate cortex (ACC) monitors errors and regulates responses, the parietal lobes contribute to attentional control, and the hippocampus consolidates long-term memory (Edwards et al., 2023; Mishra & Gazzaley, 2014). These functions parallel the demands of digital games, which require sustained attention, adaptive strategy, and integration of new knowledge across contexts.

However, despite strong evidence from neuroscience, translation into educational and design practice remains limited. “Neuroplasticity” is often invoked in education metaphorically, without clear operationalisation in pedagogical interventions (Bruer, 1997; Howard-Jones, 2014). While some studies explore attention, motivation, and reward systems in learning (Bassett et al., 2011; George et al., 2023), few propose systematic principles for deliberately engaging neural adaptability.

2.2 Reflection in Learning

Whereas Section 2.1 detailed the neural mechanisms of plasticity, this section turns to reflection as a cognitive and pedagogical process that can activate those mechanisms. Kolb’s (1984) experiential learning theory positioned reflection as the bridge between experience and conceptualisation, while later models such as Mezirow’s (1994) transformative learning and Zimmerman’s (2013) self-regulated learning highlight its function in performance monitoring, critical awareness, and motivation. Structured practices, including journaling, dialogue, and metacognitive prompts, have been shown to enhance problem-solving, transfer of knowledge, and critical thinking (Mezirow, 1991; Davis, 1997) while also improving persistence and self-efficacy (Zeidner et al., 2009).

Neuroscientific evidence complements these educational perspectives; it demonstrates that reflection activates prefrontal and cingulate regions associated with executive control, self-monitoring, and cognitive

flexibility (Løvstad et al., 2012). These processes engage long-term potentiation (LTP) and synaptic pruning (illustrated in Figure 2), which are mechanisms that strengthen relevant pathways while reducing less efficient ones (Costandi, 2016; Chen & Goodwill, 2022). Such mechanisms suggest that reflection can be understood not only as a pedagogical strategy but also as a neurocognitive driver of adaptive change (Fleming & Dolan, 2012).

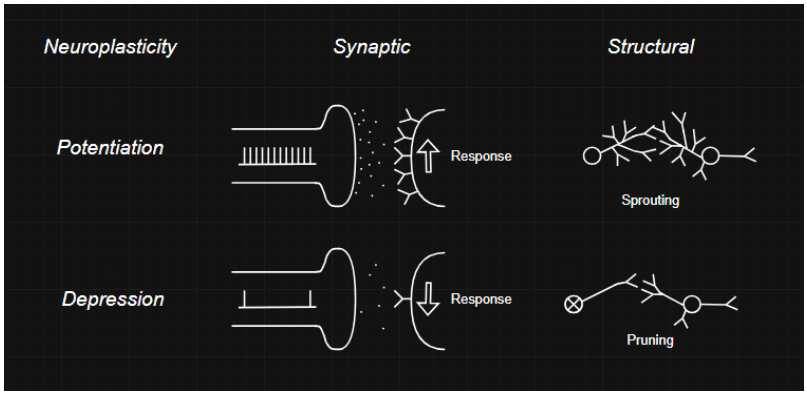


Figure 2: The illustration is drawn to show the process of potentiation (sprouting) and long-term depression (pruning) synapsis

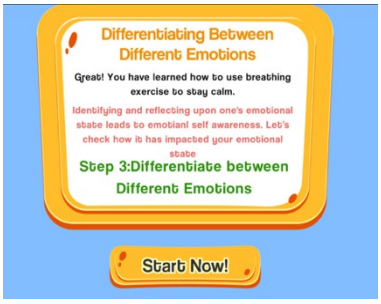
2.3 Reflective Features in Games

Having established reflection as a key mechanism for adaptive learning, this section examines how digital games provide distinctive opportunities to scaffold reflection. Building on Schön's (1983) distinction between reflection-in-action (during gameplay) and reflection-on-action (after gameplay), research demonstrates that games can support both forms through interactive feedback and immersive design (Lin et al., 1999; Villareale et al., 2020).

Lin et al. (1999) proposed a model of reflective scaffolding that was later adapted for game contexts (Villareale et al. 2020). Common features include:

- *Process Displays:* visual aids such as Heads-Up Displays (HUDs) and dashboards that make implicit processes explicit, enabling players to monitor progress and reflect on ongoing actions (Figure 3 (a)).
- *Process Prompts: i*n-game guidance or feedback that encourages players to evaluate decisions and articulate strategies (Figure 3 (b)).
- *Process Models:* benchmarks or examples against which players can compare their performance, helping to identify strengths and weaknesses (Figure 3 (c)).
- *Social Discourse:* collaborative features such as chat or multiplayer interaction that facilitate shared reflection and peer feedback (Figure 3 (d)).

These elements scaffold both individual and collective reflection, strengthening metacognition and supporting transfer of knowledge (Shaheen & Fotaris, 2024a). However, most studies remain pedagogical in focus and emphasise outcomes such as critical thinking or engagement without examining whether such reflective mechanics also stimulate underlying neurocognitive mechanisms (e.g., error correction in the anterior cingulate cortex or memory consolidation in the hippocampus). This gap highlights the need for models that explicitly link reflective features in games to neuroplastic processes.



(a) Process Displays

(b) Process Prompts

(c) Process Model

(d) Social Discourse

Figure 3: Examples of reflective game features: (a) process displays (e.g., anxiety meters on top left) (Shaheen & Fotaris, 2024a); (b) process prompts (Shaheen & Fotaris, 2024a); (c) process models comparing player feelings pre- and post-activity (Shaheen & Fotaris, 2024a); (d) multiplayer audio communication in Fortnite (Epic Games, 2017)

2.4 Gap Analysis

Although valuable insights have emerged across the three strands of literature, persistent disconnections remain. Neuroscience explains mechanisms of plasticity such as long-term potentiation and neurogenesis, but rarely translates them into actionable design principles for learning (Bruer, 1997; Howard-Jones, 2014). Reflection research highlights its role in metacognition and executive function, yet seldom theorises its direct neurocognitive implications (Mezirow, 1991; Fleming & Dolan, 2012). Game-based learning demonstrates the pedagogical value of reflective scaffolds but typically stops short of linking them to neuroplastic outcomes (Gee, 2003; Khaled, 2018). Taken together, these strands remain siloed: neuroscience describes mechanisms, education frames reflection as pedagogy, and games showcase reflective potential.

To address this fragmentation, the next section revisits RGD as a pedagogical foundation before extending it into the proposed Neuroplastic Reflective Game Design (NRGD) framework, which theorises how reflective game features may be aligned with neuroplastic processes.

3. From Reflective Game Design to Neuroplastic Reflective Game Design

3.1 Reflective Game Design Framework: A Pedagogical Foundation

The RGD framework an iterative model for structuring reflective feedback in GBL, was introduced by Shaheen et al. (2022). It builds on experiential learning theory (Kolb, 1984) to structure how games embed reflection into the learning process. It distinguishes between reflection-in-action (during gameplay) and reflection-on-action (after gameplay), operationalising both through iterative feedback loops. Figure 4 illustrates the four cyclical phases of RGD:

- *Gameplay:* players engage in concrete experiences that form the basis for reflection.
- *Assessing Conceptualisation:* formative or summative tasks prompt learners to evaluate and interpret their actions.
- *Level-Up:* players reapply acquired knowledge in new contexts, reinforcing transfer and adaptation.
- *Reflective Feedback:* feedback mechanisms encourage strategy adjustment and deeper processing.

