

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

Volume 1

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**Proceedings of the
19th European Conference on
Games Based Learning**

ECGBL 2025

**A Conference Hosted By
Nord University
Levanger, Norway
1-3 October 2025**

**Conference Proceedings Edited by
Helga Dis Isfold Sigurdardottir and
Robin Isfold Munkvold**

Volume 1

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Papers submitted to this conference have been double-blind peer reviewed before final acceptance to the conference. Initially, abstracts were reviewed for relevance and accessibility and successful authors were invited to submit full papers. Many thanks to the reviewers who helped ensure the quality of all the submissions.

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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 to a 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 on 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 *Lapitude: 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



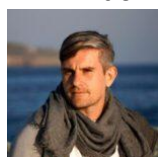
Robin Isfold Munkvold is a researcher and educator at Nord University with over a decade of involvement in the European Conference on Game-Based Learning (ECGBL) network. His research over the past 10-15 years has focused on enhancing the quality of technology programs in higher education, with specific 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

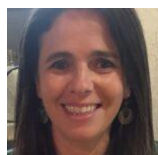


Tim Laning is the CEO and co-owner of Grendel Games, an independent award winning serious game development company from Leeuwarden, The Netherlands. Grendel Games has been focused on creating games that drive behavior change for almost 25 years. The company is focused on three different sectors: healthcare, 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 Gamelabboost in the municipality of Enschede. Guido furthermore is involved in several startups and organizations in the field of organizational improvement, applied gaming, and esports.

Best Practices in Cross-Sector Partnerships for Educational Game Design

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Abstract: Studies on learning have affirmed the importance of digital games for learning across a range of disciplines, yet the actual task of creating educational games faces the challenge of structuring productive partnerships between academic content experts, student partners, and professional game designers. Based on our team's creation of the language-learning game "Brendan's Voyage," this paper proposes scalable practices for maximizing successful collaboration in game design. As a game designed to teach medieval French language and culture, "Brendan's Voyage" has had three distinct phases: solo development, student collaborations, and professional partnerships. In 2022, the project received a two-year NEH (National Endowment for the Humanities) grant to create a deliverable educational game in conjunction with an independent game development company, Causeway Studios. Whereas academic partners are likely to emphasize the importance of accurate content and pedagogically sound game activities, game designers may reasonably prioritize the aesthetic coherence, the logistics of game mechanics, and the enjoyability of the game. These two kinds of goals are both essential to a successful educational game, yet these goals can be at cross purposes in the practical workflow of game creation. Rather than framing these as competing agendas, this paper describes clear pathways to ensure both concerns are incorporated into successful game design. These insights stand to empower other academics and game designers who hope to collaborate with maximum success toward the end of creating effective educational games.

Keywords: Game design, Educational games, Second language acquisition, Collaborative development, Cross-sector partnerships

1. Introduction

1.1 General Outline

Supported by a Level-II Digital Humanities Advancement Grant from the NEH, *Brendan's Voyage* is a five-module video game designed to teach basic pronunciation, vocabulary, and grammar of the medieval Anglo-Norman language, a variety of Old French. As a result of over a decade of development, the game evolved through many forms of solo and collaborative development. We first reflect on the project history with a focus on the various collaborative models that have produced *Brendan's Voyage* in its current form. We then elaborate a key set of best practices to help other academics refine their vision for serious games, locate professional game design partners, collaborate with multiple stakeholders including students, and produce games within budgetary constraints.

1.2 Literature Review: Digital Games for Learning

Studies affirm the educational value of digital games across disciplines (Ibrahim et al., 2012; Rooney and Whitton, 2016; de Carvalho and Coelho, 2022; Tranter et al., 2024). Ibrahim et al. (2012) emphasize that aligning gameplay with learning goals boosts motivation and engagement. Rooney and Whitton (2016) highlight the potential of games to create immersive, interactive spaces for experimentation. De Carvalho and Coelho (2022) note the effectiveness of games in stimulating intrinsic motivation and deepening engagement through immersion and structured play. Similarly, Tranter et al. (2024) demonstrate how gamification strategies, such as interactive quizzes and collaborative game-based activities, can result in increased student confidence, socialization, and improved retention of learning content. Despite this growing recognition, academic experts in diverse content areas still face challenges related to resources, connections, and funding to design educationally robust and enjoyable games (Dimitriadou et al., 2021).

This article addresses those challenges, sharing scalable practices from our work on *Brendan's Voyage*, a language-learning game developed with Causeway Studios. We outline key strategies for successful collaboration between game designers and academic specialists, reflect on outcomes and obstacles, and offer guidance for others looking to create serious games. While adaptable, the model will require adjustments based on context.

1.3 Brendan's Voyage: A Brief History

Brendan's Voyage takes the player to the twelfth-century court of Lady Adeliza of Louvain, the historical figure who likely commissioned the translation of St. Brendan's mythic ocean voyages from Latin into Anglo-Norman French. Players learn to speak, understand, and write basic Old French while exploring key aspects of French-speaking medieval England. The first three modules cover female artistic patronage, manuscript production, and medieval markets. In modules four and five, the player enters St. Brendan's story through a magical codex (Figure 1), joining the Irish abbot's journey to the Earthly Paradise with his fellow monks. The game teaches core elements of Anglo-Norman French through a narrative grounded in the political, material, and religious cultures in which the language was used (Abell & Ramey, 2023a, 2023b), offering an alternative to outdated methods of teaching medieval languages (Ramey & Wenz, 2016).

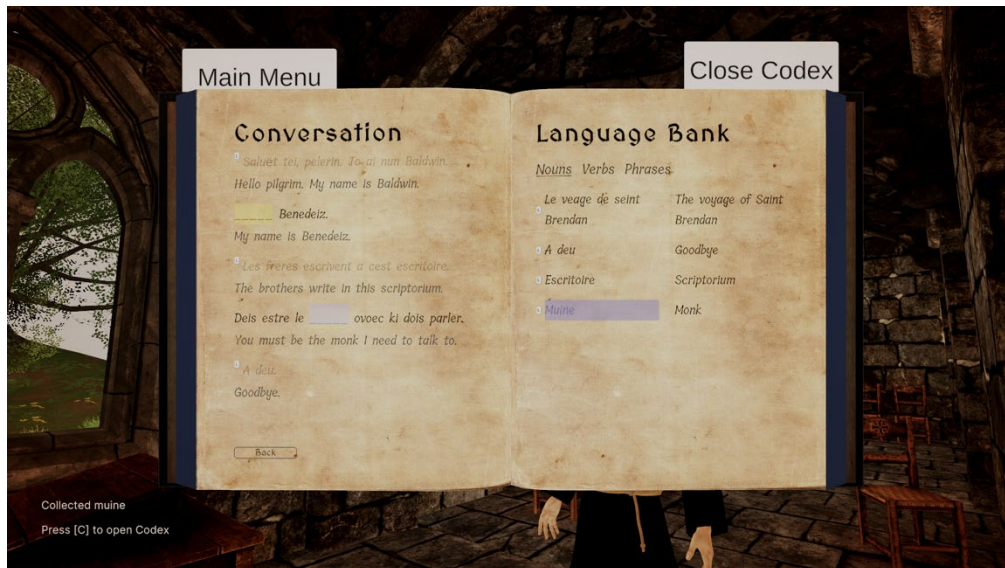


Figure 1: The interface of Brendan's Voyage allows the player to collect key vocabulary in a magical codex

Brendan's Voyage was the result of more than a decade of collaboration between Lynn Ramey (Vanderbilt), Jacob Abell (Baylor University), professional game designers, students at several institutions, and grant personnel. Throughout this process, *Brendan's Voyage* was supported through a wide variety of project development models ranging from individual design (the "solo approach") to financially supported collaboration with professional game designers.

2. Models for Game Development

2.1 The Solo Approach

The project grew out of two NEH-ODH institutes focused on training humanists in 3D cultural heritage modeling. At the 2013 institute "Humanities Heritage 3D Visualization: Theory and Practice", Ramey learned to build immersive environments using Blender, SketchUp, and Unity. She then established a video game lab at Vanderbilt University and began training students in 3D modeling and Unity. In summer 2015, she continued work at the institute "Advanced Challenges in Theory and Practice in 3D Modeling of Cultural Heritage Sites." Serving as subject matter expert and game developer provides creative control but is impractical given the complexity of the immersive language and culture platform. Many assets (especially medieval-themed) can be purchased from online sources, but the lack of artistic coherence and the mistreatment of historical contexts create discontinuity in the game. For instance, medieval women models available for purchase do not represent the variety of roles that women occupied in medieval society: women warriors and bar wenches are overrepresented, while few models can serve convincingly as a nun, scribe, or domestic worker. These limits illustrate Houghton's contention that medievalist video games often reduce women to modern stereotypes (2024). Working with a team gives fullness to a game's cultural context, bringing together specialists in the creation of art, music, sound, voice acting, programming, UI, narrative, historical context, and version control.

2.2 The Constructivist Approach: Students Creating Projects

After a period of solo work, the project shifted to a collaborative, constructivist model involving graduate and undergraduate students. This emphasized "Collaboration," one of the core values of digital humanities identified

by Lisa Spiro (Spiro, 2012). With a seed grant from Vanderbilt's Institute for Digital Learning, Ramey led a paid summer training session for students in 2015.

Following constructivist theory, which holds that learners build knowledge through active engagement (Piaget, 1973; Bada, 2015; Taber, 2024; Vygotsky, 1986), the project became a learner-driven lab. Students, faculty, and staff explored tools, roles, and narratives together. Unlike traditional solitary, text-based humanities learning, this model encouraged active problem-solving in real contexts. Game development using tools like Unity3D, Photoshop, Blender, and Perforce provided that context. Students learned by doing: designing levels, writing dialogue, customizing models, recording audio, and managing assets. Learning emerged organically from the project's needs.

After the summer session, work continued through internal institutional grants (Ramey and Panter, 2015). While students developed significant skills, the lack of effective version control and the continual turnover of key student workers prevented the game from reaching a release-worthy state. Research was clearly needed in several areas: 1) effective game types for teaching language, 2) essential elements of medieval grammar, 3) strategies for pronunciation and orality in dead languages, and 4) best practices for teaching culture and identity in an immersive environment.

2.3 The Course Integrative Approach

In fall 2017, a collaboration between STEM and humanities faculty at Vanderbilt University brought together computer science and humanities students to build 3D immersive environments using a video game engine. As a course-affiliated professor, Ramey led an interdisciplinary team of four students in creating a digital story about the transmission of medieval texts across languages and cultures. Students, assigned by the course instructors, included one with Unity experience and two computer science majors. They determined their own project scope and divided tasks based on interest and ability.

Students decided to create a game mechanic where users collect stories line by line by trading with other characters, successfully telling a story, or eavesdropping on other characters. Using the Oculus Rift, they created a fully embodied VR experience. Working with mixed groups of STEM and humanities students, faculty, and staff provided a low-cost way forward with the additional advantage of facilitating faculty-student interaction and student learning through the production of knowledge. However, the limited time (one semester) and the constraints of coursework requirements meant progress was limited. Students struggled with conveying their process in a way that a group could pick up where the last team left off. While a new team attempted to work with a project state left by a previous group, mistakes and poor choices made by the previous group frustrated the new group. For instance, the first group used a VR interface that integrated visual menuing in the gameworld. Unfortunately, the team did not troubleshoot the system, and the menus generated nonsensical choices. The second team was understandably uninterested in spending time fixing the mistakes of the first group. When working with a project across student groups where the entire team changes, the best approach would be to divide the entire project into parts or modules that can be developed independently. The basic framework, user interface, and art assets/style should be established before starting work on any of the modules, but the freedom to develop a freestanding module gives each student group the fresh start needed to build for their own goals; usually, those goals center on learning teamwork, game development, and aspects of computer science rather than the content area that the game aims to address.

At a certain point, we found that game development in a modular fashion leads to some enriching student experiences, but the game lacks the fundamental polish to be useful or even beta-test worthy. Someone needs to knit the modules together and address the inevitable bugs that will emerge. This guiding hand can come from the project head or from the eventual establishment of a lab group with paid student workers who take on increasingly managerial roles over time. This model has been implemented in several academic settings, notably by David Fredrick and his game development group Tesseract at the University of Arkansas, by David Neville at Grinnell College, and by Austin Mason at Carleton College. Each setting is slightly different, but they all work on the model of a consistent vision provided by the lab director and the establishment of a system where students who stay with the project for several years can take on managerial roles (head of art, head of sound, head developer, etc.). This lab group model provides students with credible experience in increasingly responsible roles as they head into the workforce after graduation.

2.4 The Professional Partnership Model: A Scalable Summary of (Some) Best and Worst Practices

After positive experiences working with students and faculty at the University of Arkansas and Vanderbilt, it became clear that the most robust and functional vision of *Brendan's Voyage* would require the collaboration

of a professional video game design company. To secure the needed funding, we applied for a Level II Digital Humanities Advancement Grant from the National Endowment for the Humanities. We were fortunate to receive the grant in 2022, which provided financial support for a project period of two years. After soliciting bids from multiple game companies, we chose to work with Causeway Studios owing in large part to their strong track record of producing serious games for language education.

Over the first several months of the project, the game design team and the scholarly team wrote the game script together. Based on the twelfth-century Old French tale *The Voyage of St. Brendan the Abbot*, the game would present five modules that implement environments based on the historical setting in which the Brendan poem was translated into Old French, as well as fantastical stories from the Brendan poem itself. For each game module, the scholarly team identified key language and cultural learning outcomes for players to accomplish. The team identified essential vocabulary, grammatical principles, and passages of text from the original Brendan narrative that needed to be incorporated into the modular activities. Equipped with these learning goals, the design team wrote the initial draft of the script for each module, which was then revised based on feedback from the scholarly team. Abell and occasional student partners would record the Old French dialogue in studios located on the Baylor University campus. We then repeated this process for all five modules, periodically consulting advisory personnel to ensure the linguistic production was of high quality and to affirm that the game design was conducive to successful learning. Principal production was completed in a little over a year.

Based on the process of collaborating with Causeway, our team has identified best practices for structuring successful collaboration between game designers and academic content specialists. There were also challenges. We reflect on the major results of both categories below. We hope these strategies can equip other academics with the skills they need to produce their own serious games with professional game companies. This model is scalable but will require adjustments for varying circumstances.

3. Structuring Successful Collaborations

3.1 Best Practice: Determine What Financial Resources are Available for Your Project: Solicit Multiple Bids From Game Designer Companies

Working with professional game design companies is expensive, but it can be done for less money than one might expect. The length, scope, and complexity of your game all contribute to overall costs. As an academic, you may have research funds associated with your position, internal institutional grants, or pathways to securing national grants. We built different iterations of *Brendan's Voyage* with all these varieties of funding. In short, do not assume that you cannot build a functioning video game simply because funding is in short supply. What is more, it can take multiple rounds of application to secure a national grant, as it did for us.

That said, it can be wise to develop multi-institutional partnerships to maximize internal grants or other financial resources. As of this writing (spring 2025), major digital humanities grant competitions have been terminated within the NEH; it is unclear how long this development will last, but what is clear is that scholars must innovate alternative pathways to fund serious game development for the foreseeable future. Consult other scholars who have built games, talk to grant officers, and open conversations with game companies that have a track record of producing serious games. In our experience, such companies are eager to speak with prospective academic partners, even willing in some cases to draft a provisional budget for free.

Finally, soliciting multiple bids can be extremely helpful as a way to learn about unexpected strengths and limitations of prospective video game design partners. All three companies that submitted bids for our project showed strong skills and experience, albeit at different levels. We asked for budget proposals from each company and spoke with their leaders at length about how they were uniquely suited to execute our project goals. By asking thorough questions and comparing proposals, we were able to choose our partner with confidence that they could deliver the product in a timely fashion, collaborate openly with academic partners, and infuse our vision with creative design ideas.

3.2 Best Practice: Continue to Partner With Students at a Range of Skill Levels: These Partnerships Benefit Young Scholars, Future Game Designers, and you

While working with a professional design company, we continued to collaborate with students at high school, undergraduate, and graduate levels. A local high school student approached us and described her hopes to study medieval cultures at the university level; our team invited her to research the aesthetics of key garments and architecture of twelfth-century England. The student then reported her findings in a series of Zoom calls with the design and scholarly teams present. That research yielded discernible impacts on both teams' creative

processes. Similarly, the scholarly team acquired an internal grant from Baylor University to hire a group of three undergraduate students (one of whom was a recent alumnus) to implement refinements to the game after the initial completion period. With a diverse set of skills in computer science, French language, and project management, this student group helped the scholarly team to test the game, perform key changes, and generate a website to house the game with accompanying pedagogical resources for instructors and play testers.

Partnering with students empowers future academics (Burns, 2020; Campbell, 2022; Cook-Sather et al., 2014) and game designers. Jobs are increasingly scarce in the academic humanities; while careers in professional game design still seem on track to expand in coming years, the industry is very competitive. By mentoring students within professional game partnerships, academics can help nurture future humanists and game designers while also imparting transferable skills to students who go on to work in other professions. It is equally important that student partnerships be supported fairly; exploitation of student labor is an unfortunately common practice, and we strove at every level of our project to ensure that students were receiving proper credit, support, or compensation depending on the nature of their involvement. What students receive from such a partnership can vary based on context: a graduate student may be paid as part of a grant, whereas an undergraduate might elect to volunteer their skills to help meet a requirement for a university course. Regardless, it is incumbent upon academics producing games to reflect regularly on how their students are being properly supported for their contributions.

3.2.1 Challenge: Balancing entertainment value and linguistic difficulty can present obstacles for serious games that aim to teach languages. Develop a plan for script development with game design partners

As part of our workflow, Causeway Studios asked to produce the first draft of each game module script. This approach was designed to allow the game production experts to sculpt the flow of each module with a priority for user playability and enjoyment. As the academic team, we supported the need for this approach; as academics, we acknowledged that our experience with writing game script was much less developed than design professionals. Approaching the script this way was hardly a “worst practice,” but it did present key challenges that we believe can inform future collaborations.

Again, before the game design team wrote the initial draft of each modular script, the scholarly team provided an extensive list of key linguistic and cultural learning goals that needed to be achieved in a particular module. As the game designers wrote their script for a given module, they would embed the chosen Old French words, phrases, and grammar principles into dialogue that occurred naturally through the module’s varied tasks. From a creative standpoint, this approach was invigorating; it allowed our intended language goals to be realized through a dynamic and rewarding modular plot involving tasks, multiple characters, and richly designed visual terrains. Unfortunately, this approach to script development also meant that much of the dialogue had to be translated from English into Old French. Because the game designers were (understandably) not Old French language experts, much of the dialogue in the script drafts had to be simplified or changed to accommodate the specific vocabulary, style, and syntax of medieval French. Contemporary English is very difficult to render into a dead language, and we had to therefore strike a balance between the rich language of the script drafts and the need to compose Old French text that was culturally authentic. We therefore suggest that academics work with professional design partners to establish clear procedures for script development: who will produce script drafts and how will the academic content experts contribute? What kinds of feedback will be solicited and integrated into subsequent drafts? Clear communication around these questions is essential for successful collaborative approaches to serious game design (Dimitriadou 2021).

Fortunately, in our case, all parties had goodwill for each other’s content expertise and complementary needs for the game design. In fact, the need to balance a game’s playability with the pedagogical objectives can lead to productive script revisions between content experts and game designers. We frequently had to suggest strong simplifications of English text in order to translate the script accurately into Old French.

Based on our experience, we advise other academics to reflect early in their project on a plan for script development. As the content experts driving the game’s pedagogical objectives, what content and learning goals must be accomplished by the game as a whole? How can those goals be distributed across different modules, and how many should there be? Do these modules have to be situated within a particular kind of narrative or game mechanic? Ask these questions early with your game design partners to determine who should write the script draft and how you will collaborate on revisions. As an academic content expert, you may be reluctant to give up control, but remember that game designers create games for a living. They are the experts when it comes to translating educational goals into playable games. The more you can learn to respect that expertise, the more you can let your design partners help you achieve your pedagogical goals. That said, it is equally important to

protect your vision for the overall game objectives. Just as your design partners are experts in game design, you are the expert when it comes to the particular pedagogical and learning content of the game. The more you can create an environment of mutual trust, the more both teams can learn to rely upon each other's skills.

3.2.2 Challenge: Develop a clear plan for data storage and game access.

Data storage and game hosting platforms represent significant obstacles that need to be thoughtfully confronted at the outset of the project. The game was designed using the Unity game engine, a professional tool that can yield high quality games. We knew that our scholarly team would need access to the game architecture after the project period; beta-testing would point out opportunities for revision and errors to correct. However, despite having ample abilities with Unity software, our scholarly team encountered strong limits in our ability to implement even minor changes on our own to the game following initial production.

Version control was a difficult problem to solve from the beginning, and working with an independent game company did not fully solve the issues. The team from Causeway had a pre-established workflow using Unity's built-in version control. Since we had experienced problems trying to use GitHub for game applications with our student groups, we were open to new methods of development with the proviso that the code be conveyed to us in full at the end of the project period. The Causeway team provided the code, but it proved nearly impossible to extract from Unity's version control system, largely due to the subscription or proprietary assets that were used by Causeway. We continued to encounter errors using certain parts of the code, even when all elements had been scrubbed of the previous version control system.

Furthermore, our partners had optimized their work so that it would run in WebGL, loading elements in and out as needed and reducing asset file sizes as much as possible. Without the skills and software to replicate their optimization of memory use, we found that even tiny corrections to menus or sound files could result in a game that would no longer load correctly in WebGL. This memory optimization issue had a further consequence. Our method of delivery of the final game was via itch.io, a convenient and free platform to share browser games. However, itch.io has file size and number limits that we bumped against as we made changes. These structural limitations prevented the scholarly team from having full access to the assets and architecture of *Brendan's Voyage* after the initial completion of the game. Despite impressive efforts by our design partners to help us achieve this access, some limits persisted. We were unable, therefore, to implement all the changes to dialogue that we hoped to make after playing through the game in different settings with groups and individuals.

3.3 Best Practice: Leverage the Contrasting Expertise of Designers and Academics to Amplify the Game's Cultural Richness

Our partnership with Causeway Studios revealed the unexpected benefits that emerge when academic content experts and game designers work in an environment that explicitly encourages innovation. As our design counterparts began to learn more about the medieval language and literature featured in *Brendan's Voyage*, their staff increasingly challenged their own creative development of the game design. For example, module four required the designers to create a remote oceanic island on which Paul the Hermit, a monk featured in the original Old French story, welcomes St. Brendan during a stop on his voyage. The scene is set in a fictitious vision of sixth-century Ireland. Knowing this, our design partners asked the academic team to provide photos of authentic monastic dwellings dating to this period (or as close as possible). Originally, neither team had anticipated designing such a structure. The request came as a spontaneous development that grew out of mutual enthusiasm for the project as it developed. Inspired by this enthusiasm, we provided evidence for a medieval *clochán* which housed Irish monks in the Middle Ages. While these structures are typically dated to centuries that postdate Brendan's life, we nevertheless thought the inclusion of these structures might encourage players to learn more about medieval Irish monastic cultures.

Working with the photograph in figure 2, the game design team rendered a digital version of Paul's dwelling place (Figure 3). The resulting *clochán* enriched the cultural authenticity of the module. Such authenticity, even if inexact, fuels the immersivity that Kucher identifies as a key component of successful digital learning (2021).



Figure 2: A clochán located in Ireland (Dingle Peninsula). Public domain



Figure 3: A screen capture from Brendan's Voyage: Paul the Hermit stands before a clochán on his remote island

We hope these informed suggestions can empower and inspire academics to take the next steps to envision and execute digital games in productive partnerships with game designers. In an educational landscape in which digital technologies increasingly prevail, it is imperative that academics and game designers continue to refine their collaborative practices to better serve a digitally engaged global student population. Creating serious games such as Brendan's Voyage can be costly and challenging, but the process and results can revitalize academic disciplines through mutually productive partnerships between faculty, students, and professional game designers. We have argued that the essential basis for successful partnerships between academics and game designers is a sustained practice of communication to ensure all partners are maximizing their creative, technical, and content-based contributions to the game. In conclusion, we advise academics to explore the range

of collaborative models proposed here to match project needs, budgetary constraints, and educational outcomes.

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

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A Structured Approach for Designing Effective Serious Games for Learning: Analyzing Requirements to Derive Key Components

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Abstract: Recently, serious games have attracted significant interest as learning tools in various educational and training fields. They have emerged as powerful resources for improving learning outcomes. In this research, we explore the potential of virtual experiences and game-based applications beyond the entertainment industry and examine their multifaceted impact on education. We identify and conceptualize the functional requirements and aspects involved in developing and enhancing serious games for learning. These requirements form the basis for constructing concrete components that are reusable and applicable across different domains and learning topics. They can facilitate the design process, give the development team access to high-quality and up-to-date components, and support collaboration among multidisciplinary teams. Additionally, they help reduce the complexity and effort associated with serious game design. These components are categorized into three groups to form a conceptual framework: serious game structural components, behavioural dynamics components, and user experience enhancement components. To demonstrate the applicability of the proposed approach, we applied it to develop a serious game as a web application and to redesign an existing serious game. The results indicate that our framework provides clearer guidance for integrating gaming and educational aspects, allowing for more detailed composition of game components and alignment with learning objectives. It offers graphical and textual representations of serious games, simplifying comparisons of different games and offering insights into game challenges and player engagement. Furthermore, it can be a valuable tool in providing a quick, practical reference for the development team. It helps the development team better understand the complexity of serious game design, find new ideas on how to improve games, and create high-quality, effective games.

Keywords: Serious games, Functional requirements, Game components, Game development

1. Introduction

Serious games are interactive applications that merge educational content with engaging gameplay by embedding learning objectives within a fun, motivating environment. This approach encourages players to keep playing—and consequently, keep learning and achieve better learning outcomes (Silva, 2020). Due to this characteristic, serious games play an essential role in education and have become an impactful teaching resource. They are an effective tool for engaging today's generation of learners, who are deeply familiar with technology. By leveraging modern technologies, serious games offer immersive, multi-sensory learning environments that intellectually challenge students while maintaining their interest (De Gloria et al., 2012).

Designing serious games that effectively align with specific learning objectives is challenging. It requires substantial effort to integrate pedagogical content into gameplay. The development process typically includes game design, software development, and the integration of pedagogical elements. Therefore, it involves close cooperation among multidisciplinary teams to ensure that the games are both educationally effective and engaging while meeting the students' needs. This complexity often leads to difficulties, as multidisciplinary teams may use different vocabulary and have different perspectives on the game, which can cause misunderstandings and hinder effective communication. Sparse research has been conducted to address this problem. However, existing work is often more theoretical and does not clearly distinguish the entertainment aspects from the educational content, which makes communication among the development team still difficult. In this paper, we argue for a cooperative environment that enables the development team to understand each other and communicate using a common language.

This research aims to improve the development of serious games while reducing associated costs and effort. We define the functional requirements of the design process and propose a structured framework to guide serious game development. This framework facilitates multidisciplinary team collaboration, identifies reusable components, and streamlines development steps to enable the creation of compelling learning experiences.

Our approach offers a roadmap for conceptualizing the design, development, and functioning of serious games, providing a high-level view of the key elements involved. It is valuable for educators, developers, and researchers seeking to enhance game-based learning methodologies. It encompasses high-level concepts for representing games and pedagogical aspects to help the development team build high-quality, up-to-date components.

Even though there are many existing design frameworks and approaches that offer valuable ways of designing, developing, and analysing serious games (e.g., Arnab et al., 2015; De Freitas & Jarvis, 2006). Each tends to focus

on different aspects of game design and on documenting the design process at a high level. These works have helped clarify the opportunities and limitations of serious games and explain why this type of game can be a promising tool for learning. However, they do not fully explain how the concrete components of a serious game should be structured and implemented to simultaneously achieve high levels of learning effectiveness and entertainment value. Our approach provides additional criteria and a practical basis for designing high-quality games, particularly within interdisciplinary development teams. It aims to fill the gap between the theoretical understanding of what makes an effective game and the practical steps required to achieve this in detail. Therefore, it offers a more holistic approach to game design and enables the development team to better address motivational and affective aspects of gameplay, which have been underrepresented in prior taxonomies.

This paper is organized as follows: Section 2 describes our literature review concerning the derivation process of serious games requirements. Section 3 presents our framework components. In section 4, we demonstrate its applicability by modelling serious games. Finally, conclusions are given in section 5.