These phases promote metacognitive development by requiring learners to monitor, evaluate, and refine their strategies. Applications of RGD in serious games demonstrate benefits for critical thinking and problem-solving (Shaheen et al., 2022; Shaheen & Fotaris, 2024b). However, RGD remains pedagogical in scope: it explains how reflection supports learning but does not account for the neurocognitive mechanisms that may underpin these effects. This limitation motivates the extension toward the NRGD framework.

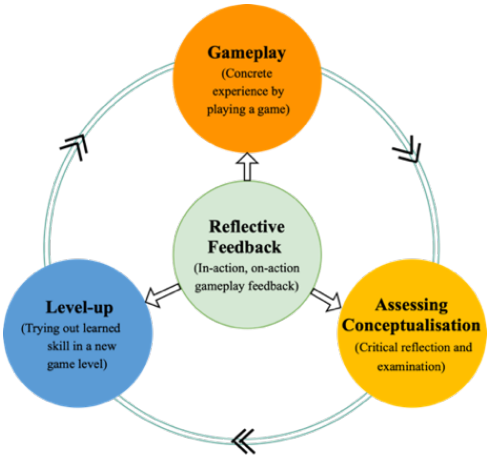


Figure 4: The Reflective Game Design (RGD) Framework (Shaheen et al., 2022)

3.2 Extending to the Neuroplastic Reflective Game Design Framework

The NRGD framework extends RGD by theorising how reflective practices embedded in gameplay may stimulate neuroplastic mechanisms. Whereas RGD conceptualises reflection as a pedagogical strategy, NRGD positions it as a potential biological driver of adaptive learning.

At its core, the framework rests on three principles. First, reflective practices are hypothesised to activate brain regions such as the prefrontal cortex, anterior cingulate cortex, and hippocampus, which are areas that support executive control, error monitoring, and memory consolidation. Through engagement, these regions may undergo long-term potentiation, synaptic refinement, and related processes of adaptive plasticity. Second, game mechanics can be understood as scaffolds for neuroplasticity: feedback loops, adaptive challenges, and metacognitive prompts stimulate activity-dependent changes, reinforcing motivation and learning through dopaminergic reward and skill reapplication. Third, NRGD integrates pedagogy with neuroscience, providing a model for why reflective gameplay can enhance not only learning outcomes but also brain adaptability.

Figure 5 depicts the four cyclical phases of the framework, adapted from RGD but extended to include explicit neurocognitive links.

- *Gameplay (Sensory Integration and Engagement):* Immersive, multisensory gameplay environments activate widespread neural networks, including prefrontal and sensory–motor regions. Repeated engagement fosters activity-dependent plasticity and is reinforced by motivational neuromodulators such as dopamine (Carrillo-Mora et al., 2017; Hötting & Röder, 2013).
- *Assessing Conceptualisation (Metacognition and Plasticity):* Critical evaluation of in-game decisions activates executive functions in the prefrontal cortex and anterior cingulate cortex, enhancing LTP and refining cognitive control (Maier et al., 2019).
- *Level-Up (Reapplication and Consolidation):* Reapplying knowledge or skills in new contexts consolidates neural circuits, promotes synaptogenesis, and may support hippocampal neurogenesis, strengthening transfer across domains (Kolb & Gibb, 2008).
- *Reflective Feedback (Adaptive Learning and Error Correction):* Timely, structured feedback activates error-correction circuits in the ACC and prefrontal-striatal loops, promoting adaptive rewiring and improving transfer of learning across contexts (Johnston, 2009).

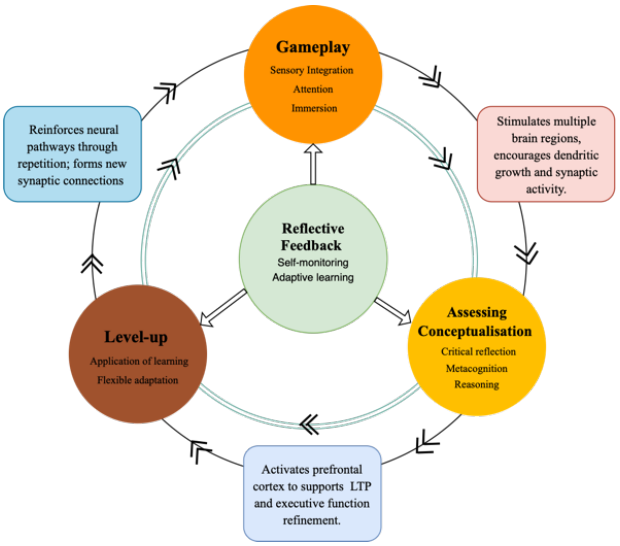


Figure 5: The Neuroplastic Reflective Game Design (NRGD) Framework adapted from RGD Framework

To illustrate how these phases can be operationalised in practice, consider a digital game for learning music theory. In the *Gameplay* phase, players explore a sound-based environment where movements synchronise with beats, activating auditory-motor pathways through multisensory immersion. During *Assessing Conceptualisation*, rhythm challenges prompt learners to use reflection tools to analyse differences between time signatures, engaging executive reasoning processes. In the *Level-Up* phase, players apply learned scales and rhythms to arrange a backing track, consolidating skills in a novel context and reinforcing adaptive pathways. Finally, in the *Reflective Feedback* phase, the game provides both in-action monitoring (e.g., pitch accuracy during composition) and on-action evaluation (e.g., comparing melodies after submission), prompting adaptive adjustment. Table 1 summarises these phases by aligning each with its cognitive function, underlying neuroplastic mechanism, and an illustrative design example.

Table 1: Mapping NRGD Phases to Cognitive Functions, Neuroplastic Mechanisms, and Illustrative Game Design

NRGD Phase	Cognitive Function	Neuroplastic Mechanism	Illustrative Example
Gameplay	Sensory integration, sustained attention, emotional engagement	Activation of auditory-motor cortices and prefrontal regions; activity-dependent plasticity; dopaminergic reinforcement	Players explore a sound-based map where movements synchronise with beats and notes, engaging multiple sensory pathways.
Assessing Conceptualisation	Critical reflection, metacognition, reasoning	Engagement of prefrontal cortex and ACC; supports long-term potentiation (LTP) and executive function refinement	After a rhythm challenge, players explain differences between time signatures using a reflection tool that prompts analysis.
Level-Up	Reapplication, transfer, consolidation	Synaptogenesis and hippocampal neurogenesis; reinforcement of adaptive pathways	Players apply learned scales and rhythms to arrange a backing track for a performance, consolidating skills in a novel context.
Reflective Feedback	Self-monitoring, error correction, adaptive adjustment	Activation of ACC and prefrontal–striatal loops; error-driven neural rewiring.	While composing, players receive pitch-accuracy feedback; after submission, their melody is compared to a target theme with revision prompts.

3.3 Limitations and Practical Implications

As a theoretical contribution, the NRGD framework has limitations that also shape its future application. First, it remains conceptual: while it integrates insights from neuroscience, education, and game design, empirical research is needed to confirm whether reflective mechanics in digital games indeed stimulate neuroplastic change. Second, methodological constraints, such as the cost, invasiveness, and ecological limitations of neuroimaging, make it difficult to capture plasticity in authentic learning contexts. Third, reflective mechanisms will vary across domains, requiring adaptation for fields as diverse as science education,

professional training, and neurorehabilitation. Finally, learner variability in metacognition, motivation, and neurodiversity highlights the importance of adaptive scaffolds to ensure inclusivity.

Despite these challenges, the framework offers actionable insights for practice. It encourages the design of gameplay experiences that combine sensory richness and meaningful challenge to promote both engagement and neural adaptability. Reflective scaffolds, such as prompts, comparative models, and feedback loops, should be integrated to strengthen metacognition and cognitive flexibility. Iterative reapplication of skills across varied contexts can reinforce consolidation and transfer, while adaptive tools can accommodate individual learner differences.