2. Deriving Functional Requirements across Serious Games

In this section, we analyse the domain of serious games by conducting an in-depth literature review. This investigation aims to provide a foundation for identifying functional requirements across different genres and topics of serious games. The goal is to highlight elements with high reusability potential for cross-domain applications and learning contexts, and to derive modular components based on these requirements. A crucial first step in identifying these requirements is to decompose the domain into its functional areas, subsystems, and desired goals. This helps determine relevant elements and high-level business use cases, which can then be selected as potential candidates for software modules or functionalities. This approach is commonly adopted among several methodologies for system development (Jaakkola & Thalheim, 2011). The requirements are identified based on: their potential for reusability across various serious games and learning contexts, particularly within the same game genre, and their relevance to enhancing the educational effectiveness of serious games.

According to their domains, these requirements are clustered into seven categories: pedagogy/learning, rules, interaction and communication, assessment, goals, adaptation, and representation, as shown in Table 1.

The identified requirements represent key functionalities that can be incorporated into serious game design as reusable components. Among them, assessment and adaptation are critical elements in educational research and are essential for creating effective learning environments. These factors are considered core functional requirements in the serious games conceptual framework, as they are applicable across different genres and domains and can be abstracted as external modules. In many cases, the functionalities are broad enough to allow for the potential integration of solutions from non-gaming contexts. Their integration significantly enhances game effectiveness and supports educational objectives and engagement. The following sections present key findings and evidence for each category, offering insights into the essential requirements for refining serious games design.

2.1 Pedagogy/Learning

This category describes the essential educational concepts of serious games, such as identifying educational methods, enabling practice and repetition, defining learning objectives, and supporting knowledge transfer. These elements are general enough to be considered as functional requirements.

Identifying the educational approach: A serious game based on pedagogical aspects should integrate multiple learning processes—social (situational), task-centered (associative), and constructivist (cognitive)—leading to the first requirement:

FR1: A serious game must offer object-focused interaction mechanisms, have task-centered goals, and also give the possibility to learn/play in social groups.

Training and repetition: essential for reinforcing skills and achieving learning outcomes, it leads to the second requirement.

FR2: A serious game should provide the ability to present learning objectives through repetitive tasks.

Learning Objectives: In serious games, learning objectives depend heavily on the game's context, especially regarding learning actions. Games must clearly present problems and learning content by integrating different

mechanisms such as objects, NPCs, or gameplay elements to directly communicate objectives. This leads to the third functional requirement:

FR3: To introduce the learning objectives, a serious game must provide interaction mechanisms.

The transfer of knowledge and skills, both within the game and between the game and real-world contexts, according to that, we formulate this requirement.

FR4: A serious game should be designed in a way that supports the progressive introduction of new skills during play.

Finally, the success of serious games depends heavily on correctly identifying educational approaches appropriate to the specific domain and target audience, ensuring that the game's design effectively supports the intended learning processes.

Table 1: Effective factors for serious games

Category	Factor	Description
1. Pedagogy /Learning	Identifying the Educational Approach (Kazimoglu et al., 2010; Yusoff et al., 2010; Zaibon& Shiratuddin, 2010; De Freitas& Jarvis, 2006).	Identifying information about how to facilitate the learning process and introduce easy-to-perceive content.
	Training and Repetition (Kazimoglu et al., 2010; Yusoff et al., 2010; Zaibon& Shiratuddin, 2010; De Freitas& Jarvis, 2006).	Providing the ability to frequently and effectively practice learning content.
	Learning Objective (Carvalho et al., 2015; Prensky, 2001; Yessad et al., 2010)	Describing the desired learning outcome that the players should have acquired at the end of a game or a learning level: skills and attitudes.
	Transfer of knowledge and skills (Yusoff et al., 2010; Zaibon& Shiratuddin, 2010; Fink, 2013).	Defining and describing the skills to be acquired through the game.
2. Rules	Game genre, roles, strategy, actions, reflection, simulation, etc (Yessad et al., 2010; Garriss et al., 2002; Bellotti et al., 2013).	Defining the main restrictions of the game and the player.
3. Interactions & Communications	Communication and interaction with the (serious) game (Prensky, 2001; Marsh& Nardi, 2014).	Defining the actions of interaction and communication with the application. These actions have to be intuitive and easy to handle.
4. Assessment	Feedback (Whyte et al., 2015; Ryan & Weinstein, 2009).	Providing information on how the players are doing and enabling tracking of their learning activities.
	Assessment Performance (Yusoff et al., 2010; Sørensen & Meyer, 2007).	Evaluating the player's performance throughout the learning process.
	Progress Performance (Zaibon& Shiratuddin, 2010; Wilson et al., 2009; Graham& Schofield, 2018).	Informing players about their level of performance.
5. Goals	Tasks, goals, levels, challenge (Sørensen & Meyer, 2007; Yessad et al., 2010; Wilson et al., 2009; Dörner et al., 2016; Laamarti et al., 2014; Martin-Niedecken et al., 2019).	Ensuring that the players are achieving a specific goal or skill.
6. Adaptation	Adjustability to player skills (Sobrinho et al., 2015; Adcock & Van Eck, 2012; Ifenthaler et al., 2012; Csikszentmihalyi, 1990; Crockett, 2016; Prensky, 2001; Kickmeier-Rust et al., 2008).	Describing a player-specific learning behaviour and ability.
	Challenging difficulty (Garriss et al., 2002; Cox et al., 2012; Jennett et al., 2008; Charles et al., 2011; Lomas et al., 2013).	Adjusting the difficulty of tasks according to the player's ability.
7. Representation	Media Component (Torrente et al., 2009; Morales et al., 2006; Ravyse et al., 2017).	Providing a visually appealing user interface and appropriate sound effects helps maintain the motivation of the gameplay.
	User Profile (Wilson et al., 2009; Annetta 2010).	It helps identify the player and personalise the game content.
	Object and character (Wilson et al., 2009; Annetta 2010).	Interaction with the game objects and the character.

2.2 Rules

This category defines the serious game's and the player's restrictions, shaping the game mechanics. It plays a crucial role by determining which actions are permitted, how task objectives can be achieved, and how players engage in tasks. Additionally, it outlines the gameplay characteristics, including available actions, strategies, and reflection. Based on this, the following requirement is specified:

FR5: The design of a serious game must adhere to a set of game rules.

2.3 Interactions and Communications

This category focuses on how components, players, and the game interact. It defines how initial communications are established, how player actions are handled, and how learning components are linked to gameplay. Based on this, the following requirement is identified:

FR6: A serious game should enable communication and interaction with other components and/or players (in the case of multi-player games).

2.4 Assessment

It summarizes the core components related to assessment in serious games, which are crucial for evaluating effectiveness and supporting player learning. Players should be challenged, receive information to orient themselves, and get feedback on their progress. Assessment plays a key role in improving games, helping players achieve learning objectives through evaluation and feedback mechanisms.

Feedback: Serious games must provide immediate or delayed feedback on player performance to guide learning and maintain motivation, this leads to.

FR7: In a serious game, there should be the capability to offer feedback on the user's behaviour.

FR8: A serious game should offer the ability to display information.

Assessment Performance: Evaluating players' actions throughout the game enables planning and strategy adjustments to improve learning outcomes.

Progress Performance: Displaying player progress (e.g., through scores or achievements) assesses learning, motivates players, and strengthens engagement.

FR9: Serious games must have an assessment component.

2.5 Goal

This category addresses how serious games define tasks, goals, and levels. Tasks should present clear, solvable problems that players can handle using their knowledge and skills. Serious games must also establish specific, transparent goals that players can perceive and achieve. Players should always know what actions are needed to complete tasks or exercises. Tasks often begin with simpler challenges and may be organized into levels, each with a set of predefined goals to guide progression and learning. The following functional requirements are derived:

FR10: A serious game has to include tasks that can be solved.

FR11: A serious game should have clear and understandable goals.

2.6 Adaptation

Serious games must allow learning content tailored to players' backgrounds, needs, and goals. Most serious games use some form of player evaluation, such as scores, to guide in-game adaptation, but stealth evaluation methods can provide even more precise adjustments. To optimize user experience, games must balance task difficulty with player skill levels, maintaining engagement through a state of flow, where challenges match abilities.

Adjustability to player skills: Games should be easy to learn but challenging to master, gradually increasing complexity as player skills improve.

FR12: A serious game must have an adaptive component to measure the performance of players' learning progress, thus adapting the game to the ability and the current skill level of players.

Challenging difficulty; Adaptivity also involves adjusting players' learning behaviors and knowledge levels to maintain challenge and motivation. The following functional requirement is defined:

FR13: A serious game should have various levels of difficulty in solving tasks.

2.7 Representation

This category focuses on how information is presented within the game. Serious games, distinct from other games, rely on content-specific elements that require high levels of player motivation and engagement.

Media Component: To enhance immersion, serious games should feature visually appealing graphics and appropriate sound effects, fostering a stronger sense of presence and greater motivation to succeed. The following functional requirement is defined:

FR14: A serious game should have the ability to display at least videos or to play audio.

Player Profile: This component manages the player's identity, enabling interaction, content customization, synchronization, and persistence across different games and learning settings. A well-designed player profile fosters a personal connection, motivating players to engage with the game. Requirement derived from this:

FR15: A serious game should have a user profile component to identify the player.

Objects and Characters: Serious games should allow players to interact with objects and non-playing characters (NPCs), which can hold information or provide objectives related to the game's learning domain. This enhances exploration and engagement, offering insight into the real world without real-world consequences. The functional requirement derived is:

FR16: In a serious game, there should be both objects and characters, allowing players to interact with them.

3. The Conceptual Framework of Serious Game

The conceptual framework developed in this research supports the design of both the structural aspects and behavioural dynamics of serious games, while also enhancing the overall user experience. Its components were derived from the functional requirements identified in Section 2, through a systematic analysis to ensure that every element contributes to fulfilling these requirements.

3.1 Serious Games Structure Model Components

The conceptual model of the serious game structure describes how the game is built and defines the role of each component in achieving the intended educational objectives. It contains the game world's layout, including characters, objects, and the mechanisms of player interaction. Table 2 presents the model components, linking each to its corresponding requirement and a brief description.

Table 2: The serious games structure components

Model Components		Derived from requirements #	Component Description
The Game-Root		No derivation needed	It plays a special role as the origin point for all other game components.
Instructional Content		FR2, FR4, FR5, FR10, FR11.	It is defined in terms of learning outcomes for the game that describe what knowledge and skills the player is expected to achieve or the subject matter that the player is required to achieve.
Player Profile		FR14, FR15	It identifies the players within the game.
Learning Motivation		FR9	These two components are highly preferable for learning environments and increase the attractiveness of serious games.
Repetition		FR2	
UI Manager	GUI Manager	FR8	It is used to display all the required information to players during gameplay. It allows audio and video playback within the game and other effects, and enables the display of GUI elements.
	Media Manager	FR14	
Objects& Character		FR15, FR3	It includes the presence of any particular objects and characters in the game world with which the player can interact with or which are used as decoration.
Reward Manager		FR9	It handles the assessment and measurement of user performance, including managing achievements and rewards. To encourage continued gameplay, strong learning performance should be rewarded.
Feedback		FR7	It manages the feedback given to the player.
Game Mechanics		FR1, FR6	It determines the type or category of gameplay and constrains the possible behaviour by describing players' actions to achieve the game objectives. It allows building methods and rules for players to interact.
Challenge, Level, Learning Outcomes		FR2, FR12	The challenge component represents a specific goal that the players should achieve, integrating problem-solving strategies and increasing their self-efficacy in case of success. The level component represents a series of smaller tasks related to the game's learning objectives, challenges, and tasks.

3.2 Dynamic Behavioural Model Components

It defines how the game responds to player actions, handles events during gameplay, and ensures the intended functionality. It also specifies how player actions are assessed and how the game adapts based on assessment results. The components derived from the identified functional requirements are presented in Table 3.

Table 3: The dynamic behaviour components

Model-Components	Derived from requirements #	Component Description
UI-Manager	FR8	It displays all the information players need throughout the gameplay.
States	No Derivation Need	It describes the initial state of a game or model
Activity (Actions)	FR3, FR10	It describes the mechanism that enables the player to interact with the game.
Event	No Derivation need	Define the interaction that occurs during the gameplay
Assessment (Task)	FR7, FR9	It represents various tasks, such as multiple-choice questions. It also evaluates the player's outcome and initiates processes to provide the player with feedback and achievements.
Adaption	FR11, FR12	It enables the monitoring of the learning progress of a player and adjusts the learning content and difficulty to match the player's skill level.

3.3 User Experience within Serious Games Environment

User experience is critical in serious games as it encompasses players' immediate reactions, emotions, and interactions with the game, which ultimately influence its effectiveness in achieving its intended learning goals (Hassenzahl & Tractinsky, 2006). It also helps the development team identify and evaluate the necessary aspects and components to create an effective serious game. This research identified three key elements that enhance it in serious games: learning, entertainment, and motivation. These aspects are grounded in established literature and provide a concrete framework for evaluating and designing serious games (Connolly et al., 2012; Arnab et al., 2015).

The learning component focuses on achieving the educational objectives of the game. It is characterized by learning mechanics such as questions and answers, tasks or actions, and opportunities for repetition and reflection (Gee, 2003; Kiili, 2005). This helps ensure that the game effectively supports knowledge acquisition and skill development. The entertainment component ensures the game remains engaging and enjoyable by integrating mechanics like rules, challenges, and interactive elements that align with the learning objectives (Sweetser & Wyeth, 2005). A well-designed serious game balances entertainment and education to maintain player engagement without undermining the learning experience (Ryan et al., 2006). The motivation component encompasses elements that entice players to continue engaging with the game, leveraging intrinsic motivators like compelling narratives and meaningful challenges, and extrinsic motivators such as rewards, feedback, and progress tracking (Deterding et al., 2011). Maintaining motivation is essential for sustaining player interest and ensuring the effective delivery of both learning and entertainment aspects.

To positively influence the learning process, a serious game must integrate learning, entertainment, and motivation aspects in a cohesive manner. For example, the game should offer a dynamic, fast-paced experience with adjustable components to accommodate varying player preferences and skill levels. It should also promote rich, affect-driven interactions by aligning the game context with player input, creating an immersive and meaningful experience (Nacke et al., 2010).

4. The Applicability of the Proposed Framework

To demonstrate the applicability and feasibility of developing serious games for learning using our proposed framework, we first applied it to redesign the existing serious game 'Senior PM Game'. It is a simple simulation game aimed at teaching project management to university students. Next, we utilized the framework in developing a serious game as a web application for teaching children's 'Learning Kids App'. It contains a list of games to teach children different skills. For example, it includes an 'Alphabetic game' for learning letters, numbers, and simple word writing; 'Arithmetic games' to learn basic calculations with addition and subtraction equations; and 'Memory Game' featuring letters, numbers, and animals. The use of a 'memory game' can help children activate their brains and prevent them from losing their cognitive response, thus improving their memory. In the following sections, we describe the design of these two serious games, aligned with our

proposed framework, and outline the steps that guide the development team in applying the framework to game design.

To effectively apply the conceptual framework in serious game design while ensuring proper integration of learning elements, we propose a structured development process consisting of three key steps:

- Conceptualization: Define the game's core concepts to establish a multidimensional perspective that aligns with learning objectives.
- Sequencing: Organize and structure key game components to create a coherent game sequence that supports the educational goals.
- Implementation: Group related actions and goals by type and corresponding components within the game sequence.

This approach aims to provide a clear reference for understanding interconnections between game elements and to systematically translate high-level learning objectives into concrete, gameplay-integrated components.

a) *The design of Senior PM Game:* The game is designed to teach the principles of project management, emphasizing the importance of effective task assignment for project success. It allows players to enhance their management skills by simulating real-world decision-making scenarios. Players are tasked with completing various project phases and evaluating how well their chosen employees perform. After each project, players receive feedback on key metrics such as completion time, cash flow, and overall project success.

At the beginning, the player selects four employees with different skills. Using this team, the player completes projects that require various combinations of skills. The objective is to maximize the score through effective resource allocation and project execution.

Following the design step, the design process begins with the multidisciplinary team describing the game concepts. They discuss the game objective, target audience, and the learning aspect. In the case of *Senior PM*, the primary objective is to enhance management skills in an engaging and interactive way. The player must strategically assign employees to project tasks, aiming to complete each project within set time and budget constraints. The educational focus is on improving decision-making in resource allocation based on team members' varied skills.

The second design step involves representing the game sequence, which helps identify the main game components; Figure 1 illustrates the game sequence of Senior PM.

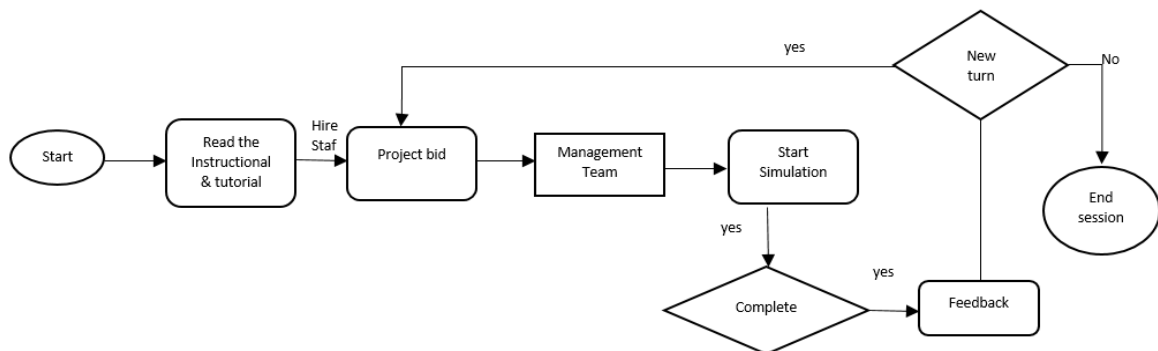


Figure 1: The game sequence of the Senior PM game

The third step is the implementation description, which organizes actions and goals according to their corresponding game components. This step provides a detailed explanation of each module or block in the game, describing the events that occur during each stage of gameplay. Table 4 presents these details, outlining how individual components function and contribute to the overall game experience.

Table 4: The Senior PM game components

Components	Description
Character & object component	Choose employees: The player chooses four employees to interact with.
UI Manager	Provide a short tutorial and instructions explaining the game's basic objectives and rules.

Components	Description
Feedback	To show interface tips and information, provide Feedback after completing any project if the player successfully completes their task within the time and the cash flow.
Project bid (Challenge/Task, reward, repetition)	It has learning components like challenges, tasks, rewards, etc. In the game, a player's task is to select or fire employees to have the best team to manage and complete the projects successfully. The reward is to get a better score and earn money.
Player Profile	Save score: Recording the points earned during each play.
Learning Outcome	Effective allocation of tasks for varying employees. The goal of the game is to make the right choice in allocating the employees who have different abilities and skills.
End of session	After completing all tasks, the player is invited to play again or to exit the game

B) *The design of the Learning Kids App*: The Learning Kids App is a container for multiple educational mini-games, developed using Vue.js. Figure 2 displays screenshots of this game, including: (a) the main screen, (b) an alphabet and numbers game for learning letters and numbers, and (c) a word learning game. Players can choose which game to play, with the core interaction involving dragging visual elements, representing a letter or number, and placing them in the correct position. Once placed, the game provides immediate audio feedback indicating whether the selection is correct.



Figure 2: Learning Kids App

The design of this game follows our conceptual framework, incorporating various components such as game mechanics, a UI manager for audio feedback, a reward manager for score calculation, instructional content, and a challenge module that manages the sub-games. Each sub-game is structured with multiple levels to support progressive learning. Additionally, interactive objects and animated characters are used to increase engagement and promote sustained attention.

5. Conclusion

This research presented a structured approach to the design and development of serious games for learning. It emphasized the integration of educational, entertainment, and motivational elements to enhance the user experience and learning outcomes. By defining functional requirements and mapping them to specific serious game components, the framework provides a practical guide for the development team to align educational goals with engaging gameplay mechanics. The implementation of the Learning Kids app and the redesign of an existing serious game, the Senior PM game, demonstrate the applicability of this approach in a real-world context. Specifically, it highlights how modular game components (e.g., adaptive challenges, feedback, UI manager, and instructional content) can be cohesively designed to create immersive and educationally

meaningful experiences. Ultimately, this approach facilitates the creation of serious games that are not only educationally effective but also engaging and motivating for diverse groups of learners. It also facilitates collaboration among a multidisciplinary team by providing a common reference for integrating educational and technical requirements. Future work could investigate whether any essential requirements or components are missing from the framework to ensure adaptability and completeness across different contexts. Further evaluations are also needed to assess its practical benefits, such as improving design productivity, as well as to validate its applicability to other game genres.

Ethical Declaration: We hereby confirm that this research does not require ethical approval.

AI Declaration: No AI tools were used to create this research.

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Cultural Games Creation: An Applied Game Jam Model

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Abstract: The present study conducts an important analysis of the operationalisation of a theoretical framework for applied game jams to cultural purposes, the Applied Cultural Jam Model, aiming to encourage youth (18-28 years of age) to develop games with and for culture. Building upon the initial study presented at ECGBL24 (Almeida et al., 2024), this work introduces significant new insights derived from the analysis of three EPIC-WE Cultural Game Jams (ECGJ#01-03) conducted between February 2024 and February 2025. These events involved 71 university students, 21 facilitators, and 4 observers, culminating in the creation of 24 games designed for cultural and educational purposes. Using the Applied Jam Framework (AJF), a holistic model proposed by Reid et al. (2020), the ECGJ considers the four AJF dimensions to enable participants to embed the cultural themes of each game jam: (i) fostering a creative environment (Problem Space); (ii) involvement of cultural stakeholders in the design and participation of the game jam (Jam Design); (iii) achievement of intended outcomes, participation and experience feedback (Jam Delivery and Outcomes); (iv) post-mortem analysis, compiling and disseminating outcomes, achievements, difficulties, and opportunities during the game jam (Follow-On Opportunity). This study ensures the proper application and analysis of the model, leading to significant results derived from the assessment of participant performance (through semi-structured interviews, questionnaires and observation grids), the influence of stakeholders (game jam design with active participation of facilitators), contributing to the model adjustments and iterations throughout the three game jams.

Keywords: Game jams, Applied game jam, Cultural games, Youth

1. A Cultural Game Jam Context

Game Jams are collaborative events where game developers and enthusiasts from varied backgrounds come together to generate ideas and rapidly prototype games within a defined theme and time limit (Kaitila, 2012; Kultima, 2015). Numerous jams are organised globally, providing several meaningful insights for the participants (Wirman & Jones, 2019), which can disseminate their developed designs in the game jam platforms, like itch.io or jam specific sites. Events like the Nordic Game Jam (2006) and the Global Game Jam (2009) introduced the widely adopted structure frequently used today, and popularised a versatile model through its globally synchronised events hosted by institutions around the world (Arya et al., 2013). According to Lai et al. (2021), a typical jam includes: (1) a 48-hour timeframe, (2) ice-breaker activities, (3) a theme reveal, (4) pitch sessions, (5) team formation, and (6) final presentations. Games are developed during the event and uploaded to their official platform. Most game jams follow the aforementioned model, which is more common than research about models and processes in applied game jam models (Conceição et al., 2024).

In the following study, we aim to demonstrate the results achieved through the application, and adaptation, of the Applied Jam Framework (Reid, Phillip & Donald, 2020) in the context of game jams with cultural purposes, aimed at empowering young people to create games with culture and for culture, over a year and a half during which the research team organised three game jams.

1.1 EPIC-WE Cultural Game Jams: The Case Study

The EPIC-WE Cultural Game Jams (ECGJ#01-03) were initiatives from the Horizon Europe EPIC-WE project, which aims to empower young people by fostering social and cultural values through game creation in cultural game jams (Almeida et al., 2024). EPIC-WE introduces a collaborative framework, based on the Quadruple Helix (QH) model, which fosters exchanges of knowledge and technology across diverse sectors (Aggarwal and Sindakis, 2022), blurring boundaries between public institutions, academia, industry, and citizens (Nørgård and Holfold, 2024).

Based on the QH framework, the ECGJs emerged as a process for young game creators (Youth) to culturally create meaningful games, with the support of a local cultural site (Óbidos Municipality), a games company (Battlesheep) and a higher education institution (HEI) (Lusófona University).

Drawing on research from the EPIC-WE project and Lusófona's Game Lab's experience in organising multiple game jams since 2014, the primary focus of the ECGJs was to promote game development inspired by cultural heritage, demonstrating how an applied game jam model could contribute to cultural research and innovation. Lusófona's empirical experience organising game jams fosters creating a carefree and playful environment for game development, more focused on knowledge sharing and well-being. There are no participation rules that impose mandatory tasks, lesson attendance, or any limitations that might make the experience feel less free. Much like a "magic circle" (Johan Huizinga, 1949), a game jam should be a safe space, a voluntary activity without demands, defined only by a time limit frame, usually during 48-72 hours.

However, game jams have always outcomes (Ryan et al., 2015) and in the specific case of the objectives involving an institution, organisation, or a sponsorship, it is common for this "magic circle" to be diluted by processes that may require a redefinition of the traditional game jam concept (Eberhardt, 2016; Goddard et al., 2014). In such cases, several authors advocate for game jams with applied purposes, thus invoking the concept of a *Serious Game Jam* (Aibara, 2020), *Slow Serious Game Jams* (Abbot et al., 2023), a restructure of the standard jam model that lacks methodologies and tools (Arnab et al., 2015).

1.2 Models for Applied Game Jams

Whenever the goal is to engage jammers in applied game jams, organisers need to offer clear guidance and support to enable the efficient development of Serious Games within the limited timeframe. An effective approach to achieve this is by creating structured missions that outline specific tasks, schedules, and deadlines, helping participants stay on track and complete their game projects within the event's duration (Aibara et al., 2020). Thus, several studies demonstrate the implementation of good practices through applied models (Costa et al., 2024), defining practical guidelines (Cornish et al., 2017), frameworks for ideation tools (Peters et al., 2021), using the Mechanics Dynamics Aesthetics (MDA) framework to the game ideation and design process (Buttfield-Addison, Manning, Nugent, 2016), to boost the game development scene (Sotamaa et al., 2020), to embedded culture (Nijdam, 2021), for the empowerment of collaborative design work (Kinnula et al., 2018), among others. The present study reflects the insights from the Serious Game Jam Operation Manual (Aibara et al., 2020) and the AJF (Reid et al., 2020) to create and improve the EPIC-WE game jam model. The developed prototype Serious Game Jam Operation Manual aims to provide a model capable of engaging participants in developing serious games, ensuring proper support for the ongoing themes within the short time frame typical of a game jam (usually 48 hours). The operation manual is divided into the Preparation Stage, the Lecture Stage, and the Development Stage.-The AJF has an important difference compared to the previous model, as it seeks to evaluate the games created in the long term. This is a gap in most studies on game jams, which primarily focus on the event and model, rather than the long-term impacts. Although the AJF model does not specify a fixed methodology, Reid et al. propose a four-step application (see Fig. 1).

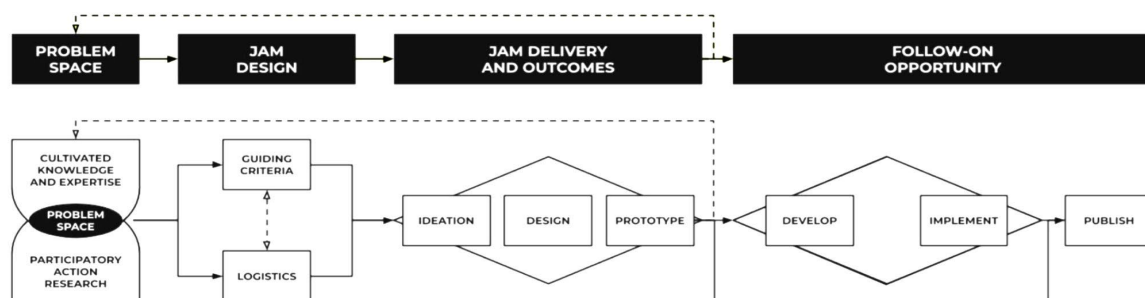


Figure 1: Theoretical Framework for Game Jams in Applied Contexts (Reid et al. (2020))

2. Methodology - Applied Cultural Jam Model

There is limited evidence of AJF application in the current state of the art (Costa et al., 2024). A notable example is its application in a different game jam format, the Serious Slow Game Jam, in which the authors emphasise the importance of reflection and reception of serious themes for the efficacy of the game jam. While traditional game jams typically last 48–72 hours, immersing participants in intense game creation, this contrasts with game development formats that can extend from months to years. Whether the "slow game jam" format can truly be considered a game jam is debatable, a topic not addressed in this context, but worth mentioning, as the present study follows the AJF guidelines within the intensive format of the traditional game jams.

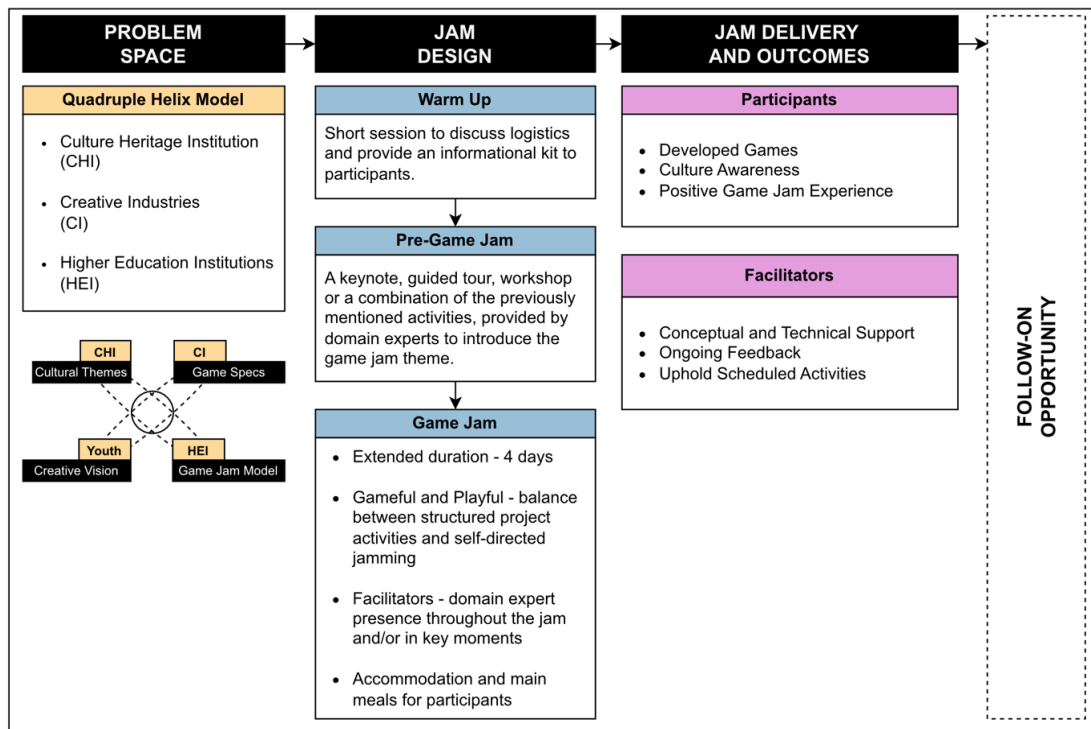


Figure 2: Applied Culture Jam Model (ACJM)

The Applied Cultural Jam Model (ACJM) represents the operationalisation of the AJF in the context of cultural game jams ECGJ#01 to #03, which are discussed in more detail below.

2.1 Problem Space

The primary objective of these game jams was to empower young people by promoting social and cultural values through the process of game creation. The design constraints for all game jams were defined through the QH model according to: (1) the Cultural Heritage Institution (CHI) Óbidos municipality cultural branch suggested themes; (2) the creative industry (CI) represented by Battlesheep, that defined the games had to be digital as a contribution to game development in the national context; and (3) the HEI represented by Lusófona University, that provided the theoretical framework for the applied game jam model; (4) to challenge youth to share their creative vision by creating games that reflect the cultural topics and values present in the themes of each game jam.

In line with EPIC-WE project directives, the themes of ECGJ#01 and ECGJ#02 were defined by the local hubs in Denmark, the Netherlands, and Portugal. For ECGJ#03, a glocal approach was adopted: the initial theme was set by EPIC-WE project leads and subsequently adapted by each hub to reflect local contexts.

2.2 Jam Design

The following section details the design and organisation of the game jams. While logistics remained largely consistent across all three events, variations are noted where adjustments occurred due to ACJM iteration or other constraints.

2.2.1 Logistics

The three ECGJ were held in Óbidos, a medieval village encircled by a castle wall. Participants were provided with accommodation in village houses and main meals (lunch and dinner) over 4 days. Additionally, transportation to and from the venue was arranged on the first and final days of the event. This arrangement was designed to immerse participants in a culturally rich environment while enabling them to concentrate more effectively on the creative tasks. Another important consideration was the duration of the events, the decision to allocate 4 days for the game jams was deliberate and aimed at compensating for the time required by EPIC-WE project activities that, throughout the event, interrupted participants' game development processes. This resulted in game jams with more than 48 hours, allowing for a good balance between gameful, more structured moments and playful ones (Goddard, 2014).

2.2.2 Guiding criteria

Introduced in ECGJ#02, Warm-Up sessions are 45-minute meetings designed to onboard participants to the cultural game jam context within the EPIC-WE project, clarify their roles, and address initial questions. These sessions also served to establish early communication with participants. While initial contact was made via email, Discord emerged as the preferred communication platform. To enhance preparedness for the game creation phase, participants are informed of themes and topics several weeks in advance, hence the term 'pre-game jam', a practice aligned with the preparation phase outlined in the Serious Game Jam operation manual (Aibara et al., 2020).

Event	Activity	Dates	Duration	Short Description	Theme
ECGJ#01	Pre-Game Jam	9 January 2024	5h	Keynote and Ideation through a guided workshop based on the MDA framework.	Óbidos UNESCO City of Literature
	Game Jam	6 to 9 February 2024	52h	Refer to the game jam schedules table.	
ECGJ#02	Warm-Up	27 March 2024	1h	Online session to discuss logistics and provide an informational kit to prepare participants.	Sustainability and Biodiversity Óbidos Lagoon
	Pre-Game Jam #1	12 April 2024	1h30m	Sustainable Development Goals - 14 Life Below Water and 15 Life on Land	
	Pre-Game Jam #2	15 April 2024	8h	Guided visit with a facilitator to the Óbidos Lagoon	
	Game Jam	29 April to 2 May 2024	71h	Refer to the game jam schedules table.	
ECGJ#03	Warm-Up	22 January 2025	1h	Online session to discuss logistics and provide an informational kit to prepare participants.	That's Not Fair December 1st 1973 Óbidos Reunion
	Pre-Game Jam	4 February 2025	8h	Group Dynamics & Ideation with shadowplay using materials collected from the village.	
	Game Jam	5 to 7 February 2025	51h	Refer to the game jam schedules table.	

Figure 3: EPIC-WE Cultural Game Jam #01-03 event breakdown

In contrast to ECGJ#01 and ECGJ#02, the pre-game jam activities for ECGJ#03 were held on the first day of the event due to scheduling constraints. This edition introduced new elements, including group dynamics aimed at fostering initial participant interaction and a visual ideation exercise using shadows with overhead projectors (see Fig. 3 and Fig. 4). While participant engagement was evident, the extent to which these activities contributed to the game creation process remains uncertain. Potential factors limiting their impact include a lack of clear connection to the jam's overarching theme and insufficient time for participants to grasp the topic thoroughly. As a result, some groups misinterpreted 'The Reunion of the Captains' with the April 25th Revolution. Another noteworthy change regarding the game jam schedules from ECGJ#01 to ECGJ#02-03 is the change of the activities' slated time from early to late morning due to participants' preference for later hours. There was an effort to strike a balance between all the necessary EPIC-WE Project's activities, how they were adapted and delivered to participants, one of the highlights is the pitch sessions with facilitators that happens early on in the game jam, providing ample time to act on the feedback and the ability to course correct without compromising too much of the development time.

EPIC-WE Cultural Game Jam #1 (ECGJ#01)				EPIC-WE Cultural Game Jam #2 (ECGJ#02)				EPIC-WE Cultural Game Jam #3 (ECGJ#03)			
Day 1	Day 2	Day 3	Day 4	Day 1	Day 2	Day 3	Day 4	Day 1	Day 2	Day 3	Day 4
10:00 Cultural Institutions Visit Guided tour	Pitch Sessions	Day 3 Team Check-in Status Report	Game Delivery and Submission Deliverables	Devlog 1 Ideation Pitch Deck	Jamming	Jamming	DevLog 4 Deliverables	Theme Exploration Opresor and Oppressed Shadowplay Ideation	Jamming	Jamming	Game Log 4 Deliverables
11:00					Devlog 2 Team Check-in	Devlog 2 Team Check-in	Jamming				Jamming
12:00	Jamming	Jamming									
13:00	Lunch			Lunch				Lunch			
14:00			Game Jam Wrap-Up Post-Mortem Surveys	Jamming			Showcase Game Presentations	Team Building Ice Breakers	Game Log 2 Pitch Team Check-in		Showcase Game Presentations
15:00	Jamming	Jamming		Devlog 2 Pitch Session	Jamming	Jamming	Game Jam Wrap-Up Post-Mortem Surveys			Jamming	Game Jam Wrap-Up Post-Mortem Surveys
16:00				Jamming				Game Log 1 Team Formation	Jamming		
17:00											
18:00				Devlog 2 Pitch Iteration	Devlog 2 Team Check-in	DevLog 3 Showcase Preview				Game Log 3 Team Check-in	
19:00	Day 1 Team Check-in Pitch Draft	Day 2 Team Check-in Interviews	Showcase Game Presentations								
20:00	Dinner			Dinner				Dinner			
21:00 to 10:00	Jamming (optional)	Jamming (optional)		Jamming (optional)	Jamming (optional)	Jamming (optional)		Jamming (optional)	Jamming (optional)		

Figure 4: EPIC-WE Cultural Game Jam #01-03 Schedules.

2.3 Jam Delivery and Outcomes

2.3.1 Participants

Only the 71 university students who participated voluntarily across the three game jams were considered for statistical analysis. The 54 high school students, whose attendance was mandatory as part of their curriculum, were excluded to preserve the voluntary nature of the sample. University participants registered independently, provided informed consent, and actively chose to engage with the serious theme of the jam.

	ECGJ#01	ECGJ#02	ECGJ#03
Total Participants	26 (100%)	25 (100%)	19 (100%)
Gender	Female 19.20%	Female 20%	Female 52.60%
	Male 80.80%	Male 72%	Male 42.10%
		Non-Binary 4%	Non-Binary 5.30%
		Prefer Not to State 4%	
Age (Average $\pm$ SP)	20.77 $\pm$ 3.08	20.48 $\pm$ 2.26	21.47 $\pm$ 2.06
Age Range	18-28 years	18-25 years	18-25 years
Nationality	PT 84.60%	PT 88%	PT 84.21%
	BR 7.70%	BR 8%	BR 10.53%
	MZ 3.90%	LA 4%	SP 5.26%
	MX 3.90%		
Education Level	HighSchool 76.90%	Bachelors 96%	Bachelors 73.70%
	Bachelors 15.40%	Not Stated 4%	Masters 15.80%
	Masters 7.70%		Not Studying 5.20%
			Not Stated 5.30%

Figure 5: ECGJ#01-03 Participants Sample

2.3.2 Observers and facilitators

During these three game jams, 4 observers from Lusófona University collected the data (surveys, video interviews) and did the observation analysis. The observers prepared all the necessary documentation for participation in these game jams (informed consent for research purposes and dissemination of results), collected testimonies through surveys (Microsoft Forms), and conducted video interviews.

Regarding the game jam guidance, 7 facilitators on ECGJ#01 and 8 facilitators on ECGJ#02 and ECGJ#03 organised and supported the participation activities.

The Lusófona University (UL) facilitators handled the game jam design, including ideation methods, recruitment of participants, preparation of materials, creation/adaptation of research instruments, and data collection throughout the event. Also focused on game design, UL facilitators provided expertise on game mechanics and development strategies, ensuring that participants had both conceptual and technical support. Battlesheep (BS), a representative from the Portuguese game industry, was present throughout all the events, providing support to the theme selection, games scope (digital format) and to the participants (game development mentoring). Óbidos municipality provided the venue and handled all logistical needs, including accommodation, meals, and materials for all partners involved. They also played a key role in selecting the cultural topics, co-organising the pre-game jam events, providing cultural facilitators, such as curators, historians, and other specialists on the game jam themes, and delivering lectures and documentation on the themes.

All the facilitators participated in the pitch sessions, providing thematic feedback (cultural facilitators) and specific insights into game making process and design choices (UL and BS). The interactions were friendly and engaging, creating a welcoming atmosphere, sometimes marked by more informal moments, such as loud music, or funny moments, where participants could feel at ease with the facilitators, contributing to more horizontal communication. Meals were shared between participants and organisers, fostering a sense of community, although this was not formally measured.

The work of the facilitators proved essential in developing games with greater depth in their thematic approach, which became particularly evident when analysing the success of the games created during the ECGJ#02 compared to those from ECGJ#01 and ECGJ#03. The key differentiating factor was the mentoring provided during that event.

During ECGJ#01 a need for an ongoing presence of the cultural facilitators was identified. This aspect was strengthened for ECGJ#02, where culture facilitators offered continuous support from pre-game jam activities to the event's conclusion. They achieved this by actively engaging with participants throughout the event, doing various check-in rounds with the teams to assess their progress and mainly to help with creative blocks or conceptual issues, which contributed to a deeper understanding of the theme. Unfortunately, due to calendar constraints, ECGJ#03 had a similar lack of cultural facilitators, contributing to fewer projects and some confusion regarding the theme.

These check-ins were also accompanied by pitch sessions, where participants presented their progress and received feedback from the facilitators. As one participant noted:

"The presence of these facilitators made it easier for us to develop something faithful to the lagoon. They shared details about the lagoon's depth, the types of boats found there, and more. I think that if it hadn't been for the guide, we would have been much more out of touch with the subject, because in the eyes of those who don't know or who don't live here, who aren't used to it or who don't have that kind of knowledge or someone to share it with, the Lagoon is just a body of water" (anonymised student name).

The participants stated the difference between exploring a theme online or being able to explore it in the real world, interacting with the environment and the experts (facilitators), and learning about places while being in them:

"Yes, I think at least from what I felt, it was that I could give more value to the theme imposed on our work and also realize that it wasn't as limiting as I thought, that we could explore it at a better level and that we had various paths to follow, not as narrow as the theme was presented at the university" (anonymised student name).

As an example, the games "Puss in Books" and "Paredes de Cor" developed on the ECGJ#01, were a direct result of participants' interaction with Óbidos local culture. In Puss in Books, the player is a cat, as the participants, while exploring around, notice the number of cats living in the village. "Paredes de Cor" is a game inspired by the marked walls the participants observed throughout the entire village, during the visits, resulting in an idea for a game:

"After the visit, we explored the town of Óbidos, and that's where we really started to notice many marked walls. Right at the entrance of the village, there was a sign prohibiting that, and that's when it really stood out and gave us the idea for the game." (anonymised student name)

2.3.3 Developed games

Through the ECGJs, participants created 21 games, plus 11 from the high school, which are excluded from this study. Fig. 6 presents the games developed in each ECGJ, which can be found at their respective itch.io jam pages (<https://itch.io/jam/epic-we-01-obidos/entries>; <https://itch.io/jam/epic-we-02-obidos/entries>; <https://itch.io/jam/epic-we-03-obidos/entries>).

EPIC-WE Cultural Game Jam #1 (ECGJ#01)				EPIC-WE Cultural Game Jam #2 (ECGJ#02)				EPIC-WE Cultural Game Jam #3 (ECGJ#03)			
Game Title	Narrative	Aesthetics	Format	Game Title	Narrative	Aesthetics	Format	Game Title	Narrative	Aesthetics	Format
Book Dweller	no	yes	digital	Birdpedia	no	no	digital	Blue Brigade	no	yes	digital
Ginjurdes	yes	yes	digital	Biz Flamingo	yes	yes	digital	Bufo Catcher	yes	yes	digital
In Search for Words	yes	yes	digital	Blooming Shadows	no	no	digital	Message of the Red Cloves	yes	yes	non-digital
Literature of Defense: Guardian of Óbidos	no	yes	digital	Criminal Fauna Identification	yes	yes	digital	The Clueless Otavio Pinto	yes	yes	digital
Lost in Words	yes	yes	digital	Encyclofishia	yes	yes	digital				
Paredes de Cor	yes	yes	digital	Óbidos Watching	yes	yes	digital				
Puss in Books	yes	yes	digital	Otter Way	yes	yes	digital				
Storyteller	yes	yes	digital	Spirit of the Lake	yes	yes	digital				
Tsundoku	no	yes	digital								

Figure 6: ECGJ#01-03 developed games

The majority of the games demonstrate, through their gameplay and aesthetics, an objective connection to the themes of the game jams, the substantial diminishing number of games from the first game jams to ECGJ#03 is mainly explained by the lower participant numbers and lack of game development experience amongst them (see fig 5.).

2.4 Follow-On Opportunity

Although this aspect is acknowledged within the EPIC-WE project's overarching goals, it has not yet been implemented. As part of the initiative, Battlesheep intends to further develop four selected games originating from various game jams. The objective is to collaborate with the original creators of these games and, alongside professional game developers, refine and produce polished versions suitable for publication on the EPIC-WE website. This work aligns perfectly with the AJF, which foresees further development opportunities for the resulting games. In this specific case, such opportunities could include the development of new business models tailored to small-scale cultural games aimed at supporting the promotion and dissemination of local culture by municipalities and cultural heritage institutions. Moreover, the initiative seeks to foster game development within these communities and leverage games as a medium for cultural dissemination, allowing local traditions and narratives to reach broader audiences and transcend regional boundaries. From Glocal to Global, the ECGJ follow-on opportunity can be a game changer for students, cultural sites, and game companies, disseminating culture through games that can transcend their local roots.

3. Discussion

Among the main objectives achieved at the ECGJ#01, the participants highlighted a greater awareness of and involvement with the culture of Óbidos, learning about creating games for culture and, consequently, learning about creating games in general. In relation to the Game Jam experience, on a scale of 1 to 7, 19.23% of the participants rated it 5, 50.00% of the participants rated it 6, and 30.77% gave it the maximum score. Considering the duration of the game jam, 22 participants (84.62%) felt that the time was adequate, while 4 (15.38%) felt that it should have been longer. Considering the cultural activities organised before the game jam, 22 (84.62%) of the participants considered that these were useful for creating games.

A post-event survey was conducted with ECGJ#02 participants to evaluate the extent to which their goals and expectations were fulfilled. Pre-game jam activities, including a visit from the Óbidos representative on April 12 and a lagoon visit, were viewed as useful by most participants for the ideation process, with 24 (69%) favouring the lagoon visit and 11 (31%) selecting the representative session. Regarding the question of whether the game jam's duration was adequate 25 participants 19 (76%) said "Yes", 5 (20%) felt more time was needed, and 1 (4%) was unsure.

Regarding the perceptions of the ECGJ#03, from the 19 participants, 10 (52.6%) considered that their expectations were exceeded, and the remaining 9 (47.4%) considered that they were achieved. When asked if the perception of the theme had changed with the activities done with facilitators before the game jam, 7 participants (36.8%) answered "No", 8 (42.1%) answered "I don't know", and 4 (21.1%) answered "Yes". This distribution may be explained by the lack of time to reflect on the activity, as it happened on the same day the game jam began, unlike the two previous ECGJs, which allowed more time beforehand. Regarding the duration of the game jam, 15 participants (78.9%) felt that the time allocated was adequate, 3 (15.8%) considered that it should have been longer, and 1 participant (5.3%) didn't know. Among the main objectives achieved at the ECGJ3, the participants highlighted gaining awareness of the importance of the 25th of April and being aware of Óbido's history.

Regarding the Problem Space, it was the presence in Óbidos that, even though the theme ended up being too broad and general, helped participants explore it, having the autonomy to make it more concrete, uniting their ideas with what they saw. The location was highly praised by the roundtable that took place at the end of each ECGJ. The participants enjoyed taking strolls and found the medieval setting inspiring for their game development, and the journey between the village and the space was beneficial for their creative process, highlighting the outside surroundings as greatly beneficial to the creative process, rather than relying on online sources:

"I liked visiting the village. The last game jam I did was at a library, and we stayed locked there almost 48 hours. It was much better here, the atmosphere, getting out of here, visiting the village, taking a stroll. We visited the village for 2 or 3 afternoons, walking around, and especially at night."
(anonymised student name).

The Jam Design presented both successes and challenges. In ECGJ#01, one of the primary limitations was the selected theme, which participants found abstract and overly broad. This lack of specificity hindered meaningful integration into the game prototypes, with several groups struggling to translate the theme into playable concepts. In contrast, ECGJ#02 benefited from key improvements. Pre-game jam activities conducted two weeks prior facilitated more structured planning and enabled participants to begin the jam with greater

clarity and readiness. Additionally, continuous support from facilitators throughout the event provided valuable guidance and contributed to a more effective development process.

According to the Jam Delivery and Outcomes, cultural facilitators effectively initiated collective reflection on the themes, which could not have been achieved through lectures or online information alone. It was the dynamic interactions during the visits that created space for dialogue, which, enriched by each facilitator's personal experience, fostered reflection:

"I think the experience was completely different because we also had a lot of people talking to us, discussing literature with us. In fact, one of the mechanics of our game was precisely inspired by something one of the speakers mentioned to us" (anonymised student).

Given the positive feedback from participants regarding the cultural activities and the presence of facilitators, future game jams would benefit from involving an even greater number of facilitators in the schedule. Improved preparation for the theme would also benefit participants. Providing the theme and relevant background materials in advance would allow teams more time to reflect, ideate, and plan. Scheduling these activities on a separate day or earlier in the event would further support the integration of insights into participants' projects. Finally, the present study cannot yet provide a concrete assessment of the Follow-on Opportunities that may emerge from this ongoing process. Four ECGJs games are in the process of further development since May 2025, with support from the games company Battlesheep, which will generate new perspectives for further studies.

4. Conclusions

The ACJM model, based on the AJF framework, presents itself as a strong proposal for fostering the creation of games with a cultural approach. When facilitators and GJ organisers supported the event by introducing thematically rich content, encouraging students to reflect on game development as artistic expression or educational empowerment, through the guided steps (framework), the results could be cultural value within the game making process. All of the ECGJs participants were engaged on the cultural site, immersed in the thematic, and developed their own projects, using digital games to express cultural perspectives shaped by the local context of the jam. Building on the analysis from previous editions, it becomes evident that the "Jam Design" phase plays a pivotal role in achieving successful game jam outcomes. Overscheduling can undermine engagement by overwhelming or demotivating participants. To address this, a carefully balanced schedule, extended game jam time, delegating research-related tasks to pre-jam sessions, allowing flexibility in pitch timings based on participants' motivation and energy levels, and ensuring active facilitator involvement throughout the event, can significantly enhance results, particularly when participants have prior game development experience.

In ECGJ#03, a shift toward participants with less experience in game development was associated with reduced output, as evidenced by a lower number of games produced and a decline in technical and design sophistication. However, the event was notably successful in integrating students from diverse fields, such as sound design and visual arts, alongside those from videogame development. This interdisciplinary collaboration was positively received by participants and enabled the creation of the first physical game in the series. By adapting to the varied skill sets within the group, participants explored alternative formats and creative strategies to overcome technical limitations:

"We chose to do a physical game based on each person's skills. We had art people, we had a design person, so there wasn't much programming or anything like that. Unlike the other groups, we focused on a physical game to really free people up." (anonymised student).

5. Limitations and Future Studies

This study presents several limitations that must be acknowledged. The most significant is the lack of concrete data from the follow-on phase, which remains ongoing at the time of writing. Moreover, although the research draws from three distinct Cultural Game Jams, this paper focuses specifically on the Óbidos Hub in Portugal. As such, it does not encompass the full range of data collected across the project. This includes qualitative data, such as interviews with participants and facilitators, and gameplay analysis conducted by external playtesters, as well as quantitative data, including demographic information, satisfaction surveys, and playtest results. Future research will include the analysis of game prototypes tested with 50–70 students from undergraduate and master's programmes and high schools. These forthcoming studies are expected to contribute valuable

understanding regarding the long-term viability and broader applicability of Cultural Game Jam models for both creative and educational purposes.

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AI Statements: This article was reviewed and refined for language clarity using Grammarly and generative AI tools. These tools were used exclusively to improve grammar and wording, without altering the content, arguments, or conclusions. As non-native English speakers, the authors maintain full responsibility for the intellectual substance and integrity of the work.

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Learning While Developing a Game: The Case of an Introductory Course on Industrial Engineering and Management

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Abstract: This paper presents a case study on the development of games by students in the first year of the Industrial Engineering and Management (IEM) undergraduate program at the University of Aveiro (UA). The development of a game is incorporated as a core assignment within the *Introduction to Industrial Engineering and Management* course, challenging students to introduce the IEM program at UA to high school scholars, thereby exploring the various facets of the IEM program and the scientific areas it encompasses. The objective is for students to incorporate the knowledge gained in classes, along with insights from their own research, into the game, doing so with imagination and creativity. At the same time, they are encouraged to consider effective communication with the target audience, whose age and interests are often quite similar to their own. To support students in structuring their game design, the *Game of Games* (www.gameofgames.net) was introduced and played during one of the classes. Students were also encouraged to use it as a framework when developing their own games. In addition to describing the experience itself, this paper also presents a game developed by one of the student groups, with two main objectives: to show an example of the work produced and the challenges encountered during its development, and to provide educators interested in Game-Based Learning with a new resource that can be adapted to their own contexts. The results of this experience are encouraging. Students showed great enthusiasm for the project and demonstrated that they had gained significant knowledge about the various areas of the IEM program, the University of Aveiro, and student life. At the same time, they developed both written and oral communication skills and created tools that may prove valuable beyond their own learning process. In fact, the games can be directly used to promote the IEM program at UA to potential future students and may also be adapted for use in other courses. Additionally, they can be employed in more informal or recreational settings, such as summer academies or themed holiday camps.

Keywords: Educational non-digital games, Game based learning, Game design

1. Introduction

This paper aims to present and analyze a case study involving the development of non-digital games by first-year students in the Industrial Engineering and Management (IEM) undergraduate program at the University of Aveiro (UA). The primary objective is to explore how game design, supported by the Game of Games tool, can be used as a pedagogical strategy to engage students in applying their academic knowledge creatively while promoting the IEM program to high school audiences. Additionally, the paper seeks to provide educators with insights and a practical example of Game-Based Learning that can be adapted to other educational contexts.

In the first semester of the IEM program at UA, students take an introductory course – Introduction to Industrial Engineering and Management (IIEM) – that covers the history of IEM, its main areas, and the role of an IEM professional in society. Throughout this course, students are required to complete assignments designed to enhance their understanding of IEM at UA.

As part of this, a key and novel assignment in the IIEM course asked students to design games aimed at high school students, with the goal of introducing them to the IEM program at UA. The objective was for students to explore the various facets of the program and the scientific areas it encompasses, thereby gaining a greater insight into it.

This paper is organized as follows: The next section provides a brief theoretical contextualization of non-digital games. Section 3 introduces and describes the *Game of Games* tool, which was employed in the development of this study. Section 4 outlines the methodology used, while Section 5 presents a case study involving a game development project carried out by a group of students, culminating in the creation of the *EGI MASTERS* non-digital game. Finally, Section 6 presents a discussion of the findings and the study's conclusions.

2. Embedding Learning Outcomes in Non-Digital Games

Over the past decades, the use of games in educational contexts has attracted growing attention from researchers and practitioners alike. As education continues to evolve to meet the needs of today's students, there is increasing recognition of the potential of non-digital games as valuable pedagogical tools (Morando and Turconi, 2022; Hall et al., 2024a). Non-digital games—ranging from traditional board games and card games to more complex simulation-based and role-playing formats—offer an array of opportunities for engaging learners in meaningful and remarkable ways.

Non-digital games refer to structured, rule-based activities that involve competition, cooperation, or problem-solving, and that do not rely on electronic or digital platforms (Ramo et al., 2020; Hall et al., 2024b). These include board games, dice games, card games, and others that foster interaction, improve social relationships, promote team spirit, cooperation, face-to-face interaction and communication with others, strategic thinking and creative engagement without screens or digital devices (Ramo et al., 2020). In educational contexts, non-digital games can be designed or adapted to align with specific learning objectives, whether in formal curricular settings or informal environments.

One of the primary advantages of non-digital games is their capacity to enhance motivation and engagement (Morando and Turconi, 2022). By incorporating elements of fun, competition, and challenge, they can transform otherwise abstract or monotonous content into an interactive and enjoyable experience (Kapp, 2012; González-Cutre et al., 2016; Dinata, 2021; Morando and Turconi, 2022; Hall et al., 2024a). This emotional engagement supports sustained attention and increases the likelihood of knowledge retention (McGonigal, 2011; Kapp, 2012; Hamari et al., 2014; Sailer and Homner, 2020;).