Together, these implications position NRGD as a blueprint for designing digital games that are not only pedagogically effective but also biologically grounded, thus offering new directions for educational innovation and interdisciplinary research.

4. Conclusion and Future Work

Despite these challenges, the framework offers actionable insights for practice. It encourages the design of gameplay experiences that combine sensory richness and meaningful challenge to promote both engagement and neural adaptability. Reflective scaffolds, such as prompts, comparative models, and feedback loops, should be integrated to strengthen metacognition and cognitive flexibility. Iterative reapplication of skills across varied contexts can reinforce consolidation and transfer, while adaptive tools can accommodate individual learner differences.

This paper introduced the NRGD framework, which extends RGD by explicitly linking reflective practices in digital games to mechanisms of neuroplasticity. By bridging neuroscience, reflection research, and game-based learning, NRGD responds to persistent disconnections between these fields and proposes reflection not only as a pedagogical tool but also as a potential driver of adaptive neural change.

The framework is structured around four cyclical phases: Gameplay, Assessing Conceptualisation, Level-Up, and Reflective Feedback. Each one is mapped to cognitive functions and neuroplastic mechanisms such as long-term potentiation, synaptogenesis, and error-driven adaptive rewiring. A music theory case illustrated how these principles can be translated into practice, supported by a summary table aligning phases, mechanisms, and design strategies. Together, these contributions provide a theoretical foundation for designing digital games that intentionally engage neuroplastic processes while deepening learning outcomes.

In addressing its guiding questions, the study (RQ1) extended RGD into the neurocognitive domain through the NRGD framework, (RQ2) mapped reflective practices to specific neural and cognitive mechanisms, and (RQ3) proposed design principles to guide educators, game designers, and neuroscientists.

Future work should empirically test and refine the framework through interdisciplinary research. Mixed method approaches that combine behavioural measures with neuroimaging could offer evidence for the hypothesised neural effects of reflective gameplay. Applications across education, professional training, and rehabilitation will also be important for exploring domain-specific adaptations. Finally, studies should examine how individual differences, such as metacognitive ability, motivation, and neurodiversity, influence the effectiveness of NRGD-informed interventions. By pursuing these directions, future research can validate and extend the framework so as to move toward digital games that not only teach but also harness the brain's capacity for adaptive change.

Ethical/AI Declaration: There is no AI tool is used in the content creation; however, Apple intelligence writing tool was used in some sentences to improve readability. All figures in the documents are referenced, and diagrams are created in draw.io online tool.

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Print-and-Play and Digital Games for a Playful Assessment of Colour Vision Deficiencies

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Abstract: The term *colour vision deficiency* (or CVD, for short) refers to a spectrum of conditions of genetic origin where one or more types of cone cells in the human retina do not function correctly, or do not function at all, leaving those affected unable to distinguish certain colours (Wright et al., 1946); this condition affects approximately 1 in 12 males and 1 in 200 females worldwide, but in Italy it is often identified only after a child has entered primary school, thus an early detection of this condition can help reduce colour-related learning challenges and social disadvantages. In order to address this issue, we designed a tile-placement and colour-matching board game which we named *ColorFit* as a playful tool for discovering potential colour perception issues. The game is meant for two players and provides a controlled environment where player behaviour – such as the choice of moves and the players' response times – can be observed and analysed to deduce possible colour vision difficulties. ColorFit is available in print-and-play format, complete with game rules, components, and a user guide. To broaden its accessibility and analytical capabilities, a digital version was also created, with a higher degree of customization, adjustable colour palettes and game conditions, and a more precise tracking of player actions, such as timing, move accuracy, and error patterns. By integrating game-based interaction with observational analysis, ColorFit offers a non-invasive, engaging, and scalable method to support the early identification of colour vision deficiencies in children.

Keywords: board games, colour vision, colour blindness, detection, colour, diagnosis

1. Introduction

Colour vision deficiency (CVD), a genetic condition caused by at least one type of photoreceptor in the human retina functioning abnormally, affects the way individuals perceive and distinguish colours, especially reds and greens (Birch, 2012). The effects of CVD are typically not considered a disability in the traditional sense, but they can create subtle though significant barriers in many aspects of everyday life, especially in school or other educational settings where colour is frequently used for learning and communication.

CVD is relatively common, especially among males, affecting approximately 8% of boys (1 in 12) and 0.5% of girls (1 in 200) globally. In Italy, as in many other countries, this condition often goes undetected until a child encounters colour-based tasks in primary school. By this point, undiagnosed CVD may already have caused challenges in classroom engagement, self-esteem and school performance, especially in subjects that rely on colour-coded information, such as geography, math, science and art.

Identifying this colour vision deficiency in the early stages of life could help mitigate the disadvantages associated to this condition and would make it possible for educators and parents to adapt learning environments to individual needs. Conventional diagnostic tools such as the Ishihara test are typically administered in clinical settings, and may not be readily available in schools. In addition to this, young children could feel intimidated by the tests, a fact which could potentially affect their reliability and acceptance.

To address these challenges, the Game4CED group ("Gamification for Colour-blindness Early Detection") created *ColorFit* (Iocco, Rizzi, 2024), a colour-matching and tile-placement board game designed as an accessible, engaging tool for the early indication of colour vision deficiencies. By embedding observational cues into a playful environment, ColorFit aims to create a low-pressure context in which children's interactions with colour can be monitored and analysed. This paper describes the conceptual design of ColorFit, its physical and digital implementations, and its potential to support non-invasive, scalable early detection for colour vision challenges in early education settings.

2. Background and Related Work

Colour vision deficiency (CVD) has been studied in clinical research for over a century. The type and severity of the condition is commonly assessed by means of standardized tests, such as the *Ishihara Colour Test*, a series of coloured dot patterns that form numbers or shapes visible only to observers with normal colour vision. These tools are effective in clinical settings (Birch, 1997) such as medical environments, but they are often ill-suited for early detection, especially in schools, where time, resources, and professional oversight may be limited.

Many alternative diagnostic methods exist, such as the *Hardy-Rand-Rittler (HRR) plates* or the *Farnsworth D-15* arrangement test. These tests offer a broader assessment of specific CVD types, but they also require controlled lighting conditions and trained supervision, constraints that make them impractical in many non-specialized settings. Digital adaptations of these tools have recently emerged, exploiting mobile and web platforms to improve accessibility. The reliability of these tests could however be of concern, since they are often administered across multiple electronic devices because of inconsistent colour calibration and display quality.

In the last few years, interest in game-based health tools has considerably grown, with a particularly sharp rise regarding educational interventions for children. Behavioural data can be collected passively by exploiting the engagement and interactivity brought forth by the game, often without the user realizing that an assessment is underway. In the context of CVD, a handful of mobile games and apps – such as *Chromatic Vision Simulator* – aim to raise awareness or simulate colour vision differences, but these tools are primarily educational or diagnostic in nature, and they often lack structured environments suitable for early detection.

Games that integrate perceptual challenges into familiar mechanics can enable subtle assessments of sensory or cognitive traits. However, for such tools to be effective in detecting CVD, they must balance diagnostic value with accessibility, enjoyment, and developmental appropriateness.

ColorFit builds on these grounds by embedding colour-based decision-making into the core gameplay mechanics of a simple, two-player board game. Unlike explicit testing tools, it encourages natural interaction with colour elements in a structured yet playful format. By observing gameplay choices – such as difficulty in distinguishing tile colours or longer response times under certain conditions – researchers and educators can infer the presence of potential colour vision difficulties. We stress that while ColorFit's strict color-dependant rules cause players with impaired color vision to perform strikingly worse than standard-vision players, which in our experience make this comparable to a clinical test, the board game can be used for early detection, and not for a full-fledged diagnosis. This section sets the stage for the following chapters, which describe how ColorFit was designed to fill this gap in the early identification landscape.