Non-digital games also foster active and participatory learning. Unlike passive instructional methods, games require learners to make decisions, apply knowledge, and adapt strategies based on feedback. This aligns with the principles of active learning and student-centred pedagogy, which are increasingly advocated across educational contexts (ME, 2021; Pais, 2023; Hall et al., 2024a; Hall et al., 2024c).

Additionally, games provide a natural context for the development of 21st-century skills, including critical thinking, creativity, collaboration, and communication (McGonigal, 2011; Kapp, 2012; Hamari, Koivisto and Sarsa, 2014). When played in groups, they encourage negotiation, shared decision-making, and collective problem-solving—skills that are vital not only in educational settings but also in the workplace (World Economic Forum, 2020).

Another key benefit lies in the accessibility and inclusivity of non-digital games. They do not require access to technology or digital literacy, which can be a barrier in some educational contexts. They can be easily implemented in a variety of settings, often using low-cost or handmade materials, making them particularly suitable for resource-constrained environments (Hall et al., 2024b).

Importantly, non-digital games provide a safe space for failure. (Salen and Zimmerman, 2024) The low-stakes environment of a game allows learners to experiment with ideas, take risks, and learn from mistakes without fear of formal evaluation. This encourages resilience, adaptability, and a growth mindset.

Despite their benefits, the effective use of non-digital games in education requires thoughtful implementation (Frye et al., 2013; Baroody et al., 2019). Poorly designed games can trivialise content, lack educational value, or exclude some learners. Therefore, alignment with learning outcomes is essential.

3. Game of Games: A Tool for Designing Educational Games

The *Game of Games* is an innovative meta-game designed to support educators, trainers, and learners in the creative process of designing educational games. Developed as both a physical and online experience, the game offers an engaging, structured method to generate, explore, and refine game-based learning concepts. It was created by Caroline Archambault from Leiden University College in The Netherlands and is accessible through the official website (<https://www.gameofgames.net>), where users can find the game objectives, printable decks, and a comprehensive set of rules and guidance for gameplay.

At the core of the *Game of Games* is the Concept Generator, a framework that facilitates idealization and collaborative design through a set of card decks and a series of guided steps. The decks underlying the Concept Generator are themed decks—*Narrative*, *Challenge*, *Mechanics*, *Assessment*, and *Transformation*—each designed to stimulate critical thinking and creativity around the components of an educational game. Players draw cards from these decks and are prompted to articulate their game ideas using the Concept Form, a structured template that captures the essential elements of the proposed game design.

The Concept Form serves as both a creative canvas and a planning document. It includes designated fields to document the working title of the game, the educational goal(s), target audience, expected learning outcomes, and contextual considerations. Players are also encouraged to define the narrative setting, identify the type of challenge or conflict at the heart of the game, and describe the core mechanics that will drive interaction and engagement. Importantly, the form asks users to reflect on the assessment strategies embedded within the game—how learning progress will be monitored and evaluated—and the intended transformation, that is, the change in knowledge, skills, or attitudes the game seeks to achieve.

Together, the Concept Generator and the Concept Form provide a low-barrier, high-creativity entry point into game design for education. They emphasize both structure and playfulness, helping users navigate the complexity of instructional game development while fostering collaboration, reflection, and innovation.

4. Methodology

This study follows a qualitative case study methodology and focuses on a cohort of 78 first-year students enrolled in the IEM undergraduate program at the UA during the academic year 2024/2025. The aim was to enhance students' understanding of their degree program while equipping them with communication tools to promote it to prospective students, specifically those in secondary education.

The initiative was implemented within the scope of the course IEM, a first-semester curricular unit designed to familiarize students with the history, scope, and interdisciplinary nature of IEM. Traditionally, this course has incorporated a Challenge-Based Learning (CBL) methodology, with students working in groups to address the essential question: "*How can the IEM program at UA be effectively promoted?*" However, to foster greater creativity and student engagement—particularly in light of the saturation of similar past projects—a Game-Based Learning (GBL) approach was introduced for the first time in 2024/2025.

In this context, students were divided into groups of 4 or 5 members, and each group was tasked with developing an educational game aimed at high school students to encourage them to explore the IEM program at UA. The goal was twofold: (i) to deepen their knowledge of the IEM program by engaging with its core themes through the process of game creation, and (ii) to produce a playful, informative tool capable of effectively introducing the program to a younger audience.

To 'break the ice' and help students structure the design of the game, the 'Game of Games' was explained and played during the first class dedicated to the assignment. Central to this process was the *Concept Form* that required each group to define their game's title, educational goals, intended learning outcomes, target audience, and gameplay structure. The Concept Form also prompted students to identify a narrative setting, define core mechanics and challenges, and consider assessment strategies and the intended pedagogical transformation.

Following this planning stage, each group was responsible for developing the full set of physical game materials—including game boards, cards, rules, and supporting elements—as well as submitting a written report explaining their design process, decisions, and alignment with educational objectives. They also presented their game in class, offering peers and instructors the opportunity to experience and evaluate the gameplay.

The students were assessed based on the following criteria:

- Creativity and clarity in defining the game concept.
- Suitability of the game to the defined objective.
- Clarity in the description of the game.
- Quality and creativity of the game.
- Suitability and quality of the materials created.
- Critical analysis of the work carried out (including its limitations).
- Oral presentation (quality of the support materials used; creativity; communication).
- Quality of the written report produced.

For the purpose of this paper, one student project was selected to be analyzed in depth: the *EGI MASTERS* game, developed by a group of four students. This game was chosen for its creativity, alignment with learning goals, and effectiveness in illustrating the potential of GBL as a tool for disciplinary exploration and science communication.

The following section of the paper describes the structure, mechanics, and thematic content of *EGI MASTERS* in detail, serving as a representative example of the broader outcomes of the GBL-based assignment.

5. The Development of EGI MASTERS

EGI MASTERS is a non-digital, team-based board game designed for two teams. It is an interactive and narrative-driven experience through which players explore the course's key areas of knowledge. These include: Energy, Operations Management, Logistics and Supply Chain Management, Quality Management, Decision Support, Information Systems, and University Life (EGI at UA). The ultimate educational objective is twofold: to communicate the scope of the IEM degree and to engage students in critical thinking, problem-solving, and collaboration.

The steps of the *Game of Games* followed in developing *EGI MASTERS* are described below.

5.1 Game Setup and Materials

The standard game materials include:

- A custom-designed board with colored paths representing each IEM area.
- A standard six-sided die.
- Two colored player pawns (red and blue).
- A Tangram puzzle per team, divided into seven uniquely shaped pieces.
- A deck of themed challenge cards (one set per knowledge area).
- A separate set of "Mystery Cards" containing surprise events.
- A score sheet and a mobile phone with internet access for multimedia challenges.

Figure 1 presents the game board, where each coloured path represents a specific area of Industrial Engineering and Management (IEM). Progressing along these paths allows players to sequentially collect Tangram pieces, each corresponding to a distinct knowledge area.



Figure 1: EGI MASTERS game board

Figure 2 illustrates the Tangram pieces, which function both as a gamification element and as a metaphor for systems thinking — players must assemble all the pieces to form a complete figure, symbolizing how IEM brings together diverse disciplines to solve complex problems in an integrated manner.



Figure 2: EGI MASTERS Tangram pieces, assembled

5.2 Rules and Game Mechanics

The game is played by two teams, each consisting of 2–5 players. Each team takes turns rolling the die and advancing its pawn across the board. Upon landing on a square, the team draws a challenge card from the corresponding thematic deck. The opposing team reads the challenge aloud. Each challenge must be answered within 60 seconds. If the response is correct, the team is awarded a Tangram piece representing that area of knowledge. If incorrect, the team may choose either to remain on the square and attempt another question in the next round or continue progressing through the board.

Challenges vary in format and difficulty. Some cards require factual answers (e.g., “What is the difference between renewable and non-renewable energy?”), others ask for applied problem-solving (e.g., “What could a bakery do to meet lunchtime demand if its oven is too small?”), and some simulate real-world decision-making scenarios (e.g., “How can a company reduce errors in packaging?”). Additionally, several cards are designed to simulate typical IEM tasks using relatable activities—for instance, process mapping is introduced through the detailed description of brushing one’s teeth or preparing a sandwich, aligning everyday actions with the logic of quality management systems.

The game introduces unpredictability and strategy via the *Mystery Cards*, which resemble the chance mechanisms in traditional board games like Monopoly. These cards can radically alter the gameplay: some allow players to move anywhere on the board (“VIP Ticket”), others force them to swap places or Tangram pieces with opponents (“Swap”), and some offer rewards such as an extra Tangram piece (“Checkmate”). Cards marked with a special symbol must be played immediately, increasing the tension and dynamics of the game.

To win, a team must collect all seven Tangram pieces—each tied to a specific IEM area—and reach the center of the board. Entry into the final square is only permitted once the Tangram is fully completed, reinforcing the educational metaphor of integration and synthesis.

5.3 Card Categories and Sample Challenges

The game features the following seven thematic decks, each tailored to communicate a key IEM concept:

- **Energy:** Focuses on sustainability, energy efficiency, and renewable sources.
- **Operations Management:** Presents real-life process bottlenecks and logistical challenges in industrial and service environments.
- **Logistics and Supply Chain Management:** Covers inventory strategies, transport optimization, and sustainable logistics practices.
- **Quality Management:** Encourages process mapping and standardization by using familiar daily activities as examples.
- **Decision Support:** Introduces structured decision-making through tools such as simulation, criteria evaluation, and SWOT analysis.
- **Information Systems:** Addresses the role of systems engineers in designing, integrating, and optimizing complex technological platforms.
- **EGI at UA:** Explores university culture, including student associations (e.g., AEGIA, JELA), academic life, and traditions within the IEM program at the University of Aveiro.

Figure 3 presents examples of cards – one from each of the seven decks – illustrating the challenge posed to the players along with the corresponding answer or solution.



Figure 3: Examples of EGI MASTERS' cards, one from each deck

6. Discussion and Conclusions

The experience of using GBL in the IEM course was highly successful, as evidenced by the students' performance, with grades ranging from 14 to 19 out of 20. This range not only reflects the students' understanding of the scientific contents and their ability to apply them creatively in the game development process, but also highlights the effectiveness of the pedagogical approach in fostering both academic achievement and practical skill development. Among the 18 games proposed by the various student groups, *EGI MASTERS* stands out for its strong alignment with pedagogical principles of experiential learning and constructivism. It promotes active engagement with the IEM curriculum, enhances teamwork, and encourages students to apply theoretical knowledge to simulated, often humorous or accessible, real-world scenarios. The inclusion of QR-code-based audio elements further diversifies learning modalities, allowing for audiovisual stimuli in a primarily analog environment.

When presenting the game in class, the development team started by promoting an interactive activity that involved all the students in the class using a quiz tool. They were also very effective in communicating the way the game works and in explaining how they created the activities for each of the sections of the game. The development team reported that designing the game required a high degree of research and creativity, and that their own understanding of IEM was deepened in the process. Despite its strengths, the students recognized areas for improvement, including expanding the number of cards per theme and developing content suitable for younger students.

Overall, *EGI MASTERS* successfully combines fun and education in a way that can foster interest in engineering studies, particularly among pre-university students unfamiliar with IEM. It exemplifies how GBL can be implemented in higher education not only as a teaching method but also as a reflective exercise in course identity and communication. Furthermore, some faculty members involved in the IEM undergraduate program at the University of Aveiro are considering using several of the games developed for promotional and educational purposes. These include public events, activities during the summer academy, and visits organized by secondary schools to the university, aimed at giving high school students a clearer understanding of the

academic programs offered. Additionally, this work is believed to offer insights and resources that educators can adapt for similar pedagogical initiatives aimed at promoting academic programs and enhancing student learning, as well as for use in more playful or informal contexts.

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Educational Games for Indirect Length Comparison in Sighted and Blind Students

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Abstract: Length measurement is one of the fundamental axes of Mathematics from early childhood for both sighted and blind children. Despite its curricular importance, many students face persistent challenges in effectively comprehending length measurement. Inclusive classrooms, where sighted and blind students learn together, add further complexity, requiring adaptive instructional materials and strategies to promote equitable learning outcomes. This study investigates the use of play-based learning, specifically Gamification and fully designed educational games, to enhance understanding of length measurement in co-educational environments. Specifically, it presents the results of implementing three (3) designed games in a group of sighted and blind students attending a general education primary school. Game A involved a conventional length measurement task augmented with basic Gamification features (scenario, cards) designed to increase student motivation and engagement without altering the task structure. Game B, incorporated additional Gamification elements such as board and pawns, while Game C was a typical (board) card game, that also included Gamification features (NFC tags). The study aimed to analyze students' behaviors and strategies in tactile exploration when performing indirect length comparisons, as well as their preferences among the three (3) games. Findings indicate that the majority of students in indirect comparisons using arbitrary units (paperclips, string) employed various tactile exploration strategies such as aligning paperclips in the same direction without gaps or overlaps and placing the string from one end to the other. Some students, however, exhibited tactile exploration behaviors that included misalignments, such as placing paperclips with gaps and different directions. When using standard (cubes) and conventional measuring tools (ruler, measuring tape), students primarily structured tactile exploration strategies, ensuring cubes were connected without gaps or overlaps and aligning ruler and measuring tapes from the "0" mark. Importantly, Game C was overwhelmingly preferred by students and led to statistically significant improvements in motivation, engagement, peer interaction, and collaborative problem-solving. The findings suggest that while Gamification elements enhance traditional tasks, purpose-built educational games that combine accessibility with educational design offer superior support for inclusive mathematics instruction. The study recommends wider adoption of such games to facilitate equitable length measurement learning in inclusive classrooms.

Keywords: Gamification, Indirect length comparison, Game design, Tactile exploration, Blind and sighted students

1. Introduction

Length measurement remains a fundamental mathematical skill and serves as one of the simplest ways to quantify continuous quantities (Johnson & Miller, 2021). Children usually grasp it by comparing object attributes like height and length (NCTM, 2023). Although modern curricula emphasize its importance (ACARA, 2024; CCSSI, 2023), teaching often focuses more on procedures than deep understanding (Garcia et al., 2022). Thus, new approaches aim to build conceptual knowledge and refine intuitive understanding (Wang & Chen, 2022).

In inclusive classrooms with sighted and blind students, adaptations like tactile materials and alternative teaching methods are essential (Morris & Sharma, 2011). Game-based learning—especially board games with tactile or audio features—can support engagement and understanding (Vankúš, 2023; Gutschmidt et al., 2021). This study explores how three educational games promote haptic strategies and indirect length comparison among four primary students—one blind and three sighted.

In light of the above, this work presents the design and implementation of three different games aimed at mapping the behaviors and haptic exploration strategies, as well as the game preferences of four (4) students, a blind and three sighted, attending a general education primary school, focusing on the different dimensions of indirect length comparison.

This study is part of broader research aimed at developing criteria for designing differentiated educational materials for the functional co-education of sighted and blind students.

The research question posed was the following:

RQ1: What behaviors and haptic exploration strategies emerge through games regarding the dimensions of indirect length comparison in sighted students and the blind student?

1.1 Theoretical Framework

Indirect Length Comparison

Indirect length comparison represents a crucial developmental stage in children's understanding of length and its measurement. Initially, children perceive length as a quantity but face challenges in accurately comparing objects (Sarama et al., 2021). Over time, they progress from direct comparisons, where objects are aligned to determine relative size, to using third objects as intermediates in indirect length comparison. This stage often involves early difficulties with tools like rulers. Eventually, children understand the relationship between length units and their application, gaining proficiency in using measurement tools such as rulers and flexible instruments for measuring curved paths (Callejo et al., 2021).

This transition marks a significant cognitive leap, as it requires children to understand and manipulate relationships between three elements: the two objects being compared and the third, reference object. Despite its importance, research indicates that many children struggle at this stage. Common challenges include misaligning reference objects, misjudging distances, or misunderstanding the principles behind the tools being used (Sarama et al., 2021). These difficulties often persist even after children are introduced to standard measuring tools like rulers, suggesting the need for sustained, conceptually rich instruction.

In educational settings, children are introduced to different types of measurement units, each with distinct characteristics. Informal or arbitrary units (e.g., paperclips, hands, string) do not require prior knowledge or formal instruction, making them accessible for young learners. However, these units often yield imprecise results and lack universal acceptance. Standard units, such as unit cubes or centimeter blocks, offer greater accuracy and comparability while still being easy for children to use without advanced instruction (Skoumpourdi, 2018). Standard composite tools, such as pre-measured strips or tactile number lines, reinforce the principle of unit consistency. These tools often bridge the gap between informal experiences and the more sophisticated use of conventional measuring instruments, such as rulers and tape measures, which require specific knowledge about scale reading, zero-point alignment, and unit interpretation (Skoumpourdi, 2018; Callejo et al., 2021).

Research indicates that sighted children face challenges at various stages of development in learning to compare lengths. Children aged 4-6 struggle with indirect length comparison using a third reference object (Matsuo et al., 2023), and those aged 5-8 experience difficulties with consistent use of measurement units. Between the ages of 8-10, children encounter problems with ruler alignment and placement, with limited understanding of the ruler's structure even at ages 9-11 (Clements & Sarama, 2007; Curry et al., 2006; Bragg & Outhred, 2004). Studies on children with visual impairments are limited, but findings suggest that learners aged 9-12 experience similar challenges in using rulers (Klingenberg, 2012; Jones et al., 2012). These children often rely on haptic and kinesthetic strategies, such as using their own bodies, to estimate length (Duran & Tufenkjian, 1969). According to the Common Core State Standards, by the end of second grade, students should be able to estimate and measure object length using a ruler (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010).

Differentiation between Haptic Exploration Behaviors and Strategies

The hand plays a vital role in how we perceive and interact with our environment, particularly through the sense of touch, or haptic perception (Smith & Lee, 2021). Haptic perception relies on two main systems: the skin and kinesthesia, which work together during active exploration (Garcia et al., 2019). Unlike vision and hearing, the haptic system is specialized in identifying material properties of objects.

Exploratory behaviors—how individuals use touch to gather and interpret sensory information—are shaped by factors such as a person's goals, prior experiences, age, and whether they have visual impairments (Johnson et al., 2019; Miller & Wong, 2022). Recent findings show that cognitive abilities like mental rotation influence these exploration strategies, and that having visual experience can improve how effectively individuals explore their surroundings through touch (Taylor & Roberts, 2023).

Designing Differentiated Material for Students with Visual Impairments

Students with visual impairments face considerable challenges when engaging with traditional learning resources. However, these barriers can be addressed through intentional, inclusive design. Research highlights the importance of principles like information economy (streamlining content for clarity), haptic feedback, and auditory cues in enhancing spatial understanding and promoting learner independence (Dulin & Park, 2020; Mason & McCall, 2019; Harley et al., 2018; Gutschmidt et al., 2021).

Educational adaptations such as computer-based simulations and tactile materials—crafted from basic or mechanical components—have proven effective in helping visually impaired students build accurate mental models of concepts (Papadopoulos & Koustriava, 2021). Studies consistently show that blind learners can match their sighted peers in texture discrimination, emphasizing the power of touch in learning (Lederman & Abbott, 1981).

More recent research reinforces the importance of multisensory learning tools, combining digital simulations with tactile and auditory elements to support deep, meaningful understanding (Papadopoulos & Koustriava, 2021; Kizilaslan & Yilmaz, 2023). The ability of blind students to perform on par with sighted students in tactile perception underlines the critical need for well-designed, accessible materials in achieving educational equity (Lederman & Abbott, 2020; Education Sciences, 2021).

2. Research Methodology

This study presents the findings derived from a group of four fifth-grade students attending a school in Thessaloniki, comprising three sighted individuals and a blind student. Instructional materials were provided in braille, and the student had prior instruction in the concept of length, supported by a special education teacher. For mobility, the student utilized a white cane. All members of the group were determined to be at a comparable cognitive and learning level, as established by their performance on a diagnostic assessment consisting of fifteen (15) tasks administered to the entire class prior to the commencement of the main study.

To preserve anonymity, participants' identities were concealed and instead represented by the capital letter 'S' (denoting "Student") followed by a numerical identifier corresponding to the order in which they participated in Game A (e.g., the first student was labeled S1, the second S2, and so forth).

The research employed a qualitative methodology, specifically participatory observation. The researcher systematically observed and documented behaviors, interpersonal dynamics, and interactions as they naturally occurred, without attempting to influence or alter them. Data collection was conducted with or without the assistance of suitable research instruments. Throughout the study, the researcher maintained a peripheral participatory role—remaining embedded within the social context but refraining from direct intervention in the group's core activities (McKernan, 1996).

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Research Tool

The research tool consisted of three educational games, developed and implemented in two stages based on Gamification principles. In the first stage, the functional characteristics of each game were defined to ensure design diversity. Game A included a narrative, rules, and text-based cards; Game B added a board, pawns, and cards; while Game C featured audio instructions and was designed to foster cooperative learning, allowing students to validate answers collaboratively. The researcher's role varied: in Games A and B, the researcher validated student responses, whereas in Game C, students acted independently.

In the second stage, a set of forty instructional cards was developed, covering topics in Mathematics (indirect length comparison) and Environmental Studies (animal identification, survival mechanisms, and reproduction).

Environmental Studies was chosen for its interdisciplinary character, integrating elements of science, technology, society, and culture. Cards in Games A and B included tactile illustrations and text in both print and braille, while those in Game C provided recorded audio instructions via NFC tags.

All games incorporated accessibility features such as tactile dice, reward cubes, Velcro clips for stable measurement, and magnetic game boards and pieces. Game rules were available in both standard print and braille. All components—cards, containers, boards, pawns, cubes, audio devices, and animal figures—were designed using AutoCAD 2021 and 3D printed with PLA filament. The accuracy of braille text and functionality of materials were validated at the Center for Education and Rehabilitation for the Blind, following procedures similar to those described by Ismah, Muthmainnah, and Damayanti (2019).

The Creation of the Cards

The development of the card content followed a two-stage process. First, the Environmental Studies curriculum and relevant zoo websites were reviewed to select animals suitable for illustrating indirect length comparison and feasible for tactile or visual representation. Next, the selected animals were categorized and linked to specific dimensions of indirect comparison, organized into three tables aligned with distinct learning objectives.

Due to space limitations, card content focused solely on length comparison tasks. Supplementary Environmental Studies information was provided in printed form after gameplay to support interdisciplinary learning.

Research Implementation Process

The research was implemented through the structured administration of three educational games—Game A, Game B, and Game C—conducted on separate days. Each session began with a trial round to acquaint the students with the game rules and mechanics. Four students, selected based on their performance in a diagnostic assessment, participated in the sessions, which were conducted in a specially prepared area outside their regular classroom.

The games were played at a shared workspace consisting of two joined desks, allowing equal access to all materials. In Game A, students took turns drawing cards containing measurement instructions in both braille and print, executing the task, and providing a response. The researcher verified each response, awarding a cube for correct answers and providing no reward for incorrect ones.

Game B maintained the same basic structure but introduced a game board with four individual paths. Correct responses enabled students to advance one square along their respective paths, reinforcing learning through visual progress.

Game C incorporated audio instructions delivered via NFC-enabled cards and a smartphone device. It featured textured paths of increasing difficulty and emphasized both individual and collaborative engagement. Students listened to audio instructions, performed measurement tasks, and then had their answers verified by a peer. Correct answers advanced the player and awarded two cubes, while incorrect answers led to a loss of one cube. Students who verified answers received or returned cubes based on the accuracy of their validation.

Throughout all sessions, video recordings focused on students' hands were used to document haptic exploration strategies, supporting qualitative analysis of their tactile interaction and engagement during gameplay.

3. Results

Before presenting the findings related to students' behaviors and strategies in haptic exploration, a clarification is necessary regarding the distinction between the concepts of *behavior* and *strategy*. In the context of this study, *behavior* refers to the use of various methods for indirect length comparison in a non-systematic manner. In contrast, *strategy* denotes the consistent use of the same method of indirect comparison in two or more of the three games.

3.1 Indirect Comparison Using Arbitrary Units (Paperclips, String)

Student 1 (S1) demonstrated consistency in the placement of paperclips across all three games, aligning them without gaps or overlaps. She assigned measurement units only in Game A. With regard to string usage, she positioned it correctly from end to end in Games A and C (Figure 1); however, in Game B, the measurement did not begin at the correct starting point.



Figure 1: Indirect comparison of objects by placing the string from one end to the other of the objects being compared

Student 2 (S2) initially placed the paperclips directly on the objects in Game A but then repositioned them correctly and consistently above the objects, assigning a unit to the measurement. In Games B and C, she maintained correct placement of the paperclips but did not include a unit. Her use of string was accurate and consistent across all games, applying it from one end of the object to the other.

Student 4 (S4) experienced significant difficulties. In Game A, his placement of paperclips was inconsistent, with overlapping and varied directions. In Game B, although he correctly placed the paperclips on the first path, he reversed their orientation on the second and omitted the unit. In Game C, his placements were correct and consistent, but again lacked unit assignment and varied in their position relative to the object. For the string, he counted knots in Game A, applied it correctly in Game B, and inconsistently in Game C, sometimes measuring only parts of the object or its full length irrespective of the task.

Student 3 (S3) (blind student) consistently placed the paperclips correctly in Games A and C but omitted the unit. In Game B, his placements were incorrect. His string usage was accurate in Games A and B. In Game C, although he measured both paths correctly in two instances, in one case, he measured only one of the two paths, using three fingers for haptic exploration of the second.

3.2 Indirect Comparison Using Standard Units (Cubes)

Student 1 (S1) consistently placed the cubes without gaps across all three games. In Game A, she did not assign a unit, whereas in Game B, both correct placement and unit assignment were observed. In Game C, her performance varied: in one case, she omitted the unit despite correct placement; in another, she included it; and in one instance, the cubes were placed with gaps and no unit was assigned.

Student 2 (S2) also showed generally accurate cube placement but rarely assigned units. In Game A, she placed the cubes correctly in both tasks but omitted the unit each time, including after tactile verification in one case. In Game B, the cubes were correctly aligned but without unit notation. In Game C, one instance showed correct placement without a unit, while another involved cubes positioned outside the objects with gaps (Figure 2), though a unit was included.

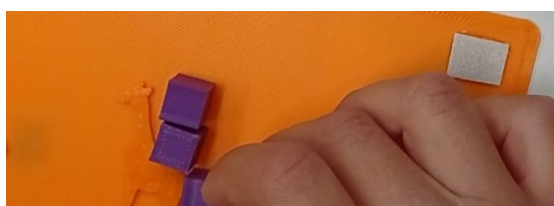


Figure 2: Indirect comparison of objects by placing the cubes outside the objects to be compared, with gaps

Student 4 (S4) demonstrated correct cube placement in Games A and B but did not assign any units. In Game C, his performance declined, with placements outside object boundaries and occasional incorrect quantities, although some were correctly aligned. Unit assignment was consistently absent.

Student 3 (S3) (blind student), placed the cubes correctly and assigned a unit in one task each from Games A and B. In later tasks, he omitted the unit despite correct placement. In Game C, most placements were accurate, but one involved gaps and incorrect alignment. Overall, his unit assignment was inconsistent.

3.3 Indirect Comparison Using Conventional Measuring Tools (Ruler, Measuring Tape)

Student 1 (S1) in Game A used the ruler and measuring tape starting from “0” and correctly assigned a unit. In Game B, while the tools were correctly placed, the unit was omitted. In Game C, she used the tools appropriately across all cards, but only once did she assign a unit to the result.

Student 2 (S2) and *Student 4 (S4)* consistently placed the ruler and measuring tape from “0” across all games but did not assign a unit in any instance. *Student 3 (S3)* (blind student) also placed the ruler and measuring tape from “0” in all games without assigning a unit. However, in one instance during Game C, the ruler was placed starting from “1” (Figure 3), and again, no unit was recorded.



Figure 3: Indirect comparison of objects by placing the ruler from "1"

The participants overwhelmingly preferred Game C, a card-based activity enriched with various Gamification elements and tactile adaptations. This preference was attributed to its original features, ease of auditory over visual instruction, and the inclusion of peer verification, absent in Games A and B. However, several factors appeared to impact student performance: the extended duration of Game C, the large number of cards, and elements such as difficulty levels and point systems, which were ultimately deemed non-essential as they did not influence the flow or outcome of the game.

4. Conclusions

In the domain of indirect comparison using arbitrary units (e.g., paperclips and string), *Student 1 (S1)* and *Student 2 (S2)* predominantly employed haptic exploration strategies, placing paperclips without gaps or overlaps. In contrast, *Student 4 (S4)* displayed irregular placement patterns—marked by inconsistent directions, overlaps, and gaps—indicating a lack of systematicity. *Student 3 (S3)* (blind student) demonstrated some inconsistency in directional placement, particularly in Game B. Regarding the use of string, *Student 1 (S1)* and *Student 2 (S2)* maintained relatively structured strategies, while *Student 4 (S4)* encountered significant difficulties in accurate placement. Despite his visual impairment, *Student 3 (S3)* applied consistent string placement and utilized three-finger tactile exploration in Game C, reflecting adaptive haptic techniques. These findings echo previous research (Lehrer, 2003; Matsuo & Nakawa, 2019; Matsuo et al., 2023) on the challenges of developing indirect measurement skills through haptic means.

When using standard units (cubes), most students applied tactile strategies, ensuring contact between cubes. Nonetheless, common errors emerged, including gaps between cubes, incorrect quantities, and misaligned placement around instead of along the objects. Such errors align with previous findings (Skoumpourdi, 2018; Strayton, 2018; Sutherland et al., 2020), which reported similar issues in cube placement during length estimation tasks.

In the context of conventional measuring tools (rulers and tape measures), most participants demonstrated basic understanding of measurement, employing haptic techniques and generally starting from “0.” However, a recurring error involved initiating measurements from “1,” a pattern also observed in earlier studies (Lehrer et al., 1999; Bragg & Outhred, 2001; Gómezescobar et al., 2020).

Students—both sighted and blind—expressed a clear preference for Game C, a gamified, card-based activity featuring adaptive elements. This preference likely stemmed from the novelty of its components, auditory instructions, and peer-verification mechanism. Nevertheless, the game’s extended duration, excessive number of cards, and unnecessary complexity (e.g., point systems, difficulty levels) hindered the flow of gameplay.

Based on these findings, it is recommended that inclusive educational settings integrate gamified activities designed to support equitable access, differentiated difficulty, collaboration, and peer feedback. Equal access can be promoted through assistive features such as NFC tags and magnets. Varying difficulty levels can accommodate diverse learning needs, while peer validation processes foster communication, engagement, and reflective learning.

These recommendations aim to enhance educational inclusivity and promote active, collaborative learning experiences for all students.

Ethics Declaration: This research was conducted in accordance with the *Convention on the Rights of the Child*, with primary consideration given to the best interests of the children involved. A key ethical principle adhered to was *Informed Consent* and the *Voluntary Nature of Participation*. The researcher provided comprehensive information about the study's objectives to both the participants and their parents or guardians. It was clearly communicated that participation was entirely voluntary and that both children and their guardians had the right to withdraw from the study at any time, without consequence. A second fundamental principle observed was *Anonymity and Confidentiality*, ensuring that the identities and personal data of participants were protected throughout the research process. Additionally, formal approval to conduct the research was obtained through a consent document authorized by the University of the Aegean and the Institute of Educational Policy.

AI Declaration: No AI tools were used in the creation of this paper.

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Railway Quest: A Gamified Teaching Platform for Concurrent and Parallel Programming

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Abstract: Teaching concurrent and parallel programming presents substantial challenges, primarily due to its conceptual complexity and the required paradigm shift from sequential programming. Railway Quest is a gamified digital platform designed to facilitate students' learning of multithreaded programming concepts through an interactive approach. The platform translates abstract programming challenges into train locomotion scenarios, wherein trains represent threads that must move along tracks while avoiding crashes, resource access conflicts, and indefinite delays. By leveraging game-based learning and gamification principles, Railway Quest enhances students' motivation and engagement through a visual and interactive representation of multithreaded executions and concurrency issues. The platform allows students to develop and execute code-based solutions, immediately observing their impact in real-time simulations presented through a low-poly isometric interface. Such approach significantly helps in conceptualizing threading constructs and synchronization mechanisms. Railway Quest supports both integrated and remote learning environments, making it an effective educational tool, especially for distance learning. The platform has been deployed in a university course in Spring 2025, with the aim to bridge the gap between theoretical knowledge and practical problem-solving in concurrent and parallel programming. Preliminary data from 45 students suggests a positive impact on students' understanding of key concurrency problems such as race conditions, deadlocks, and starvation, as well as their proficiency in utilizing synchronization tools like mutexes and conditional variables.

Keywords: Concurrent programming, Parallel programming, Gamification, Game-Based learning, Computer science education, Interactive learning

1. Introduction

Concurrent and parallel programming (CPP) is a fundamental topic in modern computer science curricula, yet it remains notoriously challenging for students to learn (Ben-Ari, 2001; El-Nashar & Nakamura, 2013; Zhu et al, 2020). The underlying dynamics, such as thread and synchronization behaviours, race conditions, and deadlocks, require a significant paradigm shift from sequential programming, involving a high level of abstraction capability. (Ben-Ari & Kolikant, 1999; Hughes et al, 2005). Traditional teaching methods often struggle to make these dynamic, complex concepts tangible and understandable.

Game-Based Learning (GBL) and gamification have shown promise in increasing student engagement and facilitating the understanding of complex topics across various domains, including computer science (Ibanez et al., 2014; Oktaviati & Jaharadak, 2018). However, applying GBL effectively to the abstract and often counter-intuitive paradigm of concurrent and parallel programming, particularly in terms of visualization, presents unique challenges and opportunities.

This paper introduces Railway Quest, an innovative gamified simulation platform developed at the University of Applied Sciences and Arts of Southern Switzerland (SUPSI). Designed for flexibility, the platform supports various learning contexts including integrated classroom settings and distance learning scenarios. Railway Quest aims to facilitate the learning of CPP concepts by translating abstract programming problems into engaging, visual missions involving train locomotion. Students write programs to control trains (representing threads) advancing through tracks and needing to manage shared resources (crossings, train stations) and avoid concurrency issues like collision risks (data races) and indefinite delays (deadlocks).

The remainder of this paper is structured as follows. Section 2 introduces the related work in game-based learning and CPP. Section 3 presents the design rationale and pedagogical approach, as well as the

development process of Railway Quest. Furthermore, Section 4 presents preliminary findings from its initial deployment in a second-year undergraduate Computer Science course in Spring 2025, evaluating its perceived effectiveness and reception by students. Section 5 concludes the paper by presenting a discussion on the findings, and directions for future work.

2. Background

To position Railway Quest, we conducted a targeted review of existing educational games and platforms for programming. The selection focused on tools mentioned in the academic literature on computer science education and popular educational game repositories. Each tool was analyzed based on its approach to teaching parallelism, the inclusion of core concurrency concepts (e.g., non-determinism, synchronization primitives), the use of actual programming languages, and its visualization strategies for abstract concepts. This analysis aimed to identify gaps that Railway Quest could address.

Computer science education has long explored game-based learning approaches to teach (sequential) programming and algorithmic thinking, as reported in the literature (Akimoto & Cheng, 2003; Cliburn, 2006; Barnes et al, 2008; Papastergiou, 2009; Ibrahim et al, 2011; Harteveld, Smith & Carmichael 2014;,, Abernethy, 2018; Zhu et al, 2020), and in off-the-shelf learning applications, with games such as *Space Chem*, *Human Resource Machine*, or *The Farmer Was Replaced*. Even though CPP has become increasingly essential in modern software development, driven by the proliferation of multicore processors, the complexities of the subject remain largely unaddressed by educational games, thereby continuing to present substantial learning challenges for students and novice developers. Unlike traditional sequential programming, adding concurrent thread execution in a software application requires a fundamental shift in how problems are approached, and solutions are structured, often involving complex concepts such as shared memory access, critical section execution, synchronization, deadlocks, and starvation.

Some games, like *Space Chem*, introduce parallel execution but only in a deterministic way, failing to capture the non-deterministic nature of a concurrent program execution. Among others, *Parapple* (Buzek & Kruliš, 2018) presents the non-deterministic aspects of such programs, yet it does not cover synchronization constructs (such as mutexes, conditional variable or barriers).

Parallel (Zhu et al, 2019; Zhu et al, 2020) is one of the few games able to introduce some of the basic CPP concepts by retaining its non-deterministic nature. Players are required to design a strategy to coordinate multiple arrows (representing threads) as they collect packages and deliver them to designated points, while correctly managing access to critical sections along their ways. While the game integrates some elements of concurrent and parallel programming, such as threads, shared resources and semaphores, it falls short in establishing a concrete connection to actual programming paradigms and practices (by using real code to program the game). Additionally, it lacks a realistic contextual scenario that helps students visualize multi-threaded executions using a metaphor-based simulation.

This paper presents the approach adopted in Railway Quest to introduce and teach CPP concepts directly with a commodity programming language (such as Java), by means of the visual metaphor of trains, significantly helping in conceptualizing threading constructs and synchronization mechanisms, encouraging situated learning.

3. Game Design and Development

This section presents the rationale behind the game design, the pedagogical considerations underlying the selected approaches, how CPP elements are tied to in-game elements, and the architecture of the platform.

3.1 Conceptual Game Design and Pedagogical Approach

The development of Railway Quest was guided by a Design-Based Research (DBR) methodology. This approach was chosen to systematically address the practical challenges of teaching concurrent and parallel programming while contributing to a deeper understanding of how gamified simulations can support learning in this complex domain. Our DBR process involved iterative cycles of design, implementation, analysis, and refinement, conducted in the authentic context of the second-year undergraduate Computer Science course “Parallel and Concurrent Programming”, which teaches CPP fundamentals in the Java programming language. The interdisciplinary collaboration between the Department of Innovative Technologies (DTI) and the Department of Education and Learning / University of Teacher Education (DFA/ASP) at the University of Applied Sciences and Arts of Southern Switzerland (SUPSI) was central to this methodology, ensuring that pedagogical

principles, gamification strategies, and technical development were tightly integrated. Railway Quest is primarily designed for individual problem-solving, allowing students to progress at their own pace. While direct in-platform collaboration or competition features are not yet implemented, the laboratory setting encourages peer discussion and collaborative problem-solving around the challenges presented by the platform, facilitated by instructors.

The central metaphor translates CPP concepts into a railway scenario: threads become trains, each following a path defined by the track layout. Shared resources critical to concurrency are represented by specific track segments, such as single-track crossings, stations, or loading docks, which only one train can access at a time. Synchronization primitives (locks, conditional variables, synchronizers) are the tools students must use in their Java code to ensure safe traversal through these critical sections and avoid resource contentions. Concurrency issues manifest visually. For example, race conditions might appear as trains attempting to occupy the same segment simultaneously (risks of collision), while deadlocks manifests as trains waiting indefinitely at crossings or when attempting to access shared resources.

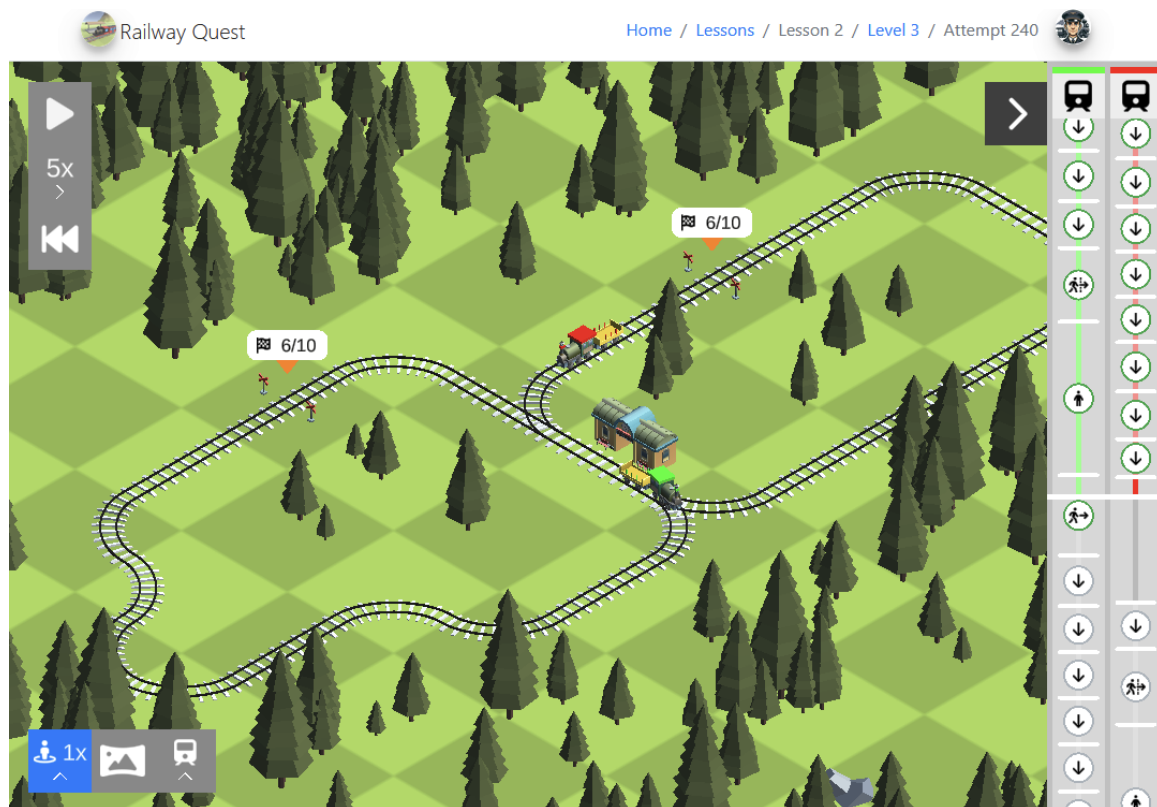


Figure 1: Trains traversing a critical section (the station)

Figure 1 shows the main interface of Railway Quest. Two train tracks share a critical section: the train station. The red train on top is correctly waiting until the station is freed by the green train, at the bottom. Students can modify the execution speed of the simulation by clicking the buttons at the top left corner of the screen, or modify the track viewpoint with the bottom left buttons. The timeline view on the right shows the commands' sequence for easier comprehension and code debugging. This view shifts top to bottom at real time, continuously showing the execution of the commands of each train. The colored top half shows the commands to be executed, the bottom greyed-out part shows the commands that still need to be performed.

The core gameplay loop was designed to involve the students visually analyzing a specific railway challenge presented on the platform (e.g., ensure two trains cross safely as shown in Figure 1, manage resource loading/unloading between trains as shown in Figure 2), writing Java code locally to control the trains' behavior using CPP constructs, and running their code to see the outcome. We designed the platform with a constructivist approach in mind, allowing the students observe the resulting train movements and interactions in the real-time visual simulation. Students can debug and refine their code based on the visual feedback until the challenge objective is met without errors, supporting formative assessment and allowing students to learn interactively. Challenges are hand-made and designed with increasing complexity, starting from basic thread execution to complex multi-thread coordination patterns. This approach was implemented to ensure that

students first acquire foundational knowledge before progressing, thereby supporting the maintenance of a continuous state of flow (Nakamura & Csikszentmihalyi, 2002) during the process.

Each challenge is explicitly designed to target specific CPP learning objectives, such as understanding mutual exclusion, implementing atomic operations, preventing deadlocks, or applying specific thread coordination patterns. The goal of each level is not to merely enable train movement, but to ensure that their *behavior adheres* to the principles and disciplines of concurrent execution. This fosters metacognitive skills, helping students understand *how* and *why* concurrency bugs happen.

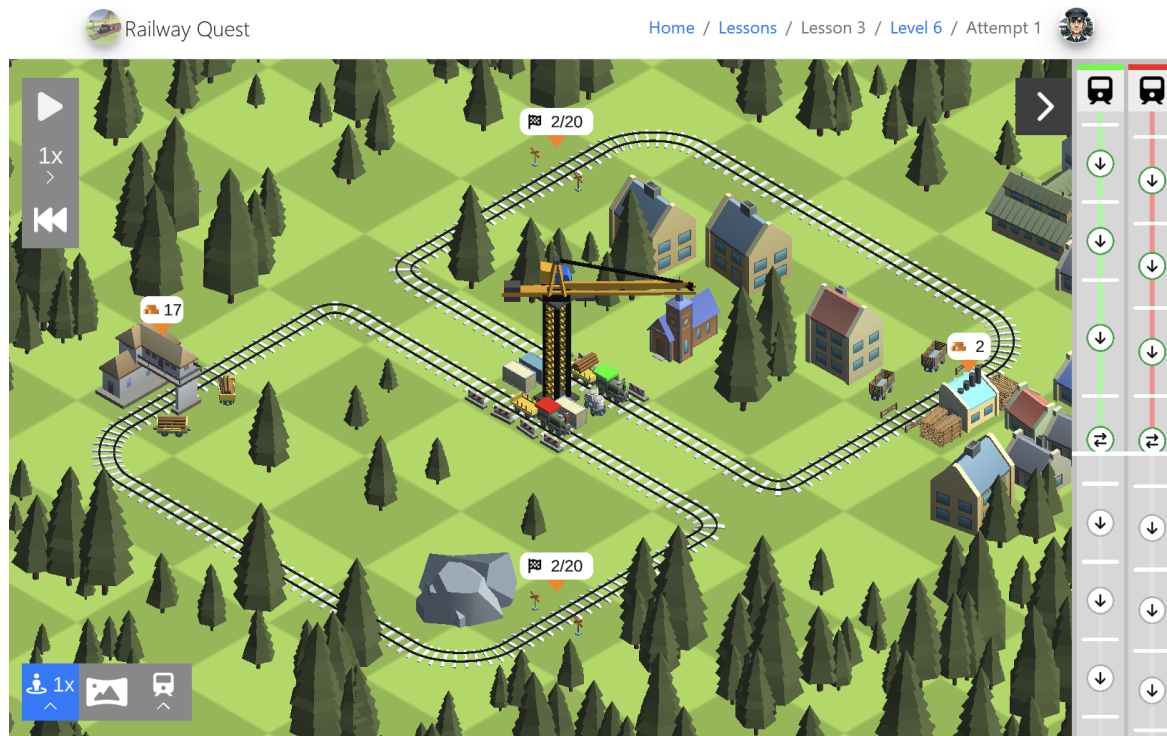


Figure 2: Trains loading and unloading resources, introducing the concept of thread coordination

Learning is guided through several mechanisms, such as scaffolding, by which challenges increase progressively in complexity, or problem-based learning (Hung, Jonassen, & Liu, 2008), by which concepts are learned by solving concrete (simulated) problems. The simulation instantly shows the results (success, collision, deadlock) of the student's code, facilitating immediate understanding and debugging. In this regard, the timeline view aids the understanding of the code execution and simplifies error correction. Following the concepts of game-based learning, students can freely test solutions without real-world consequences, allowed to re-attempt when the code execution does not yield the intended outcome. Elements like clear goals per challenge, progression through levels, and the intrinsic satisfaction of gamification in solving complex problems were introduced to enhance intrinsic motivation and lower fatigue perception. Moreover, the platform was designed to be used with teacher guidance, including contextualization, support during exercises, and debriefing sessions to consolidate learning and promote transfer of knowledge—that is, the students' ability to apply concurrency and synchronization principles learned within the platform to solve new, unseen programming problems beyond the Railway Quest environment.

3.2 Architecture

Railway Quest is a web-based platform. The main architecture of the platform was designed around the concept of having students write code on their local machines using their preferred Integrated Development Environment (IDE) and viewing the results of their code execution via the web-based visualization interface, as shown in Figure 3. The execution of the program initiates REST-based communications with the system's back-end running remotely, which conducts the simulation and supplies real-time data to the web-based visualization interface, implemented through an embedded Unity application.

When logging-in on the platform and starting a new attempt for a challenge, students are assigned a token that must be included in their code. This allows the back-end to tie the client code execution with the attempt and show the Unity train interface of the challenge on the student's web browser.

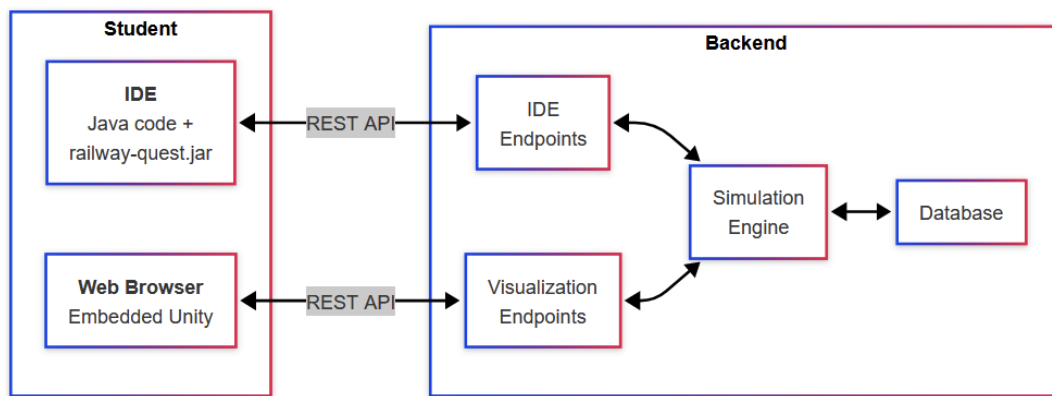


Figure 3: Architecture of the platform

The back-end simulation engine is structured around a discrete-event simulation model, which allows for control over the sequencing and coordination of concurrent events. This engine is responsible for replicating the execution behavior of the student’s code and evaluating the actions of the simultaneously running threads. The simulation engine ensures the correct execution order, therefore maintains consistency with the logical flow dictated by the student’s program. In addition to orchestrating execution, the engine incorporates mechanisms for detecting key concurrency problems such as collisions or resource access conflicts and updates the visualization accordingly in real time.

Figure 4 shows some example code snippets of a solution for a challenge which asks students to transfer wood chunks from the deposit to the factory by coordinating trains at the crane, as shown in Figure 2.

Students are tasked to define different Java classes to solve the challenge: one refers to the level itself (“WoodWorker”) which contains the class definition of GreenTrain (right-hand side code) and RedTrain (left-hand side code, on the bottom). The WoodWorker class also maintains important state, including a ReentrantLock, a Condition, and boolean flags (trainIsWaiting, transferCompleted) to coordinate the synchronization logic during wood transfer. The main() function, defined in the bottom-right corner, orchestrates the simulation by creating an instance of the WoodWorker class and setting the unique token generated by the platform to address this specific attempt. The execute() function initiates the attempt by retrieving the crane, creating and registering both trains, and starting their threads. The transferWood() method leverages locking and condition signaling to coordinate safe and ordered interaction between trains at the crane. By completing the challenge, students are allowed to move to the next challenge in the series.

4. Preliminary Test

Railway Quest was initially introduced at our university as part of the “Concurrent and Parallel Programming” course, during the first half of the Spring 2025 semester, where a total number of approximately 60 students were actively enrolled. The course was conducted weekly over a four-hour period, comprising one hour of traditional lecture, followed by two hours of laboratory sessions, and one hour of asynchronous activities (where students work independently on assignments). During the laboratory sessions, in which students practiced core CPP elements under the guidance of the instructors, they were tasked with solving challenges presented through Railway Quest, in particular for the course topics of “Introduction to thread execution”, “Race conditions and synchronization of threads”, and “Coordination of threads with conditional variables”. Teachers introduced the challenges (a total of seven fully developed levels) and students were prompted to formulate solutions by applying the CPP principles and techniques recently covered in the lecture. Lecturers were available during the laboratory sessions to help students figure how to solve the task, and to observe their interactions with the platform. At the end of the laboratory sessions, a small debriefing session took place, in which lecturers gathered insights about how the solution was found by the students.

Figure 5 displays the interface for “Level 3 - Station” on the Railway Quest web platform. The top section presents the student with the description of the scenario (e.g., two trains accessing a shared station needing synchronization), specific goals (e.g. ensuring 10 station entries and preventing collisions), and important level elements. These elements inform about specific parameters such as the number of trains and stations, suggest required programming tools like ReentrantLocks, and outline necessary train actions like calling enterStation(),

exchangePassengers(), and leaveStation(). A supplementary visual panel provides a representation of the level's layout. Beneath this section, an 'Attempts' panel presents the student's activity history for the current level in tabular format. The table includes columns for attempt number, status, resolution (SUCCEEDED/FAILED), duration, number of code executions, and date. Each previous attempt can be reviewed through an associated action button. Additionally, students may initiate a new attempt by selecting the 'New Attempt' button.

```
public class WoodWorker extends RailwayQuest {
    private Crane crane = null;
    private final Lock lock = new ReentrantLock();
    private final Condition condition = lock.newCondition();
    private boolean trainIsWaiting = false;
    private boolean transferCompleted = false;

    private void transferWood() throws InterruptedException {
        lock.lock();
        try {
            if (trainIsWaiting) {
                crane.transfer();
                transferCompleted = true;
                condition.signal();
            } else {
                trainIsWaiting = true;
                while (!transferCompleted)
                    condition.await();
                trainIsWaiting = false;
                transferCompleted = false;
            }
        } finally {
            lock.unlock();
        }
    }

    private class RedTrain extends Train implements Runnable {
        @Override
        public void run() {
            for (int lap = 1; lap <= 20; lap++) {
                move(nSteps: 6); // Go to deposit
                load(); // Load wood
                move(nSteps: 4); // Go to crane
                try {
                    transferWood();
                } catch (InterruptedException e) {
                    return;
                }
                move(nSteps: 4); // Go to spawn point
            }
        }
    }

    private class GreenTrain extends Train implements Runnable {
        @Override
        public void run() {
            for (int lap = 1; lap <= 20; lap++) {
                move(nSteps: 4); // Go to crane
                try {
                    transferWood();
                } catch (InterruptedException e) {
                    return;
                }
                move(nSteps: 4); // Go to the factory
                unload(); // Unload wood
                move(nSteps: 6); // Go to spawn point
            }
        }
    }

    public void execute() {
        startAttempt();
        crane = getCrane(Crane.Label.A);
        RedTrain redTrain = new RedTrain();
        GreenTrain greenTrain = new GreenTrain();
        register(redTrain, Train.Color.Red);
        register(greenTrain, Train.Color.Green);
        List<Thread> threadList = Stream.of(redTrain, greenTrain)
            .map(Thread::new).peek(Thread::start).toList();
        for (Thread thread : threadList) {
            try {
                thread.join();
            } catch (InterruptedException e) {
                System.err.println("Interruption occurred.");
            }
        }
        terminateAttempt();
    }

    public static void main(String[] args) {
        final WoodWorker quest = new WoodWorker();
        quest.setToken("LEVL-098J-A73Y-7SJN-RBQW");
        quest.execute();
    }
}
```

Figure 4: A possible Java-based solution for the challenge presented in Figure 2

Figure 6 shows a failed attempt. Both trains tried to access a train station, no synchronization was used in the program code, which resulted in a collision at the entrance of the station. In this scenario, the code reflects two threads concurrently attempting to access a critical section without using synchronization mechanisms such as locks. By hovering on the timeline view, students can understand what happened: a collision between two trains.

After the first half of the semester, students were asked to complete an anonymized interim survey aimed to measure their satisfaction with the course. The survey was answered by 45 students, and included Likert-scale questions rating the usefulness of various course components and open-ended questions for qualitative feedback. The 45 survey respondents represent 75% of the approximately 60 students actively enrolled in the course. This response rate provides substantial preliminary insight into the student perceptions within this cohort. The demographic characteristics of the respondents are assumed to generally align with the overall class composition of second-year computer science undergraduates at our institution.

Within the survey, two specific questions addressed the perceived utility of Railway Quest for understanding concepts and its overall usefulness compared to other resources mentioned in class. Finally, an open-ended comment was left for students to express their feelings and ideas towards the platform.

Railway Quest Home / Lessons / Lesson 2 / Level 3

Level 3 - Station

Level Informations

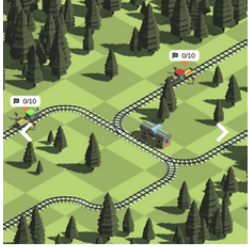
Description
Two trains access a shared station. Ensure both trains move along their tracks, enter the station, and exchange passengers without collisions. Use thread synchronization to control station access.

Goals

- Control the Red and Green trains as they travel along their tracks.
- Ensure each train enters the station 10 times.
- Prevent collisions by properly managing station access during their journey.

Level elements

- Number of Trains: 2
- Number of Stations: 1
- Programming tools: use `ReentrantLocks` and the `synchronized` keyword to synchronize train movements where needed
- Train actions: when reaching a station, first call `enterStation()` to allow the train to enter the station from the previous rail. Next, call `exchangePassengers()` to simulate passengers getting on and off the train. Finally, call `leaveStation()` to exit the station and proceed to the next section of track.