3. Design of ColorFit

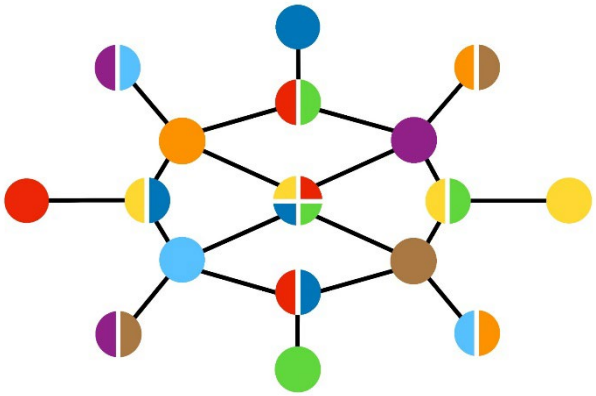
We designed the *ColorFit* board game with a clear set of constraints in mind: primarily, we wanted ColorFit to be unmistakably a game, and not a test or a diagnostic tool. This means, as with most games, that players take turns, follow a set of rules, compete in order to win and share an enjoyable experience. At the same time, the game had to remain extremely simple: the rules should be easy to understand, and anyone – without needing special training – should be able to observe a session and detect whether players are struggling with colour recognition.

Accessibility was another key requirement: ColorFit needed to be completely free to use and composed of materials that are easy to print or assemble at home. It also had to come with clear documentation explaining both how to play and how to supervise its use in more controlled settings. Last, but not least, the game needed to support multiple colour palettes, so that it could test a variety of colour vision deficiencies.

To meet these requirements, several design challenges had to be addressed. To start with, a session of ColorFit must be short and involve only a small number of participants, so that observers can closely monitor each move and easily spot colour recognition issues. This also allows researchers to run multiple sessions with the same group, each using a different colour palette, so that a broader range of diagnostic insights can be collected. By analysing aspects like the time players take on each turn and the types of mistakes they make, supervisors can gather objective indicators of potential difficulties in colour perception.

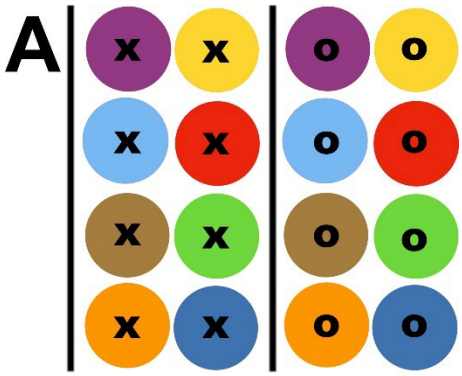
Initial testing highlighted another important consideration: we deliberately excluded references to real-world objects or storytelling elements. This was done to focus players' attention solely on colour – avoiding distractions, expectations or potential(ly misleading) associations that could influence their choices. While most board games are designed to engage a variety of cognitive skills, in our case this would have been counterproductive. ColorFit must still feel like a game, but it should not involve complex strategies or multiple layers of difficulty. The aim is to keep the experience straightforward and centred entirely on colour recognition.

In order to play ColorFit, a game board has to be chosen among 4 different variants.



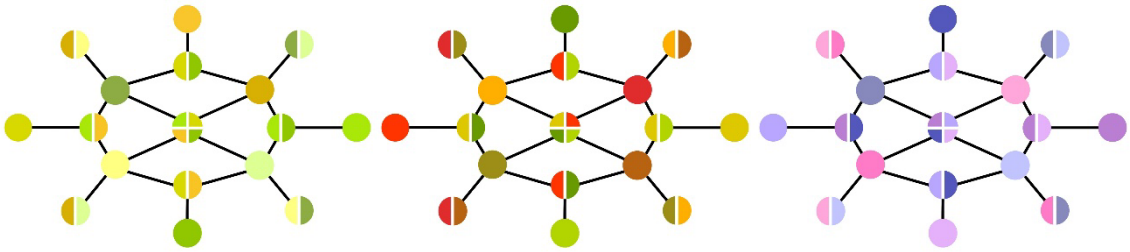
Picture n. 1 - The standard board for ColorFit.

The correspondingly coloured tiles are to be distributed between the two players, with one player receiving the tiles marked with the symbol "o" and the other those marked with "x".



Picture n. 2 - The corresponding "A" tokens

The variants only differ in terms of colour palette, while the connectivity of the underlying graph remains unchanged. The variants were baptised as "*spring*", "*autumn*" and "*winter*" boards, with reference to the palettes involved.



Picture n. 3 - The "spring", "autumn" and "winter" ColorFit boards.

The first player is randomly selected, and he or she have to place one of their tiles on any node on the graph that matches the tile's colour. Players then take turns placing one tile at a time on the board, making sure that each tile is placed on a node that is directly connected to one already occupied and that shares the same colour

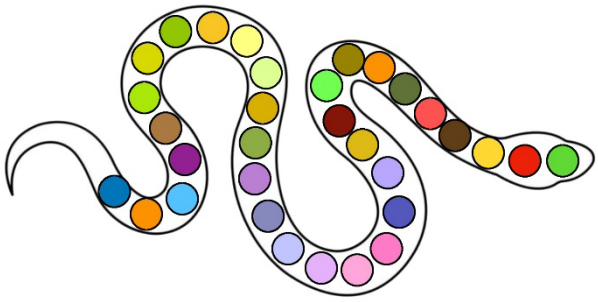
as the tile being placed. If a player has no valid move – i.e., no available nodes that match their tile's colour, they must skip their turn. The first player to place all their tiles is declared the winner.

The predictivity of ColorFit was tested in our laboratory at the University of Milan with a group of colorblind players, who confirmed that the colors in the standard board (Picture n. 1) were indeed quite easy to distinguish, but were however useful to test whether the rules of the game had been picked up correctly by the players. On the contrary, the "seasonal" palettes (Picture n. 3) showed promising predictivity, highlighting differences in the performances of colorblind and standard-vision players.

A full ColorFit set consists of a series of printed documents and game components, which specifically include:

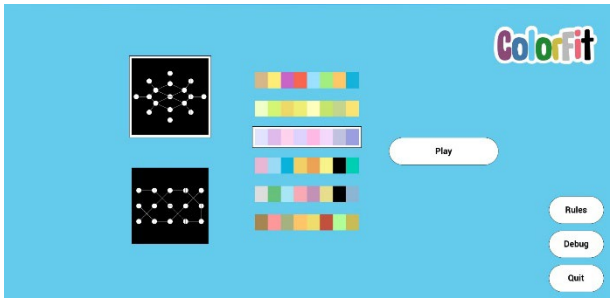
- An introduction to the Game4CED project
- Guidelines for using ColorFit in the classroom
- The complete game rules
- A variety of game boards, each featuring different colour palettes
- Colour-coded game tiles corresponding to the different boards

A single-player version of the game was also developed. In this case, the board consists of a snake-shaped path divided into coloured tiles, but the overall gameplay proceeds as usual: the player must place the coloured tiles in the precise order in which they appear on the snake-shaped guide.



Picture n. 4 - The "solitaire" version of ColorFit.

A digital version of ColorFit was also developed as part of a master thesis program. With respect to its analogue version, some of the features of ColorFit are enhanced in the digital version: beside customizable colour palettes and graph connectivities, the program enforces the game rules, and therefore it does not allow the player to make illegal moves; when he or she tries to place a coloured token in the wrong section of the board, it informs the player and waits for a correct move to be sent to the game.