Attempts New attempt

#	Status	Resolution	Duration	Runs	Date	Action
1	STOPPED	SUCCEEDED	9:05	7	25/02/2025 - 22:59:58	▶
2	STOPPED	FAILED	01:43	1	28/02/2025 - 08:29:42	▶

Figure 5: Web interface of one level on the Railway Quest web-based platform

Railway Quest Home / Lessons / Lesson 2 / Level 3 / Attempt 390

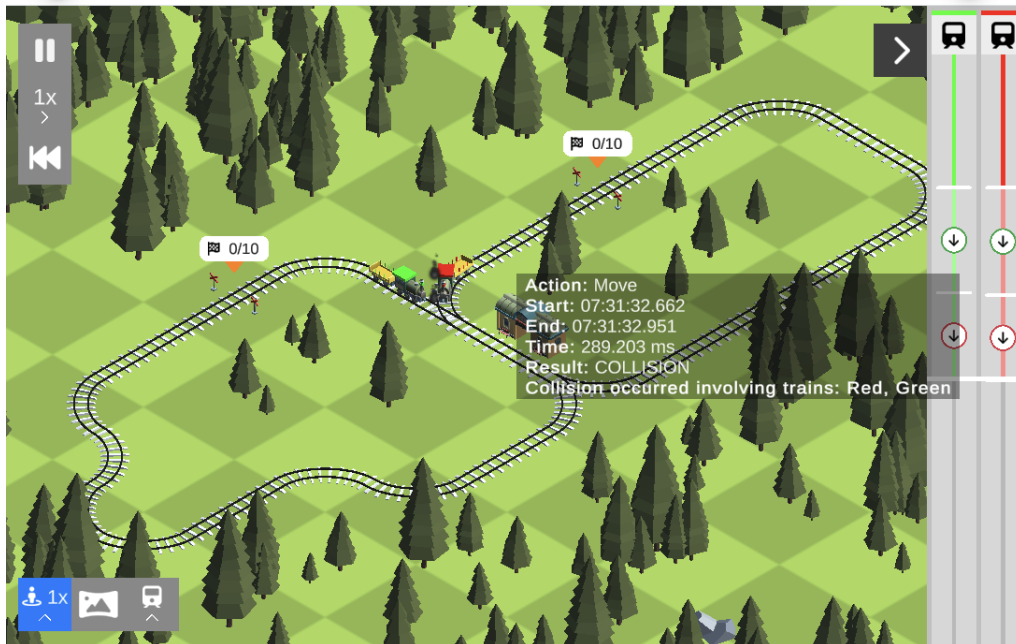


Figure 6: Trains collided, the attempt failed

5. Results

The first question regarding Railway Quest was "Railway Quest made it easier and quicker for me to grasp the concepts during both group and solo exercises". The answers are shown in Figure 7.

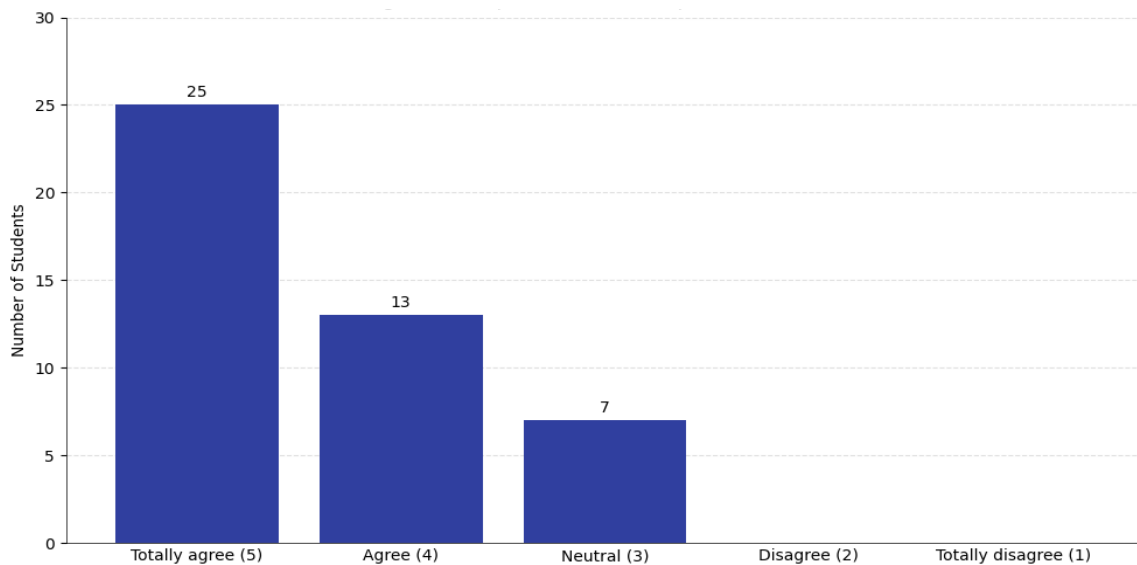


Figure 7: Answers for "Railway Quest made it easier and quicker for me to grasp the concepts during both group and solo exercises"

The average score given by students was 4.4 out of 5 (N=45, with 84% agreeing or totally agreeing). Among the various items in the questionnaire addressing the educational tools employed during the course, this question yielded the highest mean score, indicating a particularly positive student perception of the platform. Such result strongly suggests that students perceived Railway Quest as being very effective at its core goal: breaking down complex, abstract topics into something more understandable and visually intuitive. The fact that 84% of students rated it a 4 or 5 further emphasizes this widespread positive perception of its impact on their learning and comprehension.

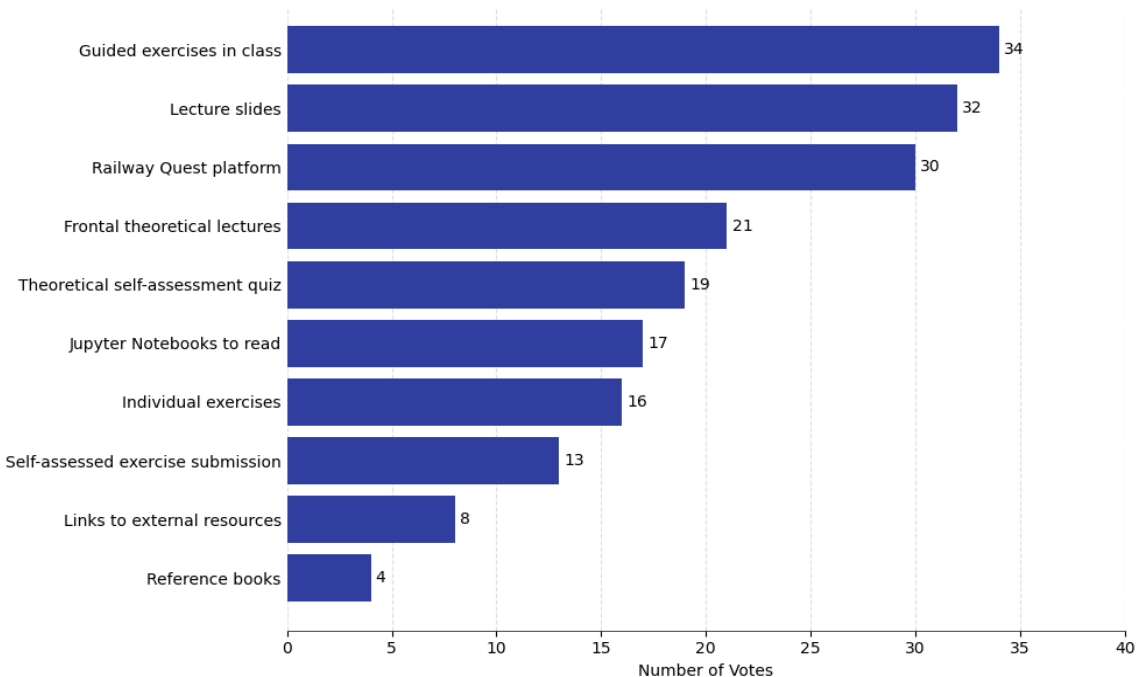


Figure 8: Answers for "What activities or resources do you find particularly useful for your learning?"

The second question was a multi-choice question asking, "What activities or resources do you find particularly useful for your learning?". Answers are shown in Figure 8. Railway Quest ranked 3rd (out of 10 options, receiving 30 votes), behind guided exercises and lecture slides. This ranking could imply that students view Railway Quest not just as a novelty, but as a valuable and central part of their learning experience during the course. Its perceived utility is comparable to fundamental teaching methods like practical exercises and core theoretical materials (slides). This high ranking validates its importance within the course structure from the students' perspective and suggests it effectively complements other teaching approaches.

The final open-ended comments reinforced the quantitative data results. Students praised Railway Quest for providing *"an excellent possibility to visualize the concept of Threads and various concurrency problems"*. Many highlighted the engaging and motivating aspects (*"I love the trains! They are pure dopamine!"*, *"beautiful... very fun and stimulating"*, *"the best addition to encourage doing the exercise series because you get immediate visual feedback and it's very pleasant"*). The platform was perceived as more effective for immediate understanding than traditional terminal output. Constructive criticism mainly focused on a desire for *"more levels"* potentially optional ones, and suggestions to increase its usage within the course.

These student testimonials corroborate the platform's aim to enhance motivation and engagement through its visual and interactive nature, as claimed in Section 1. The high ratings for enjoyment and perceived utility in understanding concepts further support this.

Moreover, these results encourage further development of the platform, with the addition of more levels and gamification elements (i.e., badges, visual progression, rankings, ...), as well as support for lecturers (i.e., lecturer dashboard with insight on usage data, level editor, ...). There were no negative comments regarding Railway Quest, or its use within the laboratory sessions.

6. Conclusion and Future Work

This paper presented Railway Quest, a platform for innovative application of GBL principles to the challenging domain of concurrent and parallel programming. By translating abstract concepts into a visual, interactive, and gamified railway simulation, it aims to lower the cognitive barriers associated with learning CPP.

Preliminary results from its first deployment are very positive, indicating that students find the platform highly useful, engaging, and effective in making complex concepts more understandable. The combination of immediate visual feedback and gameful challenges appears to be a successful strategy for this specific learning context.

Future work will focus on expanding the content by adding more diverse and advanced challenges, potentially including optional ones, based on students' feedback. We also plan to develop a teacher dashboard to better support monitoring and formative assessment and conduct a more rigorous evaluation of learning outcomes beyond student perception. Exploring support for other programming languages and integration with Learning Management Systems as a MOOC are also potential future directions, as well as collaborative development scenarios or even adapting the curriculum for different educational contexts, including advanced high school courses. The preliminary findings presented in this paper are based on student self-reported perceptions and satisfaction. The current study did not include a comparative analysis with a control group or direct measures of learning outcomes (e.g., comparative exam scores or standardized concept inventories), which could be part of a future work.

We believe Railway Quest demonstrates the significant potential of tailored, gamified simulations as effective pedagogical tools for complex topics in computer science education, fostering both deeper understanding and increased student engagement.

Ethics Declaration: The interim feedback survey described in this paper was conducted in accordance with the institutional guidelines for course evaluation at our institution. Participation was voluntary, and student responses were collected anonymously to ensure confidentiality and protect privacy. Standard procedures for obtaining informed consent for participation in course feedback activities were followed.

AI declaration: We confirm AI tools were not used during the creation of this paper.

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Transforming Math Anxiety into Engagement: The Impact of RPG-Based Gamification on Middle School Students

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Abstract: In both classroom settings and everyday life, it is common to encounter phrases such as "Math is not for me," "I'm not good at scientific subjects," "I can't do it," "I don't understand anything," "What's the use?", and "I've always had bad grades in maths". These expressions reflect various forms of anxiety, frustration, and lack of confidence in one's mathematical abilities. Addressing these negative perceptions is crucial for improving attitudes towards mathematics, especially for students and their academic success. This research presents a case study on gamification's impact on middle school students' perceptions of mathematics in the Italian-speaking region of Switzerland. Inspired by role-playing game (RPG) dynamics, students take the role of fantasy characters navigating a structured world, facing challenges to earn points and progress through the story. The teacher acts as a game master, guiding the narrative while minimizing direct intervention. The game system includes an explorable map, individual and collaborative tasks to improve mathematical and social skills, and a progression system rewarding both academic performance and positive behaviour. Storytelling elements enhance immersion, while challenges requiring problem-solving or strategic skills promote deeper engagement. Preliminary observations suggest reduced maths anxiety and more positive attitudes towards the subject, though results appear to differ by gender. These findings indicate gamification's potential as a supportive educational tool, warranting further research.

Keywords: Mathematics anxiety, Gamification, Middle school education, Game-Based learning, Attitude improvement

1. Introduction

How many times in class, but also in everyday life, do we encounter common phrases about mathematics such as: "Math isn't for me", "I'm not suited for scientific subjects", "I'm not capable", "I don't understand anything anyway", "What's the use?", "I've always had bad grades in math". These expressions are just examples, but they reflect various forms of anxiety, frustration, and lack of confidence in people's mathematical abilities. Addressing these negative perceptions is fundamental to improve students' attitudes towards mathematics and their academic success.

Gamification, which consists of applying game elements to non-game contexts like education, could make learning mathematics more engaging, more motivating, and less frustrating. It also has the potential to transform students' negative perceptions, making mathematics a positive and stimulating experience. By transforming mathematics from a task perceived as arduous into a fun and stimulating activity, gamification can radically change students' perspectives. The healthy and friendly competition encouraged by games can motivate students to improve their skills without feeling overwhelmed.

This research project aims to explore if and how gamification can influence the perception of mathematics among middle school students in Ticino, the Italian-speaking part of Switzerland. Specifically, it investigates whether a gamified approach can contribute to prove students' attitudes and reducing their math anxiety towards the discipline.

2. Theoretical Framework

2.1 Attitude Towards Mathematics

Attitude towards mathematics is a complex construct involving affective (feelings, emotions), behavioral (tendencies, self-efficacy), and cognitive (beliefs, opinions) components, a framework originally described by Rosenberg and Hovland (1960). These dimensions interact dynamically to shape students' engagement and perceptions. Negative beliefs can lead to anxiety and hinder self-efficacy, creating a cycle of avoidance and poor performance (Zan et al., 2006; Mensah et al., 2013). Moreover, research underscores the importance of promoting self-efficacy and intrinsic motivation, as supported by Bandura's (1997) theory of self-efficacy and Ryan & Deci's (2000) self-determination theory. Fostering positive attitudes and confidence is crucial.

2.2 Mathematics Anxiety

Mathematics anxiety is a feeling of apprehension interfering with mathematical problem-solving in academic and daily life. It is influenced by emotional and cognitive factors, fear of errors, working memory load, and can manifest physiologically (Richardson & Suinn, 1972; Luttenberger et al., 2018). Mathematics anxiety negatively impacts performance and can deter students from STEM fields. Incidence varies by gender and age, often increasing during middle/high school, with females frequently reporting higher levels, possibly due to stereotype threat (Else-Quest et al., 2010; Devine et al., 2012; Dowker et al., 2016). Strategies to reduce mathematics anxiety include fostering a growth mindset (Dweck, 2006), using innovative teaching methods like gamification (Hamari et al., 2014), anxiety management techniques, and creating supportive learning environments (Shields, 2005).

2.3 Gamification

Gamification uses game-design elements (like avatars, narratives, feedback, levels, points, competition, collaboration) in non-game contexts to boost motivation and engagement (Deterding et al., 2011). It differs from Game-Based Learning (using full games) and Serious Games (games for specific non-entertainment purposes). In education, gamification aims to increase engagement, motivation, and learning, often providing immediate feedback (Hamari et al., 2014; Dicheva et al., 2015; Alt, 2023). However, potential downsides include superficial learning, unequal competition leading to stress, declining interest over time, and over-reliance on extrinsic rewards (Kapp, 2012; Hamari et al., 2014). Measuring its effectiveness requires rigorous methodology. Some studies show mixed results on attitude impact despite student enjoyment (Karamert & Vardard, 2021; Bragg, 2007).

3. Methodology

To investigate the impact of gamification on students' attitudes and anxiety towards mathematics, this study adopted a research-action design, relying primarily on quantitative data gathered through questionnaires administered before and after the intervention period. The research took place during the 2024/2025 school year within a specific second-year middle school class in Ticino, comprising 16 students (9 females and 7 males) aged 12 to 13 years old. This class presented a dynamic mix, characterized by heterogeneity in student profiles, a lively classroom atmosphere, and observable signs of initial low motivation towards mathematics. It is important to note that the small sample size suggests the findings should be interpreted as context-specific rather than broadly generalizable.

The research unfolded through a sequence of planned phases, beginning with an initial exploratory questionnaire to understand the students' baseline perspectives. The questionnaire was followed by the design of the specific gamification structure tailored for the class. Subsequently, pre-intervention questionnaires were administered to establish baseline measures for attitude and anxiety. The core phase involved implementing the gamified mathematics activities over a seven-week period, primarily during two dedicated weekly laboratory hours. Following the intervention, the same questionnaires were administered again to capture any changes. The final phase involved the analysis of the collected pre- and post-intervention data.

Two validated instruments were selected to measure the key variables. To assess attitudes, the Attitudes Toward Mathematics Inventory in Secondary Education (ATMSE) was utilized (Suherman & Vidákovich, 2022). This instrument, adapted from Tapia and Marsh's (2004) ATMI specifically for the middle school context and translated from English for this study, measures four dimensions across 26 items: Self-perception, Value, Enjoyment, and Perceived Achievement in mathematics. For measuring math anxiety, the Modified Abbreviated Math Anxiety Scale (mAMAS) (Carey et al., 2017) was employed. This 9-item scale is designed for younger students and effectively distinguishes between anxiety related to learning mathematics and anxiety stemming from evaluation situations.

The gamification intervention was designed as an immersive Role-Playing Game (RPG). Students took the roles of "apprentice heroes" within the fantasy narrative of the "Kingdom of Armathia," embarking on a quest against the "Lord of Shadows." Key gameplay elements were integrated to foster engagement, including an explorable, non-linear map that guided progress, integrated storytelling moments, and a variety of individual and collaborative challenges that required mathematical problem-solving. Students chose from distinct character classes (Mage, Ranger, Barbarian, Thief, Warrior), each possessing unique abilities, and could acquire additional power-ups through purchasable ability/tool cards. Each class is designed to support different gameplay approaches, giving students the opportunity to adopt a style that suits them best. Strategic classes like the Mage and Ranger emphasize puzzle-solving and team support (the mage allowing students to simplify a task, the

ranger allowing to earn more experience points), while aggressive roles such as the Barbarian and Warrior focus on combat and endurance (the barbarian automatically defeating lesser enemies, the warrior having various supporting abilities during fights). The Thief, representing a more tactical style, centres on resource management and manipulating game dynamics (stealing cards from other teams, or avoiding penalties from a failed check).

A multi-faceted scoring system tracked progress: Team Hit Points (THP) reflected collective resilience, Personal Points (PP, represented as Red Dobloons) rewarded positive behaviours and participation, and Experience Points (Exp, represented as Blue Dobloons) were earned through demonstrating disciplinary competence by completing mathematical tasks. Accumulating Exp was necessary to purchase cards and advance through the game's narrative arc, with students collaborating within designated teams. Figure 1 shows some of the in-game elements printed and ready to be used in class: Exp, PPs, a map of the area, purchasable items, and some handouts such as two chapters and one character sheet.

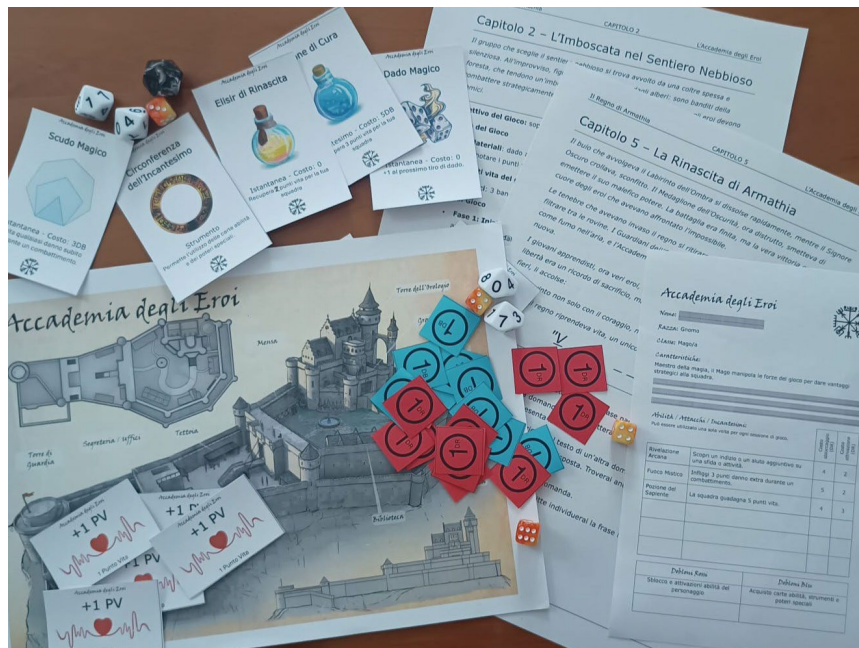


Figure 1: Printed in-game elements used in class

In practice, classroom activities were explicitly framed as missions within this overarching storyline. The journey begins at the Academy of Heroes (Figure 2), a central and symbolic location within the "Kingdom of Armathia". Here, students, transformed into "apprentice heroes," face their first challenges, each set in recognizable areas of the school. There is no predetermined order: students move autonomously, freely choosing their own path. Unlike in a traditional educational journey, student progression is not entirely linear. This approach allows players to decide which challenges to tackle first and in what order to explore the different areas of the map. Among the proposed activities are:

- The Library, where heroes must reconstruct a secret message using equivalent fractions;
- The Alchemy Lab, where they need to construct a cube to seal an unstable magic potion;
- The Canopy, where they design a perfect circle as a magic barrier.

All activities aim to reinforce and deepen the topics introduced and explored during large group classes. The focus is not solely on training specific skills, such as applying formulas, but also on developing problem-solving abilities. The gamified context motivates students not only to practice exercises that might otherwise feel tedious in a traditional setting, but also to engage with complex challenges that students with low self-efficacy might be reluctant to tackle under conventional pressure and performance evaluation conditions.

A group gameplay example can be seen in Figure 3.

Each session typically started with narrative prompts setting the scene, followed by hands-on mathematical tasks often structured collaboratively or leveraging the students' chosen character roles. Throughout this process, the teacher took the role of a game master, guiding the narrative, presenting challenges, monitoring progress, and dynamically adjusting the difficulty or flow based on the students' engagement and understanding.

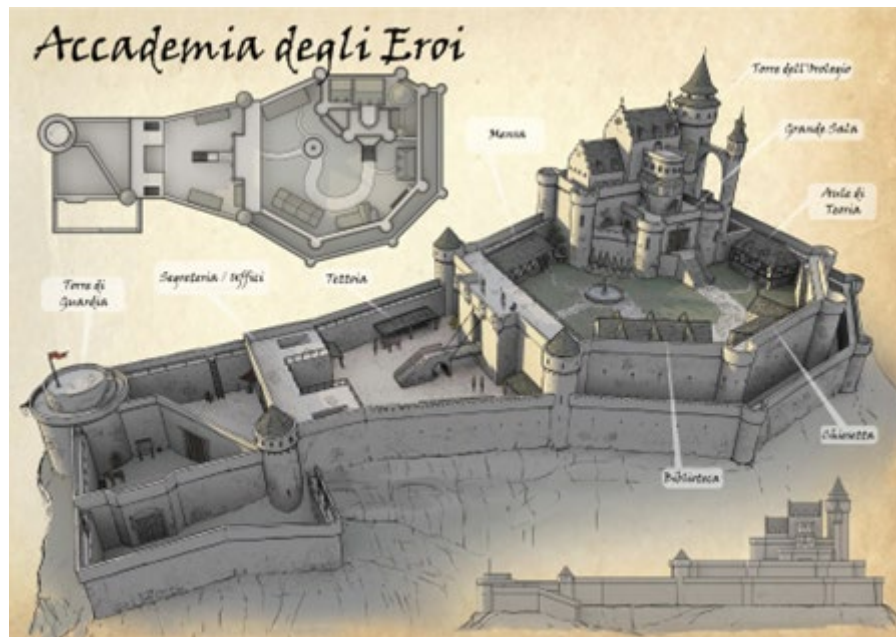


Figure 2: Map of the Academy of Heroes, a central and symbolic place to explore within the "Kingdom of Armathia"

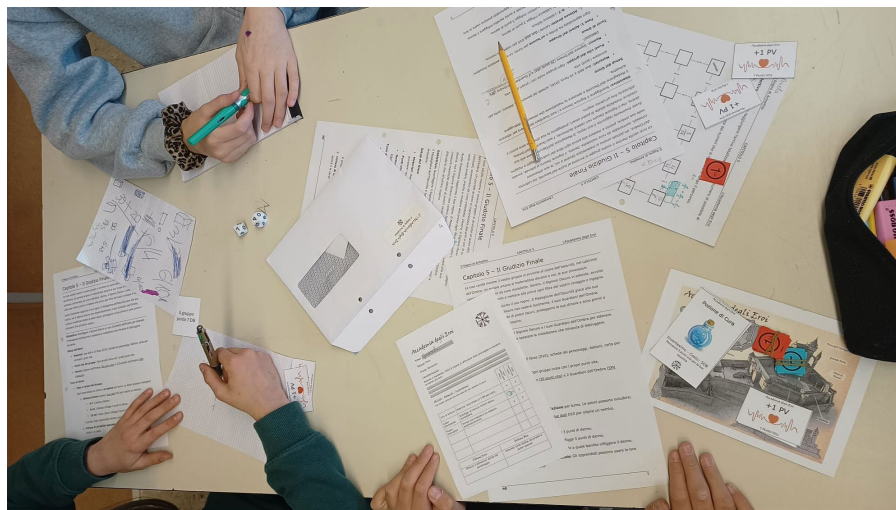


Figure 3: Students engaged in the fifth quest, "The Final Judgment"

4. Results

The analysis of data collected before and after the gamification intervention reveals notable trends and significant differences, particularly concerning gender, in students' attitudes and anxiety towards mathematics.

4.1 Baseline Perceptions Before Intervention

Initial insights were gathered through the exploratory questionnaire administered at the outset. This revealed a distinct contrast in how students perceived mathematics versus games. Mathematics was generally viewed as more complex, demanding, less intuitive, and less enjoyable than games, perceptions that were especially pronounced among female students. While mathematics was acknowledged as useful, this view was held more strongly by male students. Students' engagement with games varied. Although board games and video games were part of their leisure activities, roughly half the class reported not playing video games, a factor supporting the decision to implement a board game / pen-and-paper RPG rather than digital gamification infrastructure for inclusivity. A visual comparison of these initial perceptions regarding mathematics and games across different characteristics is presented in Figure 4.

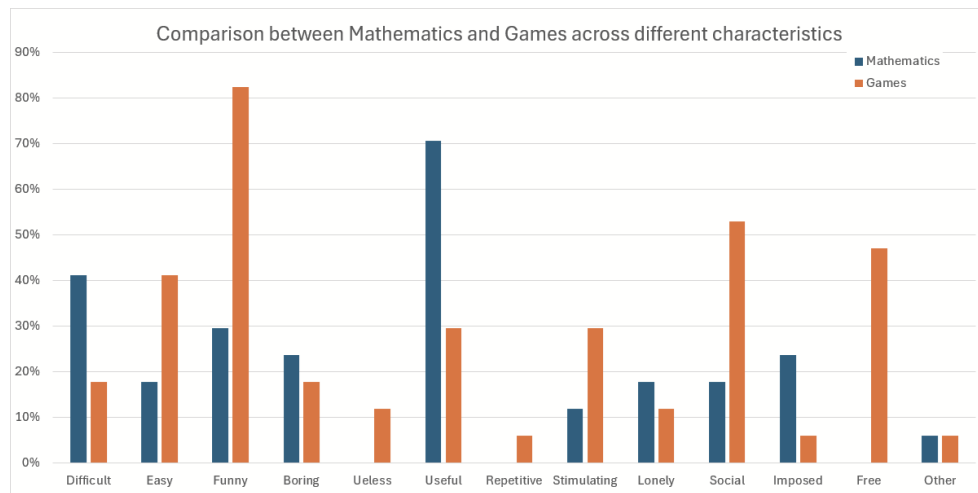


Figure 4: Comparison of students' perceptions between Mathematics and Games across different characteristics

The pre-intervention administration of the Attitudes Toward Mathematics Inventory in Secondary Education (ATMSE) demonstrated high internal consistency (Cronbach's $\alpha=0.97$). The baseline attitude scores indicated a significant gender difference: male students reported considerably more positive attitudes (indicated by lower scores) than female students across the four measured subscales (Self-perception, Value, Enjoyment, Perceived Achievement) and in their overall scores. Furthermore, while female students' attitude scores were relatively clustered, male students' scores exhibited greater variability, suggesting a wider range of attitudes among them. Figure 5 provides a box plot illustrating these pre-intervention ATMSE responses and the gender comparison.

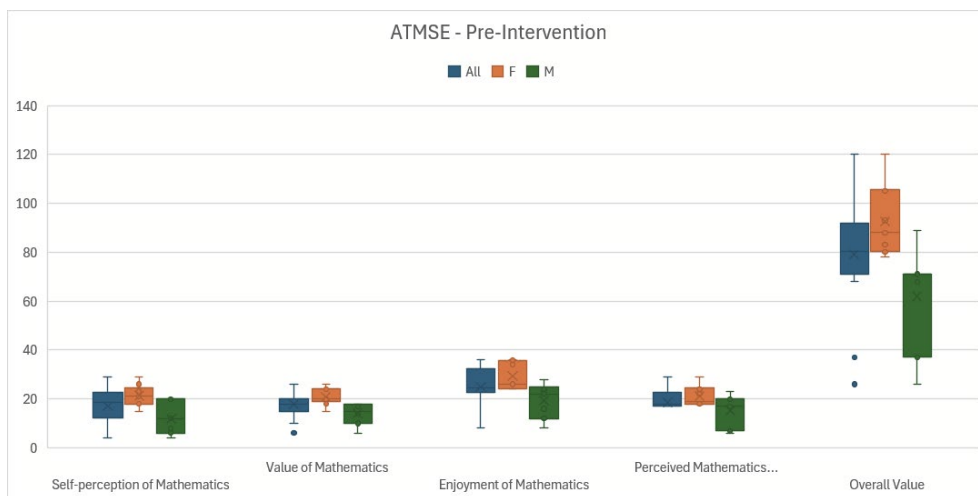


Figure 5: Box plot of ATMSE questionnaire responses pre-intervention, with gender comparison

Similarly, the pre-intervention assessment using the Modified Abbreviated Math Anxiety Scale (mAMAS) showed good internal consistency (Cronbach's $\alpha=0.88$). Overall, the class reported moderate levels of math anxiety at baseline. However, mirroring the attitude results, a significant gender disparity emerged: female students reported substantially higher levels of anxiety than male students, both concerning anxiety related to learning mathematics and anxiety linked to evaluation situations, as well as in their total anxiety scores. Again, male students' anxiety scores displayed greater variability compared to female students. These baseline anxiety levels, differentiated by gender, can be seen in Figure 6.

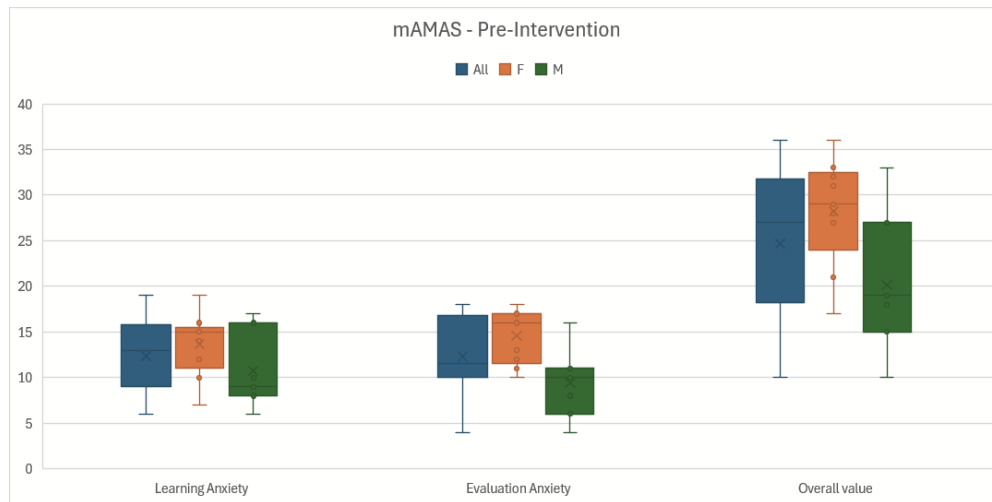


Figure 6: Box plot of mAMAS questionnaire responses pre-intervention, with gender comparison

4.2 Changes Following the Gamification Intervention

After the seven-week intervention period incorporating the RPG-based gamification, we once again administered the questionnaires.

The post-intervention ATMSE results maintained high internal consistency (Cronbach's $\alpha=0.97$). While male students exhibit again more positive attitudes towards mathematics than female students overall, there was a statistically significant improvement in the average attitude score for the entire class (a decrease of 4.3% in the total score, $p=0.014$), suggesting the intervention positively impacted overall attitudes. This can be seen in Figure 7. A breakdown of these changes, comparing pre- and post-intervention scores with gender comparisons, is detailed in Table 1.

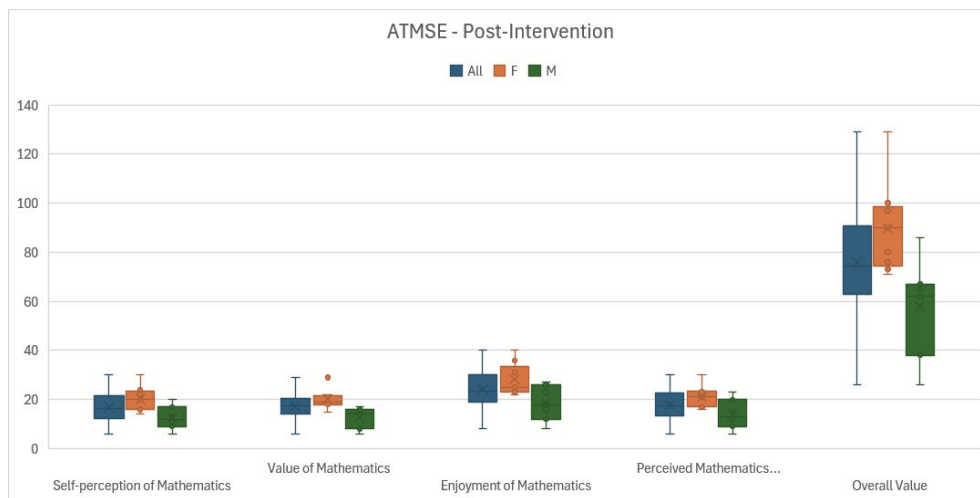


Figure 7: Box plot of ATMSE questionnaire responses post-intervention, with gender comparison

Examining the gender-specific changes in attitude (Table 1) reveals nuances within the overall positive trend. Female students demonstrated improvements across all attitude dimensions, with the largest (though not statistically significant) shifts seen in self-perception (-5.2%) and enjoyment (-3.4%). Their perceived achievement changed minimally (-1.6%). Male students also showed an overall improvement (-6.2% total score, $p=0.028$), driven by statistically significant gains in their perception of the value of mathematics (-8.2%, $p=0.015$) and substantial, though not statistically significant, improvements in perceived achievement (-8.4%). The overall improvement in perceived value for the entire group was also statistically significant (-4.6%, $p=0.043$).

Table 1: Paired Samples Test (ATMSE) with gender comparison of changes in math-related attitudes pre- and post-Intervention

	Gender	N	Mean differences	% Differences	SD	Cohen's d	p-Value
Self-perception of Mathematics	F	9	-1.11	-5.2%	2.62	-0.42	0.239
	M	7	-0.71	-5.4%	1.25	-0.57	0.182
	All	16	-0.94	-5.3%	2.08	-0.45	0.092
Value of Mathematics	F	9	-0.56	-2.7%	1.81	-0.31	0.384
	M	7	-1.14	-8.2%	0.90	-1.27	0.015
	All	16	-0.81	-4.6%	1.47	-0.55	0.043
Enjoyment of Mathematics	F	9	-1.00	-3.4%	2.55	-0.39	0.273
	M	7	-0.71	-3.7%	1.89	-0.38	0.356
	All	16	-0.88	-3.5%	2.22	-0.39	0.135
Perceived Mathematics Achievement	F	9	-0.33	-1.6%	1.22	-0.27	0.438
	M	7	-1.29	-8.4%	2.50	-0.51	0.222
	All	16	-0.75	-4.0%	1.88	-0.40	0.131
Overall Value	F	9	-3.00	-3.2%	5.85	-0.51	0.163
	M	7	-3.86	-6.2%	3.53	-1.09	0.028
	All	16	-3.38	-4.3%	4.84	-0.70	0.014

Turning to math anxiety, the post-intervention mAMAS results yielded good internal consistency (Cronbach's $\alpha=0.83$). While there was a slight decrease in the average overall anxiety score for the entire group (-7.6%), this change did not reach statistical significance. However, analyzing the results by gender revealed a significant divergence. Female students experienced a statistically significant reduction in their overall math anxiety (-16.9%, $p=0.045$). This improvement was driven by a significant decrease in anxiety related to learning mathematics (-18.7%, $p=0.044$) and a notable, though not statistically significant, decrease in evaluation anxiety (-15.3%). In contrast, male students exhibited an increase in overall math anxiety (+9.2%), stemming from non-significant increases in both learning anxiety (+8.0%) and evaluation anxiety (+10.3%). This contrasting pattern in post-intervention anxiety levels between genders is shown in Figure 8 and in Table 2.

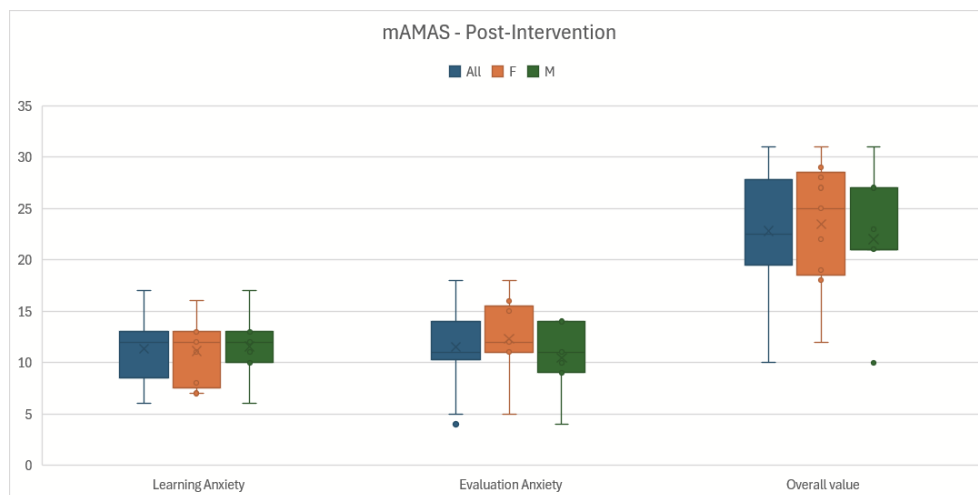


Figure 8: Box plot of mAMAS questionnaire responses post-intervention, with gender comparison

Table 2: Paired Samples Test (mAMAS) with gender comparison of changes in math-related attitudes pre- and post-Intervention

	Gender	N	Mean differences	% Differences	SD	Cohen's d	p-Value
Learning Anxiety	F	9	-2.56	-18.7%	3.21	-0.80	0.044
	M	7	+0.86	+8.0%	2.54	+0.34	0.407
	All	16	-1.06	-8.6%	3.34	-0.32	0.222
Evaluation Anxiety	F	9	-2.22	-15.3%	4.02	-0.55	0.136
	M	7	+1.00	+10.3%	2.45	+0.41	0.322
	All	16	-0.81	-6.6%	3.71	-0.22	0.395
Overall Value	F	9	-4.78	-16.9%	6.04	-0.79	0.045
	M	7	+1.86	+9.2%	3.93	+0.47	0.258
	All	16	-1.88	-7.6%	6.10	-0.31	0.238

5. Discussion

This paper investigated how gamification affects students' attitude and anxiety towards mathematics.

Overall attitude towards mathematics (ATMSE) showed a slight trend towards improvement for the whole group. Female students improved more in self-perception and enjoyment, while male students improved more in perceived achievement and value. This might suggest the intervention helped female students feel more confident and find math slightly more enjoyable, while male students felt they performed better and saw more utility in the subject post-intervention.

The most striking finding relates to math anxiety (mAMAS). While the overall group showed a non-significant decrease, there was a statistically significant reduction in anxiety for female students, contrasted by a non-significant increase in anxiety for male students. This suggests the RPG-based gamification intervention was particularly effective in lowering anxiety for female students in this context, but potentially counterproductive for males.

This gender difference may be given from the different starting points in anxiety levels. Girls, who started with higher levels, may have benefited more from the engaging, narrative-driven, less competitive (compared to typical classroom assessment) environment, reducing pressure. Male students, who started with lower anxiety, might have perceived the game mechanics, especially the accumulation and spending of points (dobloons), as a new form of performance pressure, leading to increased anxiety. The in-class observations highlighted reluctance of students to *spend* earned points, supporting the idea that resource management introduced a pressure element.

The study also implicitly addressed the feasibility of implementing such a gamification approach. Conducting it within smaller lab groups was deemed beneficial for management and immersion. The choice to avoid a digital approach aimed for inclusivity given varying student experience with digital games.

The small sample size limits generalizability. The intervention period was relatively short (7 weeks), which might be insufficient for significant attitude shifts. The study relied on self-reported quantitative data; qualitative data (like interviews or detailed observational notes) could provide deeper insights into students' experiences and the reasons behind the observed gender differences. The high Cronbach's alpha for the ATMSE might indicate item redundancy.

To complement the standardized questionnaire data, students were asked an open-ended question soliciting their personal impressions: "Would you continue this activity? Would you recommend it to other students? Briefly explain why". While the responses obtained (Figure 9) were not extensively detailed, a clear appreciation for the fun and playful aspect of the gamified activities emerged ("Yes, because it is fun", "I would recommend it to other students because it is fun"). Students commonly perceived these activities as lighter and more accessible compared to traditional lessons ("Yes, because it feels like doing a light and fun activity"). On the other hand, it is important to note the feedback from one student who found the dynamic too slow, lamenting a perceived lack of progression in the disciplinary content ("No, because we slow down with the math curriculum"). Although simple, these open-ended responses highlight the general positive reception of the

engaging nature of the gamification but also underscore the challenge of finding activities that maintain appropriate pacing and interest for all learners, pointing towards the need for differentiation even within a gamified structure.

This qualitative feedback reinforces the quantitative findings. The general enjoyment aligns with the slight improvements in attitude but also hints at why the impact wasn't universally positive for anxiety; factors like pacing and perceived progression can also influence student experience alongside the core game mechanics.

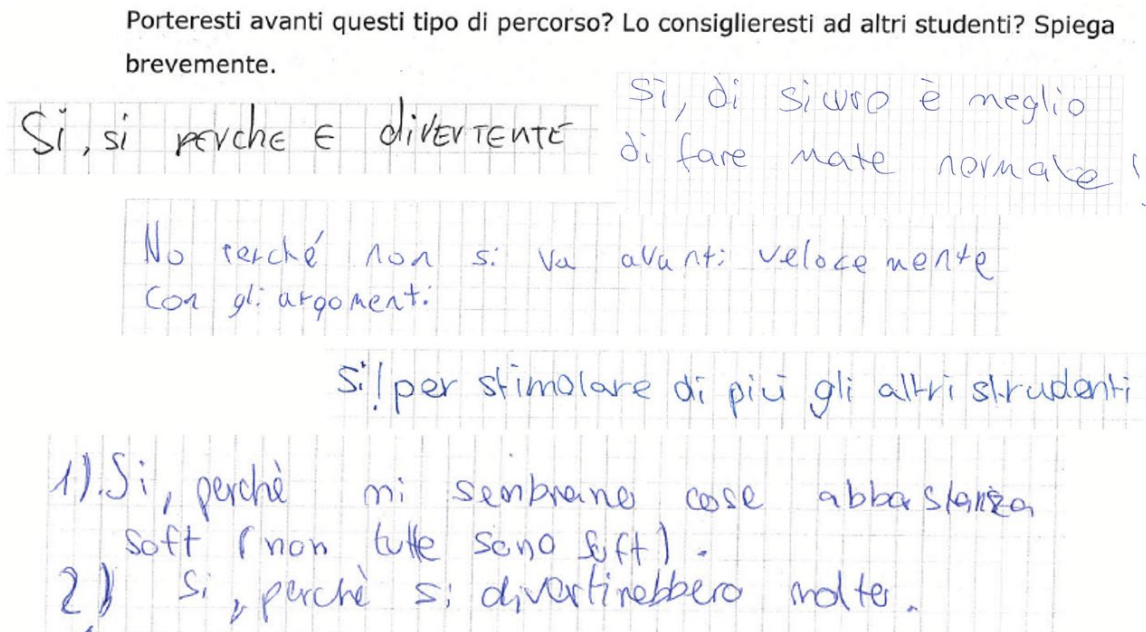


Figure 9: Some of the students' answer to the open-ended question "Would you continue this activity? Would you recommend it to other students? Briefly explain why"

6. Conclusion

This research explored the impact of an RPG-based gamification intervention on a second-year middle school students' attitudes and anxiety towards mathematics within a specific middle-school classroom in Ticino, Switzerland. Although not generalizable, the findings indicate that the effects of gamification are complex and not homogeneous across all students or measures. The intervention showed a statistically significant improvement in the overall attitude towards mathematics for the class, suggesting that the engaging, narrative-driven approach of the gamified activity can indeed foster a more positive disposition towards the subject.

The impact on mathematics anxiety revealed a gender divergence. Female students, who entered the study with higher baseline anxiety, experienced a statistically significant reduction in math anxiety, particularly concerning the learning aspect. This suggests that the gamified environment could potentially be perceived as less pressured and more supportive and was particularly beneficial for them. Conversely, male students showed a non-significant increase in anxiety, suggesting that certain elements of the gamification, possibly related to performance tracking or game resource management, might have inadvertently introduced new pressures for them.

In the qualitative feedback at the end of the activity, students generally reported finding the gamified activities fun, playful, and more accessible than traditional lessons, aligning with the observed improvements in overall attitude. This highlights the affective benefits of the approach. Yet, feedback also included concerns about the pacing being too slow for some, indicating that even within an engaging gamified structure, adjusting to diverse learning speeds and ensuring an adequate challenge remains a critical consideration for teachers.

Ultimately, this study highlights that gamification is not a panacea but rather a pedagogical approach whose effectiveness heavily depends on careful design, adequate mechanics employed, and the characteristics of the learners, including gender. On the one hand, the significant reduction in anxiety for female students is a promising outcome, on the other hand the contrasting result for male students serves as a reminder to monitor implementations closely and adapt strategies to avoid (unintended) negative consequences. The potential to make mathematics more engaging and less anxiety-provoking seem to exist but requires deep understanding

and responsive application. Further research, ideally involving larger, more diverse samples, longer intervention periods, and robust mixed methods designs incorporating detailed qualitative analysis and quantitative measures, is essential to unpack these complexities and guide the effective use of gamification in mathematics education.

Ethics Declaration: The data collection for this study was carried out in accordance with current ethical and institutional guidelines. Informed consent was obtained from the parents/guardians of the participating students, as well as approval from the school principal. All information was treated confidentially and used exclusively for research purposes, in compliance with applicable data protection regulations.

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Creation of Retro Games Room Supporting Student Belonging

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Abstract: Video games when utilised in academic settings have the potential to enhance the student learning experience through their immersive qualities. When integrated and combined with course curriculum they can aid student engagement and retention. Video games, when also applied within a social context in education have the ability to contribute to student success at university through supporting and facilitating student wellbeing, inclusion, equality and a sense of community. The aim of this paper is to present a case study about the co-creation of a retro games room by students and educators within a BSc (Hons) Computer Games Development programme at a Scottish University. The idea behind the retro games room was to offer a multifunctional space where students can socialise, relax and share their passion for gaming out with their core academic studies. The room has fostered a sense of community and belonging among students making them feel part of their academic programme. The paper provides a scoping review of the academic literature associated with supporting student belonging in higher education via student identity and engagement. In addition, the paper presents predominately quantitative results on the students' experience of using the room to develop a sense of community and identity with a view to enhancing student ownership and belonging on the programme. The paper illustrates the logic and justifications made regarding the proposed use of the room from a student belonging perspective. It denotes how a combined community of practice and affinity space approach, with a shared interest of bringing students together has the potential to enhance their overall positive wellbeing. The paper also provides a solid case study for other educators to reflect on regarding ways to enhance the student experience on their respective programmes from the grass roots level.

Keywords: Retro games, Video games, Student belonging, Community of practice, Affinity space

1. Introduction

A particular challenge that colleges and universities find difficult to overcome and address is retaining students once they have enrolled (Kimbark et al., 2017). In addition to the concept of student retention, academic schools and departments remain preoccupied about ensuring that students maximise their student experience whilst undertaking their studies (Tight, 2019). Closely aligned with the aspect of student retention is the notion of student engagement. According to Wolf-Wendel et al., (2009) engagement is also associated with the areas of involvement and integration which relate to one another. Student involvement relates to “... *the amount of physical and psychological energy that the student devotes to the academic experience*” (Astin, 1984, p. 518). Examples of this might be engagement with studies, spending more time on campus, joining student societies and interacting with other students and staff members. Student integration theory (Tinto, 1987) focuses on the extent to which students are able to participate and acclimatise with the academic and social systems of a college or university. It can be argued that academic and social integration are similar in theoretical constructs to that of student involvement. Tinto's theory of student integration also focuses on the notion of commitment where there are two types: goal and institutional commitment. Goal commitment relates to the aim of completing your studies at your academic institution whereas institutional commitment relates to retention at your current institution. These concepts of commitment relate to the notion of student belonging which in the context of higher education refers to “... *students' subjective feelings of connection and integration with their institution and campus community*” (Pedler et al., 2021, p. 398). This psychosocial construct is influenced by students' educational context and interpersonal relationships (Gillen-O'Neel, 2019).

Post Covid-19, the educational landscape has significantly altered where academic institutions and educators have to consider and initiate novel ways to support student belonging, enhance student engagement and retention. One way to potentially achieve this is through the use of immersive technologies an example of which are video games. A salient quality of video games is that they are interactive. A perception of video games are that they “... *are designed for players to actively engage with their systems and for these systems to, in turn, react to players' agentive behaviors*” (Granic et al., 2014, p.66). The diversity of game genres and platforms used to video games them means that they can be applied in a wealth of educational contexts. By definition, video games are engaging in the sense that students are intrinsically motivated to play them often dictated by personal enjoyment, fun and the aspect of participation that can facilitate collaboration among peers. Player engagement, from a gameplay perspective, relates to the gaming experience often associated with the concepts of immersion and flow. This paper provides an overview of how the utilisation of an on-campus space, in the

form of a video games room, when factoring in the theoretical constructs of student belonging, has the potential to enhance the student experience on a computer games development programme.

2. Student Belonging and Community of Practice

2.1 Concept of Student Belonging

Belonging, in the context of higher education, is a “multi-faceted concept” that has now gained greater attention post Covid-19 where it encompasses institutional approaches towards enhancing support practices related to mental health, inclusive pedagogies and curricula to boost student engagement, progression and retention (Webster, 2022). It can be argued that there is a psychological component associated with connectedness related to the notions of belonging and inclusion. One perspective to view student belonging is to consider ways in making “... *students feel accepted, respected, included and supported by the educational communities and settings in which they are involved*” (Berryman and Eley, 2019, p. 993). The notion of student belonging in higher education can be associated with a wide range of factors such as academic and social engagement, creation of personal spaces on campus to allow students to engage with one another and being able to relate to the aesthetics and environment of their surroundings (Vytniorgu, 2022). The concept of belonging in the domain of education has been researched from different perspectives in an attempt to understand and conceptualise student belonging. Araujo et al., (2014) have proposed a three-tiered “Belonging Model” that supports students through the transition of the student lifecycle. In this context, students belong to their professional cohort or programme, their interdisciplinary learning environment or school and the global intercultural networks associated with their specialist subject areas. Goodenow’s (1993, p.80) Psychological Sense of School Membership (PSSM) Model perceives belonging relates to situational and social factors that relate to “... *the extent to which students feel personally accepted, respected, included, and supported by others in the school social environment*”. Additional theoretical underpinnings related to student belonging, that can provide educators with ideas on how to support the notion within education are summarised in table 1.

Table 1: Theoretical underpinnings supporting student belonging in education (table by authors)

Theoretical Underpinning	Author(s)	Concepts and Understanding	Recommendations for HE Practice
Tinto’s Student Integration Theory	Tinto (1975, 1993)	Academic and social integration affect student persistence. Student success in academic performance enhances confidence and commitment. Student belonging equates to student retention where students need to feel a sense of connectedness academically and socially.	Programmes at HE level require to promote initiatives to allow students to become more affiliated and involved within the academic and student community at university. Consider ways to facilitate academic and social integration to support student persistence.
Strayhorn’s Model of College Student Belonging	Strayhorn (2018)	A sense of belonging is viewed as an essential and fundamental human need with the outlook that when met students are more likely to excel in their educational environments.	Reflect on ways to promote inclusion that relate to students’ identities and create on-campus environments that support this. Ensure that belonging is factored into academic programmes, strategic plans and retention initiatives.
Student Involvement Theory	Astin (1984)	Focuses on the notions of physical and psychological energy that students assign to their academic experience. Involvement fluctuates and is dynamic. Academic and social involvement contribute to a student’s belonging, development and persistence.	HE institutions need to focus on the concept of student involvement and student time as a resource and how it is applied between the learning process and campus engagement. Students should be encouraged to actively participate in activities on campus and programmes must promote involvement.
Social Identity Theory in Higher Education	Tajfel and Turner (1979)	Belonging is influenced by group affiliations. Students socially categorise themselves into groups and find belonging in these groups through social identity (e.g., race, culture, gender).	Establishing inclusive learning environments, adhering to identity-affirming and involving the student voice in campus initiatives. Develop identity-affirming spaces that support and facilitate in-group and intergroup experiences.

2.2 Communities of Practice

Communities of practice (CoP) is a term that was coined by Lave and Wenger in 1991 and relates to people engaging with one another in a social context who share common interests in sharing experiences and knowledge on a certain topic sometimes in an informal setting. The commonality of the subject area is what traditionally brings members of a community of practice together through a notion of shared identity. The three key components of a CoP that include the concepts of domain, community and practice (Jakovljevic et al., 2013). The domain of a CoP is the shared interest, motivation or passion about a specific subject area or activity that gels the members of the community together with a shared identity. It is traditionally viewed as the starting point of any CoP where there has to be a sense of focus with voluntary membership attracting various members who share their knowledge, experience and expertise on an activity or past time (Mercieca, 2017). The aspect of community is defined by three underlying concepts: joint enterprise, mutual engagement and shared repertoire (Wenger, 2000). The formation of a CoP involves members establishing a collective aim, rationale or purpose defining the boundaries and scope of the community – essentially the rationale behind why the community is being established. This relates to the concept of joint enterprise. The notion of mutual engagement relates to the belonging of the community members through communication, interactions and connectedness. Mutual relationships are further accentuated through diversity where homogeneity is not primarily a core requirement (Wenger, 1998). The idea of shared repertoire is associated with the set of resources that evolve over time that members use, are familiar with, enhance and develop. Shared repertoire does not remain constant but naturally evolves as the CoP expands. The repertoire of a CoP includes “... routines, words, ways of *doing things, stories, gestures, symbols, genres, actions or concepts*” (Wenger, 1998, p. 83).

3. Video Games, Immersion and Student Belonging

3.1 Video Games and Immersion

Gaming, or the activity of playing video games, have often been associated with concepts of enjoyment, fun, immersion, engagement, flow and player experience. Predominately, when relating to the player experience, the concepts of immersion and flow are often intertwined. In the context of video gaming, “... *immersion is concerned with the specific, psychological experience of engaging with a computer game*” (Jennett et al., 2008, p.643). The concept of flow, associated with immersion and gameplay relates to “... *a feeling of complete and energized focus in an activity, with a high level of enjoyment and fulfilment*” (Schell, 2015, p.138). Stated from another perspective, “*The Flow Channel is the state of mind that makes us to stay focused on an activity. When we loose the flow, we switch to another activity*” (Sala, 2013). Various categorisations of immersion exist such as sensory, challenge-based and imaginative immersion (Emri and Mäyrä, 2005). Sensory immersion focuses on aspects of audio-visual stimuli, challenge-based relates to the player’s level of cognitive ability to overcome hierarchical challenges within the game where imaginative immersion is associated with the player’s emotional connection with the game’s story, narrative, world and even character development.

3.2 Video Games and Affinity Spaces

The immersive characteristics of video games also have the potential to support and facilitate the notion of an affinity space (Gee, 2017). Affinity spaces are places that can be either physical or virtual where people share their common interests and knowledge about a specific area. For example, students coming together to share their passion for video gaming equates to having a shared interest and commonality. Affinity spaces have a socio-cultural focus (Gee, 2018) to them where engaging in video games via their immersive qualities allows gamers to share their interest or passion for a particular type of game. The level of player engagement is enhanced by interest-driven participation where the challenges of gameplay can stimulate intellectual engagement, “*kinaesthetic involvement*” (Calleja, 2011, p.55) and social engagement via being connected with friends and other players (Schønau-Fog and Bjørner, 2012).