Picture n. 5 - The interface of the digital version of ColorFit.

In addition to this, the game also records latency times, an important parameter given by the time between the start of a turn and the moment in which a player places a coloured token; these values are shown to each player together with the pair of wrongly associated colours.

Picture n. 6 - With respect to the analog version, digital ColorFit enforces the game rules, and therefore it does not allow the players to place tiles incorrectly.

4. Methods for observational analysis

ColorFit represents an unusual application of game-based learning (GBL) where the actual learners are the people who administer the game-based test as a means to assess the player's ability in color discrimination without resorting to labelling or naming conventions. ColorFit was introduced to pre-school and to elementary school classes, each consisting of approximately twenty students. The students were divided into groups of four, with two playing at a time while the other two waited for their turn. Each student received a personalized player card marked with a unique identification code, along with a score sheet to keep track of the number of games played, as well as their wins and losses.

During the activity, students had the opportunity to play on different versions of the game board, starting from the standard board as to check if the rules had been understood correctly, and later on moving to those featuring "spring", "autumn", and "winter" colour palettes. Each student played at least three matches for each board, with at least one of those games supervised by a member of the Game4CED project team. The supervised match was also recorded on a video camera: during this match the players received no direct feedback, so that any bias or mistake could be determined by rewatching the video. In a typical session, students with specials needs or having difficulties with game rules were invited to try the solitaire version of ColorFit presented above.

During the systematic observation phase, specific observation protocols were designed in the form of structured coding grids. In the first trial phase, data collection was conducted in two formats: paper-based grids (completed manually) and a digital version that could be completed online. In addition to direct observation, video recordings were also used in selected classrooms (Baldacci, Frabboni, 2013).

During the trial phase, it became apparent that completing the observation grids in real time was a major challenge due to the large number of variables that had to be taken into account simultaneously. It became apparent that this complexity impaired both the accuracy and the completeness of the recorded data. Therefore, video recording was systematically introduced to enable retrospective coding. This approach not only improved the precision and reliability of the observation process, but also enabled the involvement of external coders, increasing the objectivity and validity of the data collected.

5. Pilot testing and discussion

The pilot testing phase of the game was conducted with the primary aim of assessing the clarity of the rules, the children's understanding of the game mechanics (Nesti, 2017), the variability in the duration of the game sessions and the role of the mediator or observer during these sessions. The test included a sample of seven school districts, which comprised ten school sites, in various locations in Northern Italy, mainly in the Emilia Romagna, Lombardia and Veneto regions. Following preliminary contacts, the testing was authorised by each school board, and school officials were given forms in advance to hand out to the parents, for them to know the types of observations that would be carried out, including an ethics declaration. Parents uninterested in the proposed activity could prevent their children from participating by not authorising or by not signing the form. No interactions with the school pupils took place following the tests. A total of 52 classes took part, including 7 pre-school and 45 primary school classes. The sample consisted of 1009 students (558 boys and 516 girls), including only those present at the time of screening; absent students were excluded from the dataset.Within this cohort, 36 students were identified as potentially colourblind, representing a prevalence rate of 3.6%. It is

important to emphasize that this was an early detection and not a definitive diagnostic procedure. The purpose was to identify suspect cases and to communicate them to school and families. The observed prevalence is lower than the national average, which is estimated to be around 8.5% for males (Maffia *et all*. 2022). The group of observers included members of the Game4CED project, previously authorised by each school; no specific training was required for the observers, as their role was merely to relate the game rules and record game sessions. Observers kept from providing feedback to the players, in order not to influence their observed performance. Observers highlighted an active participation of the children, this allowed to observe children's behaviour more carefully, especially those who consistently made mistakes when placing the pieces on the board, mistakes that were related to colour matching rather than adherence to the actual rules.

Students who made a higher number of mistakes during the game often perceived the game as "difficult" and began to spontaneously develop compensatory strategies, for example: imitating the peer's moves, mirroring the game's progress on the board, asking for support from a peer, repeatedly asking peers or adults, verbalizing the colours to gauge reactions, or in more difficult cases, deciding to give up the game altogether. The children who made the most mistakes associated a single tile with multiple colours on the board.

In these cases, a second phase of individual play was introduced to rule out possible causes such as colour vision deficits, environmental factors such as lighting or print quality, or social factors such as interaction with peers, competitiveness, or contamination by the opponent's behaviour. This second phase included an individual game session with the snake-shaped path, designed to more accurately assess children's colour perception.

Among the critical issues identified during the pilot project, one of the most common concerned the understanding of the rules of the game, in particular the use of the "X" and "O" symbols on the tiles. Many children attributed functional meanings to these symbols, such as "X = block" and "O = permission to play", or interpreted them as conditions for a move, such as only playing where their tile "opened the way", or trying to form a winning line (similar to tic-tac-toe). This misunderstanding was counteracted by formulating the purpose of the symbols more clearly in the rules.

In addition, many children pointed out that it was unclear whether they should be played face up or face down, as the rules did not provide for this. Children aged 3 to 5 tended to lay the tiles flat on the table rather than holding them, as the latter presented a challenge. Those who tried to hold all the tiles in their hands often lost concentration while looking for certain colours or catching dropped tiles, so the teacher often intervened and suggested placing the tiles on the table instead.

In contrast, primary school children, unless instructed otherwise by their teacher, usually held all their pieces in their hands. This limited the strategic game considerably. In the first round, many children pointed out to the game masters that whoever starts first is likely to win. These comments showed that the strategy was primarily based on managing one's own colours without considering the opponent's resources.

An important observation concerned the reasons why the children preferred to hold the tiles in their hands. During the initial presentation of the activity, students were asked if they were familiar with board games. Among the most common answers were "Briscola", "Rubamazzo", "Scarta la carta" and the modern "UNO". In all these games, the cards are usually held in the hand and hidden from the opponent. This suggests that the confusion is due to the fact that the game tested consists of tiles that resemble cards, inadvertently leading children to play in a similar style. It is expected that this issue will be resolved in the final version of the game, where the distinction between cards and tiles will be more clearly defined.

Interestingly, some children who initially held the tiles in hand later asked to see their opponent's colours during subsequent rounds. When asked why, they explained that revealing the opponent's colours allowed for more strategic play: *"If I can see what my opponent has, I can decide what to play to block them and stop them from getting the colour they need to finish."*

Other children, playing with face-up tiles randomly placed on the table, tended to play with the tiles in the order they were laid out, significantly limiting their colours options.

In preschool, greater flexibility was allowed regarding the rules for tile placement so that children could focus more on the perception of colour.

From a data collection perspective, the snake-shaped path game proved to be particularly valuable for assessing the youngest participants. It was conducted in two different modalities: in the first modality, all the coloured tiles were randomly placed on the table and the children were asked to arrange them in the correct order in the body of the snake. In the second modality, which was introduced to address difficulties related to visual scanning between too many tiles and keeping children focused on perception, children were given one tile at a time, taking care to avoid similar colours in the sequence— to ensure that selection was based on colour recognition rather than order of placement. The snake-shaped path modality also proved particularly useful in cases where competitive dynamics interfered with children's ability to make accurate colour-based decisions. Several children intentionally placed tiles on similar but incorrect colours in their desire to win, even though they were aware of the difference. This tendency showed how peer interaction can influence performance, and how important individualized and non-competitive play environments are in order to avoid false positives when colour discrimination skills are being assessed.

One of Colorfit's greatest strengths is its remarkable flexibility of play, making it accessible to a wide range of age groups and catering to the various special educational needs in schools.

6. Future Work

While many results have already been reached (Iocco et al., 2024), many goals are still within reach.

The Game4CED project is structured around four interrelated work packages (WPs), each addressing a key dimension of research, development, education, and dissemination related to accessibility in board games, with a particular focus on supporting individuals with CVDs. WP1 focuses on the development of evaluation tools and inclusive game design; WP2 addresses the topic of teacher training and educational resource development; WP3 ensures broad dissemination of results; and WP4 oversees project coordination and implementation. The following is a summary of the main objectives and activities within each work package. As to WP1, devoted to scientific research, criteria are being developed to evaluate the accessibility of a variety of board games, with an emphasis on colour vision deficiencies. While a framework has already taken shape, its application on the most voted board games according to the popular BoardGameGeek website is still ongoing. In WP2, devoted to education, the project aims to raise awareness and build teacher capacity around colour blindness and inclusive education through a structured toolkit and professional development. The toolkit will by the end of the project include videos, booklets, an online evaluation tool, a colorblind-friendly palette and various screening materials. As to WP3 and WP4, devoted to disseminating and managing the project, both activities are proceeding at full pace, with our group participating in various international symposia and conferences to present the early results of our research.

7. Conclusion

Using board games as tools for the early detection of colour blindness represents a meaningful step forward in preventing the challenges often associated with this condition. We believe that ColorFit offers a fast and effective way to identify individuals who may have difficulty perceiving colours.

The dissemination of the ColorFit documentation serves two main purposes: first, to raise awareness about colour vision deficiencies – particularly in educational settings – and second, to help identify and support students affected by these conditions from an early age. In this context, ColorFit could become one of the first board games of its kind to be used in schools independently, without the need for external experts.

We want to conclude by emphasizing that while board games like ColorFit can be useful as preliminary screening tools, they are not a substitute for medical diagnosis. Rather, they serve as a helpful starting point – providing early indications that may warrant further medical evaluation for colour vision deficiencies.

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Preserving Cultural Memory through Narrative Games

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Abstract: This article interrogates four narrative-driven video games as sites for the production, mediation, and transmission of cultural memory. Each title is anchored in distinct modalities of remembrance—ranging from post-Soviet historical and folkloric imaginaries to subjective affective trajectories and speculative, future-oriented mythologies. While situated in divergent cultural and temporal contexts, these works converge in their deployment of immersive storytelling and interactive world-making as mechanisms for negotiating cultural narratives and sociopolitical themes. To structure our analysis, we employ the T.R.E.E.S. framework—Tourism, Responsibility, Exploration, Environment, and Story—as a critical heuristic for examining how ludic design engenders processes of meaning-making and mnemonic inscription. By situating these games within a human-centered theoretical paradigm, we contend that interactive narrative constitutes not merely a representational strategy but a dynamic technology of cultural sustainability and an emergent vector for social innovation.

Keywords: Videogames, culture, heritage

1. Introduction

In an era of rapidly advancing technology, digital platforms are increasingly used to serve the public good – from education and healthcare to cultural heritage preservation. Interactive digital media, especially video games, have a unique capacity in this effort. Games are more than entertainment; they can act as cultural archives, educational tools, and empathy-generating experiences. Recent scholarly work underscores that digital games can facilitate the preservation and dissemination of intangible cultural heritage, engaging users in active cultural communication and ensuring cultural knowledge "surviv[es] over time" through technological adaptation (Wang and Men, 2025). In other words, narrative-rich games can become vessels of cultural memory, carrying stories, values, and histories into the future.

This article examines four narrative-driven video games – Last Days of Lazarus, Sea of Solitude, Season: A Letter to the Future, and Black The Fall – and analyzes how each preserves and represents cultural memory. Each of these titles is deeply rooted in personal or collective pasts: from post-Soviet national trauma and folklore to individual emotional journeys and futuristic folklore. Despite their diverse settings, all four games employ immersive storytelling and interactive world-design to engage players with cultural narratives and social themes. Using the T.R.E.E.S. framework (Tosi and Ochoa, 2025), we evaluate each game along these dimensions. This approach reveals how games can serve as virtual tourism to cultural landscapes, as ethical playgrounds fostering empathy, and as narrative spaces encoding history and values. By exploring these case studies, we gain insight into the potential of narrative games to function as digital cultural heritage tools, preserving memory and provoking reflection for players around the world.

2. Post-Soviet Remembrance in Last Days of Lazarus

Last Days of Lazarus (Darkania Works/GrimTalin, 2022) is a first-person adventure steeped in the history and spiritual ethos of post-communist Eastern Europe. Set in Romania around the turn of the millennium, the game follows Lazarus, a man returning to his childhood home after his mother's death, only to uncover supernatural occurrences entwined with his family's and nation's past. The developers have described the title as "a letter of love" to Romania, recreating real locations and religious practices within the game world. Indeed, Last Days of Lazarus functions like a digital time capsule of Romanian cultural memory: it takes place in a society still coming to terms with its communist past, and its narrative tapestry weaves together historical trauma, Orthodox Christian imagery, and local folklore (Brierley, 2022; Peterson, 2022).

2.1 Tourism

Last Days of Lazarus offers a guided tour of Romanian locales laden with cultural significance. It leads players through intimate spaces—a cramped Soviet-era apartment, a candle-lit village church, a snow-covered cemetery—each filled with authentic details like Orthodox icons and folk art. By exploring these faithfully recreated settings, players effectively become cultural tourists in a virtual Romania, experiencing its post-Soviet atmosphere firsthand. The game's curated objects and architecture turn the journey into a cross-cultural experience, allowing outsiders to appreciate Romanian heritage from the inside (Brierley, 2022).

2.2 Responsibility

Although Last Days of Lazarus does not have branching choices, its narrative places moral weight on the player. Lazarus—and by extension the player—must confront guilt and historical injustices entwined with his family. Solving puzzles to unearth buried secrets becomes an act of remembrance and reconciliation. The game treats collective trauma with gravity, asking the player to honour the memory of a nation's painful past through empathy. Even without a morality meter, players often feel responsible for acknowledging and "righting" the wrongs of the past (Peterson, 2022).

2.3 Exploration

Exploration is key in Last Days of Lazarus. Players scour each environment for letters, photos, and Soviet-era memorabilia that reveal the story. The deliberate pacing encourages absorbing historical details rather than rushing. While the progression is chapter-based and linear, within each chapter players can search every corner, effectively acting as archaeologists of narrative. This interactive uncovering of personal and political history ensures the player actively participates in rediscovering cultural memory (Peterson, 2022).

2.4 Environment

The game's environments themselves tell stories. The family apartment is rendered with lived-in realism—Orthodox icons on the walls, faded photographs, and clutter that hint at family secrets—grounding the supernatural plot in a tangible cultural space. Folkloric and religious imagery woven into puzzles and scenery (iconography, ritual objects, church paraphernalia) help preserve bits of Romanian intangible heritage in digital form. Each location—from a bleak concrete apartment block to a misty graveyard—is haunted by history, and together these spaces form a digital memorial to Romania's transitional era (Brierley, 2022).

2.5 Story

Last Days of Lazarus blends family drama, supernatural horror, and historical allegory to explore Romania's post-communist trauma. Lazarus's journey to uncover his family's buried secrets gradually reveals wartime atrocities and communist-era crimes. By using otherworldly elements as metaphors, the game makes confronting this painful history more accessible and emotionally resonant, echoing traditions of magical realism. Ultimately, facing these dark memories—no matter how strange or painful—is shown to be necessary for healing. The story invites players outside Romania to empathise with an Eastern European perspective often overlooked, preserving cultural memory through an immersive, cathartic narrative (Brierley, 2022; Peterson, 2022).

3. Inner Demons and Empathy in Sea of Solitude

Sea of Solitude (Jo-Mei Games, 2019) shifts the focus from national history to personal and emotional memory in a contemporary urban setting. Set in a flooded, nightmarish version of Berlin, the game follows a young woman named Kay as she navigates a submerged city transformed by her feelings of loneliness and despair. In this introspective adventure, Kay herself has become a monster—a reflection of her self-perception—and the other "monsters" she meets are actually her family members and loved ones, each consumed by their own traumas. The game's concept was inspired by creative director Cornelia Geppert's real-life struggles with depression and isolation, as well as those of people close to her, lending Sea of Solitude a deeply personal authenticity (Favis, 2019; Cintron-Gonzalez, 2023). The result is a poignant depiction of mental health issues through symbolic storytelling and evocative environments that has resonated with many players.

3.1 Tourism

Sea of Solitude takes the player on a metaphorical tour of a young woman's inner world rather than a real city. As Kay navigates a half-submerged, distorted Berlin, familiar urban sights are twisted by her loneliness and despair. This surreal environment makes the player a tourist in Kay's psyche, illustrating how a modern city can feel empty and threatening through the eyes of someone overwhelmed by isolation. By "sightseeing" in this psychological landscape, the game fosters empathy for experiences of loneliness that often go unseen (Favis, 2019).

3.2 Responsibility

Though Sea of Solitude has no explicit moral choices, its narrative is about compassion and accountability. Kay must take responsibility for her own emotions and also help her loved ones (manifested as monsters) confront theirs. Instead of fighting creatures, the player "wins" by listening, forgiving, and comforting—turning monsters

back into humans through empathy. The game thus reinforces that true responsibility in an emotional crisis is to understand and support, not to battle (Cintron-Gonzalez, 2023).

3.3 Exploration

Sea of Solitude encourages slow, introspective exploration. Players wander the flooded city at their own pace, discovering bottled messages and other remnants of Kay's life that reveal backstory. With no enemies or timers, players are free to linger and reflect as the world subtly changes with Kay's emotional progress (storms calm as conflicts resolve). In this way, exploring the environment becomes a journey through Kay's memories and feelings, allowing players to engage deeply with her emotional narrative (Favis, 2019).

3.4 Environment

The environment is Sea of Solitude's most powerful storytelling tool. Dark waters and storms rage when Kay is overwhelmed by fear or anger, while moments of calm and sunlight emerge as she finds hope. The city is both realistic and surreal: recognizable buildings stand empty amid giant creatures and fantastical weather, symbolising how mental illness can distort one's world. This visual metaphor for loneliness and depression communicates emotional truth across cultures. The game was recognised by mental health advocates for portraying isolation and hope authentically (Oculus, 2019).

3.5 Story

Kay's story in Sea of Solitude is simple yet deeply personal: she learns that she is not alone and that the darkness can recede. Geppert drew on her own and others' experiences of depression (Favis, 2019), giving the narrative sincerity. The monsters Kay faces are her family's and her own inner demons—her bullied brother, her estranged parents, her grieving lover—and helping them also means healing herself. By the end, Kay sheds her monster form by forgiving herself and those she loves. This cathartic journey resonated with many players: some felt understood and others even sought therapy after playing (Cintron-Gonzalez, 2023). Sea of Solitude not only preserves a snapshot of how our culture talks about mental health, but it actively helps people feel less alone.

4. Archiving a World in Transition in Season: A Letter to the Future

Season: A Letter to the Future (Scavengers Studio, 2023) is a serene, meditative adventure explicitly centered on preserving cultural memory. The game is set in a beautiful yet melancholic world on the brink of a great change—the imminent end of the current "season," which represents an era. The player controls Estelle, a young woman from a secluded mountain village who ventures out for the first time to document the wider world's cultures, histories, and landscapes before they are swept away by this mysterious change. Armed with a bicycle, a camera, an audio recorder, and a journal, Estelle travels as a wanderer-archivist: she records sights and sounds, interviews the people she meets, and assembles a collection of memories—a literal "letter to the future" encapsulating what it was like to live in this time. Season's emphasis on slow, mindful exploration and documentation makes it a contemplative experience, often described by players as a playable travel diary or ethnographic study (Alabastro, 2023). In essence, the game itself is a cultural time capsule compiled by its creators, paralleling Estelle's in-game mission of cultural preservation (Sullivan, 2023).

4.1 Tourism

Season turns gameplay into cultural tourism. As Estelle, you bicycle through picturesque regions and document vanishing cultures by photographing, sketching, and audio-recording your surroundings. The game treats each fictional community with respect—you might record an elder's folk song or photograph a mural of an ancient legend, moments akin to preserving real traditions. With no combat or urgency, Season invites players to explore at leisure, like travellers savouring a foreign land. By acting as both tourist and archivist in this virtual world, the player gains an appreciation for the fragility and beauty of cultural heritage (Sullivan, 2023).

4.2 Responsibility

Season instils a sense of duty to preserve memories. Estelle embarks on her journey because she feels obligated to capture her era's essence for the future, and players share this burden by deciding what to record in her journal. You cannot document everything, so each photo or audio clip carries weight—what you choose to preserve will shape how this world is remembered. The game quietly makes you a curator of culture. It also encourages respectful engagement: in conversations, you can respond with empathy or participate in local

customs (like joining a monk in a final ritual). By slowing down and caring about each story, Season models an ethic of preservation and respect for cultural heritage (Alabastro, 2023).

4.3 Exploration

Exploration is the heart of Season. With no enemies or time pressure, players are free to wander and follow their curiosity. In one valley, for example, you can discover a deserted market, a mural on a cliff, or remnants of a farewell festival—uncovering the story of a community's final days in whatever order you choose. The more closely you explore and observe, the richer your journal becomes and the clearer the bigger picture grows. Season rewards patience: a faint bell sound or a pattern in graffiti can lead to hidden insights. This gentle, open-ended exploration often sparks reflection; as you coast through sunlit fields or silent streets, you cannot help but contemplate impermanence and change in your own life (Sullivan, 2023).

4.4 Environment

Season's world is rich with story and sensation. Each location feels like a snapshot of an ending era—say, a town square still adorned with festival lanterns but eerily empty as evacuations loom. The game engages sight and sound equally: you not only see the ruins and sunsets, you also record ambient sounds (wind in chimes, prayers in a temple), which makes you keenly aware of the life in each place. By listening and observing, you actively help memorialise the environment. Nature is treated with reverence throughout; the game shows how deeply cultures are tied to their landscapes. As the "season" (and the world as these people know it) draws to a close, Season movingly portrays how losing a place means losing the culture connected to it. The emotional impact of leaving each area—feeling as if you have said goodbye to a living world—underscores how well Season uses its environment to make players care about cultural and ecological memory (Alabastro, 2023).

4.5 Story

The narrative of Season unfolds through the memories you collect rather than a conventional plot. There is no villain to defeat; instead, the story emerges as a mosaic of personal histories from the people and places Estelle encounters. Key revelations (like the true nature of the "season" change) add poignancy to your journey, but the focus is on preservation. The brilliance of Season's storytelling is that it makes you care about a world you know is transient. You feel an urgency not to fight against change, but to save what you can of it—photographing a way of life before it disappears. In effect, the player becomes a custodian of cultural memory, much like an oral historian recording stories before it is too late. By the end, when the season changes, the moment is bittersweet: you cannot stop the change, but you have preserved a slice of that world in Estelle's journal. It is a gentle call to action for our own lives as well: cherish the present and carry its lessons forward as a "letter to the future" (Sullivan, 2023).

5. Remembering Oppression: Dystopian Memory in Black The Fall

Black The Fall (Sand Sailor Studio, 2017) returns us to Eastern Europe – this time through a fictional dystopia rooted in the cultural memory of Romania's communist era. Often described as a Limbo/Inside-like puzzle-platformer, Black The Fall distinguishes itself by drawing heavily on historical reality. It is directly inspired by the oppressive conditions under Nicolae Ceaușescu's dictatorship, which lasted from 1965 until its violent end in 1989. The game casts the player as an unnamed machinist (nicknamed "Black") attempting to escape a grim industrial labour camp in a totalitarian state. Throughout Black's side-scrolling journey, the game world is filled with imagery and scenarios that reference life under a communist regime: surveillance cameras that shoot on sight, loudspeakers blaring propaganda, giant portraits of the "Dear Leader," and downtrodden workers obeying routinised commands. These elements are not generic dystopian tropes—they are carefully modelled after real events and iconography from Romania's communist period. The Romanian developers have noted that Black The Fall was born of personal and collective memory: lead designer Cristian Diaconescu was a child during the 1989 Revolution and vividly remembers the fear and propaganda of that time. The team "tied in their own repressive past" to the game's design, aiming to convey to players "what it might be like to live under a totalitarian regime" (Fiscutean, 2017; Orosz-Réti, 2023). In effect, Black The Fall is both an interactive memorial and a warning, translating lived historical experience into gameplay.

5.1 Tourism

Black The Fall offers an unsettling tour of a totalitarian society. The game is linear, but it immerses players in a grim recreation of 1980s Communist Romania under Nicolae Ceaușescu. You traverse factories, housing blocks, and train yards that each showcase aspects of life under oppression—forced labour, constant surveillance, ubiquitous propaganda (Fiscutean, 2017). In one scene, actual footage of Ceaușescu's speeches flickers in the

background, underscoring that this dystopia draws directly from history. For those unfamiliar with Eastern Bloc history, Black The Fall serves as a harrowing glimpse into that world—more experiential than a textbook because you are trying to survive it. One critic called it "a fictional journey through a dystopian hellscape" rooted in real Romanian communism (Orosz-Réti, 2023). By placing the player inside this nightmare, the game functions like a playable museum of oppression and forces you to confront a dark chapter of cultural memory.

5.2 Responsibility

Black The Fall confronts the player with uncomfortable ethical trade-offs. Escaping the regime is righteous, but survival sometimes comes at a moral cost. For example, at one point you must use a mind-control device to sacrifice another prisoner as a distraction so that you can slip by—a choice the game forces upon you. Moments like this, where you save yourself by endangering someone else, instil guilt and mirror the cruel dilemmas people faced under tyranny. By making the player complicit, the game highlights the theme of responsibility versus survival. In the end, Black himself makes a small but symbolic stand: he helps pull down a giant wall (evoking the Berlin Wall) as a popular uprising unfolds. The developers do not cast him as a grand hero, but they let you feel the satisfaction of contributing to the regime's collapse. On a meta level, finishing Black The Fall means you have borne witness to its cautionary tale—an "actually existing" dystopia that warns what can happen if we forget the past (Orosz-Réti, 2023).

5.3 Exploration

The lack of freedom to explore in Black The Fall is itself part of the storytelling. The game confines you to a narrow, side-scrolling path—fitting for a world where movement and choice are brutally restricted. This imposed linearity makes the player feel the regime's claustrophobic control firsthand. Even so, you engage in a kind of systemic exploration: each level is a puzzle where you learn how the oppressive machinery works and find ways to subvert it. You observe guard patrols, exploit blind spots in cameras, and use factory equipment to outsmart the system. In one sequence, you march in lockstep with brainwashed workers to avoid detection, briefly experiencing enforced conformity. Occasionally, the camera pulls back to reveal the vast scale of the dystopia—endless factories and countless prisoners—giving you a glimpse of the regime's scope. Ultimately, Black The Fall uses limited exploration as a narrative device: you feel truly trapped until the moment you finally break free (Fiscutean, 2017).

5.4 Environment

The world of Black The Fall viscerally evokes Cold War-era oppression. The colour palette is drab grey and black, with flashes of red warning lights and communist stars, immediately signalling danger and control. The environments draw on real historical details: grim factories where humans are treated as cogs, dingy barracks plastered with propaganda, secret nooks where someone risks tuning in to Radio Free Europe (Fiscutean, 2017). These touches root the game's fiction in actual 20th-century Romania. The developers even include Ceaușescu's likeness and propaganda speeches, blurring fiction and reality. A powerful visual metaphor comes when Black drives an armoured machine through a towering concrete wall (clearly evoking the Berlin Wall) and steps into the rain-soaked freedom beyond. The sky opens up for the first time, symbolising liberation. In effect, Black The Fall's environment serves as an interactive memorial to life under dictatorship. It preserves the look and feel of that oppressive era in a form players can experience firsthand. Those who lived through similar times have praised its authenticity, while others have found it an eye-opening education in oppression (Orosz-Réti, 2023).

5.5 Story

Black The Fall tells a story of oppression and liberation with almost no words. You begin as a voiceless worker pedalling a factory machine and end amidst a revolution that topples the dictatorship—all conveyed through gameplay and imagery rather than dialogue. The narrative is rich in symbolism: for instance, a small one-legged robot befriends Black and later sacrifices itself to save him, adding a poignant note of friendship in an otherwise brutal world. The game's message is a warning about how easily freedom can be crushed and how people can be made complicit (the silent workers pedalling in unison). Yet it also offers hope: even the worst regimes can fall. In the final moments, Black emerges to see a flag with its tyrannical emblem cut out—a direct reference to Romania's 1989 revolution (Fiscutean, 2017; Orosz-Réti, 2023). By explicitly tying its climax to a real historical event, the game ensures the player understands the real-world parallel. Created by developers who themselves remember life under communism, Black The Fall stands as both a memorial and a cautionary tale. It transforms personal and collective memories of oppression into a universally accessible story, reminding players that these lessons remain painfully relevant.

6. Conclusion

By examining Last Days of Lazarus, Sea of Solitude, Season: A Letter to the Future, and Black The Fall through the T.R.E.E.S. framework, this article has shown how narrative-driven video games function as powerful vessels of cultural memory. Each title transforms individual or collective pasts into interactive experiences: Romanian post-communist trauma, deeply personal struggles with mental health, a fictional world on the cusp of disappearance, and a dystopia reflecting real histories of dictatorship.

While these games differ in setting, mechanics, and tone, they share a commitment to preserving memory through immersive environments, exploratory play, moral or emotional responsibility, and narrative resonance. In this way, they act as digital archives and empathy engines, offering players opportunities to engage with cultural memory not passively but through lived, interactive experience.

The T.R.E.E.S. framework has proven effective in structuring this analysis: Tourism (seeing and experiencing worlds as cultural spaces), Responsibility (facing moral or emotional weight), Exploration (discovering histories and meanings), Environment (world-building as cultural preservation), and Story (narrative as mnemonic device). Together, these dimensions demonstrate how games go beyond entertainment to become cultural artefacts in their own right.

Ultimately, narrative-rich video games can complement traditional archives, museums, and oral traditions as carriers of cultural memory. As this study shows, their ability to immerse players in perspectives and histories fosters deeper cultural empathy and ensures that stories, values, and lived experiences endure in collective consciousness.

7. Ethics declaration

Ethical clearance was not required for the research

8. AI declaration

Open AI chat GPT 5 (Auto version) has been used to double-check the proof-reading and “professional fashion” style required by ad hoc prompt.

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