Beyond supporting student collaboration, accessibility and shared interests, an affinity space that encompasses a video games room can also support the notion of a learning community. For example, commercial video games can support the development of metacognitive skills which is deemed essential to develop effective learning (Checa-Romero and Gimenez-Lozano, 2025).

4. Creation of Retro Games Room

4.1 Rationale Behind Games Room Idea

This section of the paper provides an overview of how the concept of student belonging was supported and facilitated through the development of a retro games room on the BSc (Hons) Computer Games Development programme at the University of the West of Scotland (UWS). The primary foundation and thinking behind the room was motivated by how best to enhance the student experience on the games programme and at the university.

The concept of the student experience is one that has become prevalent within higher education institutions though defining it appears to be slightly vague (Benckendorff et al., 2009). The student experience encompasses a multitude of factors that can impact a student's positive experience at university that include: social integration and belonging, the student voice and participation and achievement of academic and personal goals. There was also a consideration to try and support the concept of the sticky campus. This is viewed as giving "... *primacy to the students' social experience of learning by blurring formal and informal elements of campus spaces*" (Berman et al., 2024, p.74). The development of a safe and communal space for students to use would have the potential to enhance student wellbeing and belonging on campus, a place to socialise and to aid student retention on the programme. The logic for the room's design did adopt a spatial approach adopting the view that "... *space is socially constructed...*" and that "... *social relations and interactions are affected by space...*" (Samura, 2018, p.21).

4.2 Bridging CoPs and Affinity Spaces

When designing the room, the educators did not view affinity spaces as a distinct concept from a CoP but considered both constructs to be "*mutually reinforcing*" (Jones et al., 2016, p.115). It was considered that the room could have a dual purpose where it could be used by students to discuss their coursework within their project teams in the form of study groups thereby facilitating collaboration and mutual learning with a heavy emphasis towards the notion of shared repertoire. The notion of the CoP would emphasise the notion of shared practice through coursework projects whereas notion of the affinity space would cater for events, meetups and hobby related interests (e.g., the Tabletop Society). Both theoretical constructs would support the aspect of a sense of community building and student engagement where shared identity and practice could be shared among the students.

4.3 Student voice, TEQF and Co-Creation

When establishing the idea of the retro games room, staff members on the games programme valued the relevancy and importance of incorporating the student voice providing the students with a sense of empowerment towards the layout in addition to what should be included in the room. Furthermore, the underpinning of the room was influenced by the institution's values of respect and inclusivity in addition to two of the key principles of Scotland's Tertiary Quality Enhancement Framework. A core component of the framework is the notion of student engagement and partnership emphasising the incorporation of the student voice – "*Every student, every place, every level*". The room was able to embody this through adhering to the 3 C's model of staff-student co-creation, namely, community, collaboration and cohesion (McIntosh and May, 2025) which when interconnected supports the concept of relational education or pedagogy (Su and Wood, 2023) that values the notions of cultural and social awareness where the logic behind the room was to create an inclusive, safe and respectful environment for students to connect with one another. The process of co-creation, which is dynamic and grounded in the theory of change, would assist towards establishing an "... *enduring sense of belonging and connectedness...*" through "...*relational approaches and dialogue in collaboration*" (McIntosh and May, 2025, p. 40).

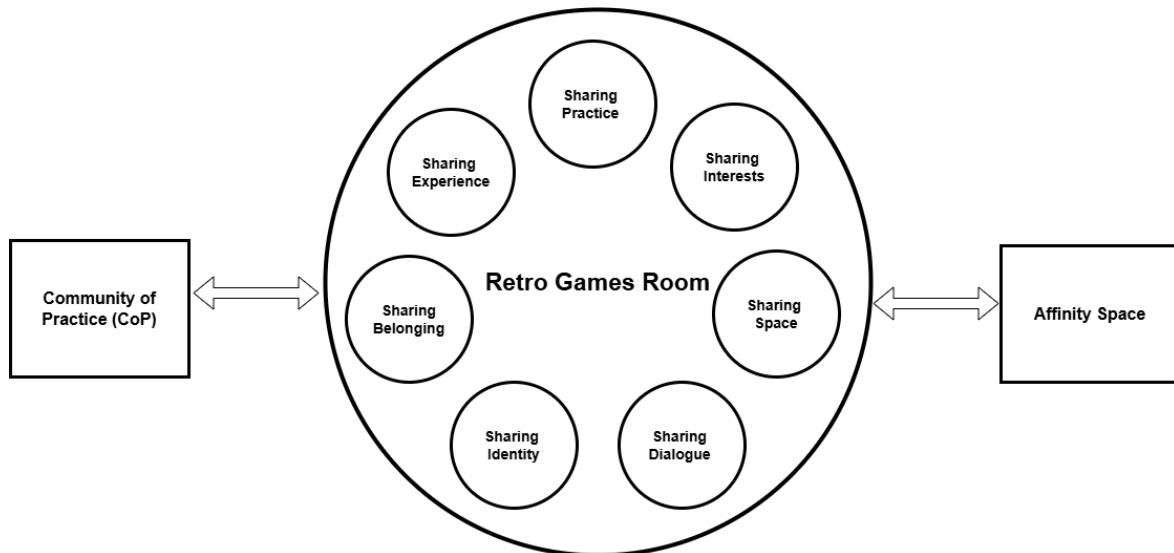


Figure1: Bridging CoP and Affinity Space (figure by authors)

Figure 1 provides an illustrative overview of how the concepts of CoPs and affinity spaces have informed the underpinnings of the retro games room. The affinity space aspect allows the students to share their passion for gaming. The CoP element offers students using the room an opportunity to collaborate and share ideas in a games setting related to project work. Figure 1 gives a depiction that whilst CoPs and affinity spaces are distinct in theory and practice, commonalities and co-existence can be found through subject area of study, coursework, sharing and exchanging ideas in addition to sharing interests and passions for gaming.

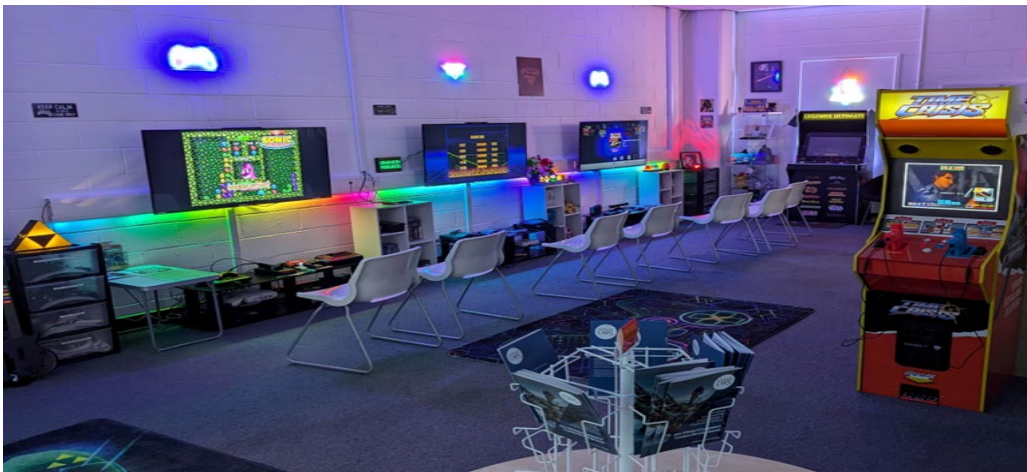


Figure 2: Accommodating student belonging in the retro games room

Figure 2 gives a sense of scale of the retro games room and the use of space allowing the students to engage in various activities in the context of an affinity space but also providing a safe space where students can formally discuss practice and share ideas related to coursework.

5. Initial Student Feedback

It was important to receive student feedback about the retro games room to ascertain views about its use and general perceptions whether students thought that it enhanced their overall experience on the computer games development programme. The questionnaire adopted a predominately mixed methods approach though the weighting was primarily quantitative. The sampling approach adopted was non-probability where convenience sampling was used based on the ease of access of participants and that the area of focus related to the Computer Games Development programme. An acknowledged limitation of the questionnaire was the low response rate with only 22 students on the programme having completed the questionnaire. Resulting from this, descriptive statistics were used as no generalisations were being formed which ruled out the use of inferential statistics being unable to obtain a sample from a larger population.

22 students from differing years of study completed the questionnaire. 18 (81.82%) were male, 2 (9.09%) were female and 2 non-binary/third gender (9.09%). Age range varied from 18 to 31 indicating a young age group overall. Students were asked on average, roughly, how many hours they spent using the retro games room per week. 5 students reported that they spent less than one hour (22.73%), 10 stated one to two hours (45.45%), 5 confirmed two to four hours (22.73%), 1 spent four to six hours (4.55%) in the games room with 1 stating over ten hours (4.55%). Students were also asked why they played computer games with a range of speculative reasons provided to them. The results can be seen in table 1.

Table 1: Student reasons for playing computer games

	STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE	TOTAL	WEIGHTED AVERAGE
Fun/Enjoyment	95.00% 19	5.00% 1	0.00% 0	0.00% 0	0.00% 0	20	1.05
Completionist motive (i.e., in finishing a game).	36.84% 7	52.63% 10	5.26% 1	5.26% 1	0.00% 0	19	1.79
Escapism (e.g., being immersed in the game).	52.63% 10	42.11% 8	5.26% 1	0.00% 0	0.00% 0	19	1.53
Socialising (e.g., playing with friends).	57.89% 11	21.05% 4	21.05% 4	0.00% 0	0.00% 0	19	1.63
Loyalty towards a game (e.g. a particular game franchise).	22.22% 4	38.89% 7	33.33% 6	0.00% 0	5.56% 1	18	2.28
Entertainment	85.00% 17	15.00% 3	0.00% 0	0.00% 0	0.00% 0	20	1.15
Curiosity (i.e., playing a new game, different game genre).	42.11% 8	47.37% 9	10.53% 2	0.00% 0	0.00% 0	19	1.68
Competitiveness	35.00% 7	35.00% 7	25.00% 5	5.00% 1	0.00% 0	20	2.00
Relaxation	66.67% 12	27.78% 5	5.56% 1	0.00% 0	0.00% 0	18	1.39
Autonomy (freedom to explore, play the game).	42.11% 8	52.63% 10	0.00% 0	5.26% 1	0.00% 0	19	1.68
Improvement (e.g., bettering a score, completing a level).	35.00% 7	45.00% 9	20.00% 4	0.00% 0	0.00% 0	20	1.85
Develop gaming skills	40.00% 8	30.00% 6	25.00% 5	5.00% 1	0.00% 0	20	1.95
Obtain a feeling or reward/sense of achievement	55.00% 11	25.00% 5	15.00% 3	5.00% 1	0.00% 0	20	1.70

Students were also asked the question whether the retro games room provided them with a sense of student identity on their programme. 18 students responded to this question with 5 non-completions. 8 (44.44%) strongly agreed that the room provides them with a shared sense of student identity whilst on campus, 5 (27.78%) agreed and 5 (27.78%) neither agreed nor disagreed. 1 student did however state that did not consider the primary purpose of the room to be a space to promote identity: *"I don't personally get what about the space is meant to promote identity, equality and diversity. It's a space where peeps can relax and enjoy the common interest of video games. Not a place for announcing personal identity beliefs"*. We also asked students whether the retro games room had enhanced their student experience on the computer games development programme. 18 students replied to this question with 5 non-completions. 12 students strongly agreed (66.67%) that their student experience had been enhanced via engagement with the games room. 3 agreed (16.67%), 2 neither agreed nor disagreed (11.11%) whilst 1 student surprisingly disagreed (5.56%). Students were also asked to rank what concepts that they considered the games room supported. This can be seen in table 2.

Table 2: Student views regarding the supportive features of the games room

	A VERY GOOD EXTENT	A GOOD EXTENT	NEUTRAL	A POOR EXTENT	A VERY POOR EXTENT	TOTAL	WEIGHTED AVERAGE
▼ Social space to relax with my peers.	83.33% 15	16.67% 3	0.00% 0	0.00% 0	0.00% 0	18	1.17
▼ Safe space to meet other students on my programme (forming new connections).	50.00% 9	44.44% 8	5.56% 1	0.00% 0	0.00% 0	18	1.56
▼ Fostering a sense of student identity on my programme.	44.44% 8	33.33% 6	22.22% 4	0.00% 0	0.00% 0	18	1.78
▼ Caters for social inclusion on my programme (e.g., gaming events, competitions).	50.00% 9	44.44% 8	5.56% 1	0.00% 0	0.00% 0	18	1.56
▼ Provides potential for use a learning space.	38.89% 7	33.33% 6	27.78% 5	0.00% 0	0.00% 0	18	1.89
▼ Promotes student autonomy on the programme.	55.56% 10	16.67% 3	27.78% 5	0.00% 0	0.00% 0	18	1.72
▼ Supports student equality and diversity.	50.00% 9	16.67% 3	33.33% 6	0.00% 0	0.00% 0	18	1.83

Students were quite positive about how the community of practice (CoP) approach had worked between staff and students regarding using the room and facilitating social interaction within it. 18 students responded to this question with 5 non-completions. 12 (66.67%) students strongly agreed that this was the case, 3 (16.67%) agreed with 3 (16.67%) neither agreeing nor disagreeing. The question was also asked whether using the games room had impacted students on the games programme to remain on campus for longer. 18 students responded to this question with 5 non-completions. 12 (66.67%) strongly agreed to this question, 3 (16.67%) agreed, 2 (11.11%) neither agreed nor disagreed where 1 (5.56%) student provided a qualitative response primarily agreeing: *“Yes, but class work forces me to rush home to get more work done. Would love to spend more time in there, especially if there was more multiplayer/Co-op options other than Mario and Street Fighter titles”*.

There was a positive response towards the notion that the games room was viewed as a good place to socialise with peers between classes. 18 students responded to this question with 5 non-completions. 11 (61.11%) strongly agreed and 7 (38.98%) agreed that the room catered for social interaction among their peers on the games programme. The majority of the students also agreed that the games room had made their programme and time at university more engaging. 18 students responded to this question with 5 non-completions. 11 (61.11%) strongly agreed, 6 (33.33%) agreed with 1 (5.56%) neither agreed nor disagreed. Students were also asked to state anything that they would like to mention about the games room (e.g., its impact on the programme, their experience of using it). Only 7 open-ended responses were received which were the following:

- “Very good place especially for after or before a class as before we would be waiting around in a bland common area and provides an opportunity for meeting the other years of the course and other courses. It is also an excellent advertisement for the course as it shows the passion of the staff”.
- “I love the games room. But it's lack of multiplayer/Co-op titles of my interest doesn't make me want to bring a mate from the class in there to have a game”.
- “It's very interesting and exciting to have such a cool room in our university. Sometimes me and my friends spend there a couple of hours per week. It's always nice to immerse ourselves in the industry of old games and find something new”.
- “Good way to get to know classmates by playing games together”.
- “Helps break the ice between introverted people by getting them to do something they both enjoy”.
- “It has encouraged students to donate any of their unused consoles to allow others to play and the students are encouraged to bring decorations or to write ideas for competitions”.
- “Would be good if network connection was available for some games (like destiny on Xbox) for multiplayer”.

6. Conclusions and Recommendations

The aim of this paper was to provide an overview of how the development of a video games room within a higher education institution has the potential to support the notion of student belonging. Furthermore, the paper has indicated that the room can also accommodate students and staff using it within the theoretical and practical remits of a community of practice (CoP) and an affinity space. An acknowledged limitation of the study was the relatively low response rate to the questionnaire where it is problematic to formulate any generalisations. It is most likely not surprising that the students who completed the questionnaire were overall very positive about the games room and its use. It would be useful to undertake additional research in relation to student perceptions on-campus spaces to support student belonging across differing educational disciplines.

In the context of this particular case study, it appears evident that a common and shared interest among students' enjoyment for video games can accommodate the concepts of a CoP and affinity space. The social-cultural aspect of video games when combined with their immersive qualities provides students with direction, purpose, connectedness and commonality in the confines of a safe space to share their interests.

Whilst not every academic institution might have access to gaming facilities, there are however common and salient factors that educators and higher educational institutions can reflect upon when contemplating utilising on-campus spaces to support student belonging. One aspect to consider might be to create the space utilising a bottom-up or grassroots approach thereby involving the student voice and the concept of co-creation. Other factors might relate to identifying a common purpose and use for the space, where the space will be located on-campus and accessibility issues as well, support and buy in from staff, the relevant university school and institution as a whole, usage patterns for the room, health and safety concerns and the integration of any technology if required. Some general considerations in terms of how to initiate or support an on-campus space are illustrated in figure three. It could be argued that considerations impacting the use of on-campus space for students is something higher educational institutions should reflect upon in terms of accentuating and supporting student belonging, retention and progression. This however is something that continues to remain a challenge in the post Covid-19 era.

Figure 3 provides a pictorial overview for educators regarding factors they should consider when creating spaces on-campus to support student belonging and wellbeing. This is in no way an exhaustive list of considerations and requires further empirical research in addition to further engagement with the academic literature. The figure is informed from the authors' own personal experience, logical and practical considerations in setting up the retro games room. This illustration of factors can act as a starting point for other educators to reflect upon if using an open space on their campus for similar purposes. In addition, these potential factors for creating an open space for students to utilise can be enhanced and built upon in terms of contributing to the figure or through time, the development of a generic on-campus space implementation framework.

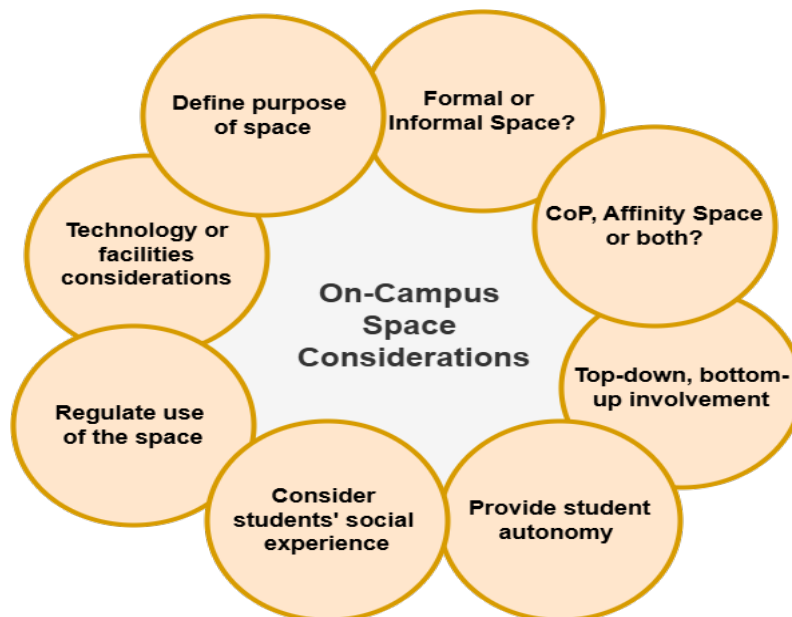


Figure 3: Factors to consider when creating an on-campus space (figure by authors)

Ethical Clearance: Due ethical procedures were adhered to within the context of this study where participation for the students was voluntary and they could withdraw from the questionnaire at any stage. Participant anonymity was adhered to as was the confidentiality of the data obtained. In terms of ethical clearance, the case study was deemed to be of low risk hence there were no issues relating to ethical clearance.

AI Declaration: No AI tools were used in the writing and creation of this paper. Diagrams were created by the authors using the software draw.io and tables created using MS Word by the authors.

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From Curriculum to Gameplay: A Workshop Method for Educational Game Design

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Abstract: This paper presents a structured workshop methodology for designing educational games to enhance the initial conception phase in game development with educators as a target group. It uses a combination of Björk's game design patterns (Björk et al., 2003) with Anderson's Learning Taxonomy Action Verb Groups (Anderson and Krathwohl, 2001), creating a matrix that connects educational goals with game mechanics. This structured approach is designed to assist educators, who may lack experience in game development, in generating more effective educational game design concepts. The four-step process begins with an introduction and instruction of the method used and continues with the atomization of a learning topic into smaller, specific objectives. This step leaves educators with more manageable learning goals. The third step uses a matrix that maps gameplay patterns and elements from Björk et al. (2003) to Bloom's Taxonomy objectives, identifying appropriate game design patterns. This helps educators see which game design elements support specific learning goals, enabling them to create more engaging educational games. A companion application was developed to simplify this process, allowing participants to browse and filter patterns efficiently, as well as generate random combinations for inspiration. Lastly participants reflect on found gameplay elements to form an educational game design. This Methodology was applied in an ongoing project and the outcomes of the workshop are currently used in the development of the educational game "The Analyst" at the Technical University of Darmstadt. In this project a serious (educational) game is developed to teach the diagnostic process in sport, psychology and pedagogy.

Keywords: Educational games, Serious games, Game design, Workshop, Education

1. Introduction

Serious games have repeatedly proven their effectiveness in supporting their non-entertainment purpose called characterizing goal (Dörner et al., 2016). But they have a massive downside: They are far from trivial in development. To tackle this problem researchers like Horn et al.(2023) developed authoring tools specifically to help teachers and trainers to develop their very own educational games.

Additionally, a lot of frameworks and patterns for the design of Serious Games were created to

tackle the same issue were proposed. A large proportion enables the user to evaluate a game based on various criteria (e.g. Carvalho, et al., 2015) and others are very abstract and simply give rough guidelines to design such a game (e.g. Groff, et al., 2015). The latter usually require some kind of experience in games and game design or are just useful for evaluating a finished game. In those frameworks made to create a game and in tools like GameTULearn (Horn et al., 2023), the initial conceptualization is often neglected, and it is assumed that the author [the educator] starts with an already refined concept of a game.

Therefore, educators must either possess a pre-existing concept and vision for the game they wish to develop, have a comprehensive understanding of game design and its elements, or require structured guidance to get to their educational game idea.

In our collaborations with educators interested in using educational games, we frequently encounter the issue that educators do not know where to begin or what even is possible. This workshop addresses that problem by starting from the very beginning: Educators are guided through the entire process from refining their learning

goals over using a combination of Bloom's taxonomy and Björk's game design patterns(Björk et al., 2003) to address their learning goals to the initial conceptualization of an educational game.

2. Related Work

2.1 Related Frameworks

Many Models and Frameworks exist to assist the creation of (educational) games.

The Mechanics, Dynamics, and Aesthetics (MDA) framework by Hunicke et al.(2004) introduces a foundational view of games but lacks guidance for idea generation. Building on this, the Design, Play, and Experience (DPE) framework by Winn (2009) expands the MDA model to explore the interplay between the developer and the player, emphasizing early definition of learning goals, although it offers limited practical tools for conceptualization. The Art of Serious Game Design (ASGD) framework by Toronto Metropolitan University (2023) advances DPE by incorporating ideation cards and a glossary to streamline brainstorming. While the ability to formulate key questions is a strength, a notable weakness lies in the provision of comprehensive game design and development information, specifically regarding feasible options and established best practices.

The Game Rules Scenario Model (GREM) by Zarraonandia et al. (2015) focuses on modularity and reusability by emphasizing the context of learning, but provides little support for initial conceptualization. Similarly, the Activity Theory-based Model of Serious Games (ATMSG) by Carvalho et al. (2015) categorizes serious games into various activities, but primarily serves as an analytical rather than a creative tool.

The Four-Dimensional Framework (4DF) by De Freitas and Oliver(2006), while offering a reflective tool for evaluating games based on context, learner specification, and pedagogy, does not aid in generating ideas. The Exploratory Learning Game Design Model by De Freitas and Neumann (2009) adapts Kolb's experiential learning theory for complex virtual contexts but remains abstract and impractical for game conceptualization. The Balanced Design Framework by Groff et al.(2015), though extending evidence-centered design principles, remains focused on assessment rather than idea generation. Lastly, the Learning Mechanics-Game Mechanics (LM-GM) by Arnab et al.(2015) which is a powerful model to analyse serious games but is a helpful resource since it too maps gameplay mechanics onto bloom learning taxonomy.

Table 1: Overview of related frameworks

Framework	Authors	Year	Focus	Limitations
MDA	Hunicke et al.	2004	Foundational view of games	Lacks guidance for idea generation
DPE	Winn	2009	Interplay between developer and player, learning goals	Limited practical tools for conceptualization
ASGD	Toronto Metropolitan University	2023 (earlier iterations exist)	Incorporates ideation cards and glossary	Lacks Provision of best practices
GREM	Zarraonandia et al.	2015	Modularity and reusability, context of learning	Little support for initial conceptualization
ATMSG	Carvalho et al.	2015	Categories serious games into activities	Analytical rather than creative tool
4DF	De Freitas and Oliver	2006	Reflective tool for evaluating games	Does not aid in generating ideas
Exploratory Learning Game Design Model	De Freitas and Neumann	2009	Adapts Kolb's experiential learning theory	Abstract and impractical for game conceptualization
Balanced Design Framework	Groff et al.	2015	Extends evidence-centered design principles	Focused on assessment rather than idea generation
LM-GM	Arnab et al.	2015	Maps gameplay mechanics onto bloom learning taxonomy	Helpful resource but not for idea generation

The issue has been addressed multiple times; however, when creating an educational game, it is imperative to involve educators in the creative process of a game designer. The methods and frameworks highlighted aim to provide a structured understanding of what constitutes a game to facilitate the creation of these games. Some efforts focus on mapping educational principles onto gameplay principles, offering a reference system where "if educational outcome A is desired, employ gameplay feature B." These approaches emphasize formalization so that designers proficient in both disciplines can achieve optimal results.

What remains lacking is an ideation phase for educators who are inclined toward utilizing game-based learning approaches and educational games but do not possess the requisite knowledge to design a game. One method addressing this gap is detailed in the *Art of Serious Game Design* by the Toronto Metropolitan University (2023). The authors developed a workshop wherein educators respond to various questions to generate a repository of ideas. A game designer subsequently uses these ideas to create a game design. However, if an educator wishes to design their own game, it is crucial to develop a method that empowers educators to act as the actual game designers, selecting what best aligns with their classroom needs.

Given that it is unrealistic to expect educators to possess extensive knowledge of all game design principles, a simplified approach is necessary: Game Design Patterns.

2.2 Game Design Patterns

Björk et al. (2003) describe game design patterns as "a part of the interaction possible in games, and together with other patterns they describe the possible gameplay in a game ". These patterns aim to be used for game design and in particular creative design work, so a perfect fit for a method that tries to support the conceptualization phase, one of the most creative phases in this work. The book and the accompanying online Wikipedia¹ contain 633 different game design patterns, each with a name, core definition, general description, how to use it, consequences of using it, relation between patterns and references to it in other patterns.

The core definitions and names can be a great source of inspiration when trying to develop an idea, but 633 patterns can be quite overwhelming. So, we need a way to lead educators to a smaller selection of patterns relevant to their current needs and ideas.

2.3 Taxonomies for Learning

There are numerous taxonomies for learning, but one of the most widely used is the 5-point taxonomy developed by Bloom (1956) and revisited by Anderson and Krathwohl (2001), in which the authors categorize the cognitive process dimension into 6 categories:

Remember, Understand, Apply, Analyse, Evaluate and Create.

Each category also has related Cognitive Processes as seen in Table . These Processes or 'action verbs' can be used to describe atomic learning objectives.

¹<http://virt10.itu.chalmers.se/index.php/Category:Patterns>

Table 2: The Six Categories of the Cognitive Process Dimension and Related Cognitive Processes (Anderson and Krathwohl, 2001)

Process Categories	alternative Names
1. Remember	
1.1 Recognizing	Identifying
1.2 Recalling	Retrieving
2. Understand	
2.1 Interpreting	Clarifying, Paraphrasing, Representing, Translating
2.2 Exemplifying	Illustrating, Instantiating
2.3 Classifying	Categorizing, Subsuming
2.4 Summarizing	Abstracting, Generalizing
2.5 Inferring	Concluding, Extrapolating, Interpolating, Predicting
2.6 Comparing	Contrasting, Mapping, Matching
2.7 Explaining	Constructing, Models
3. Apply	
3.1 Executing	Carrying out
3.2 Implementing	Using
4. Analyze	
4.1 Differentiating	Discriminating, Distinguishing, Focusing, Selecting
4.2 Organizing	Finding, Coherence, Integrating, Outlining, Parsing, Structuring
4.2 Attributing	Deconstructing
5. Evaluate	
5.1 Checking	Coordinating, Detecting, Monitoring, Testing
5.2 Critiquing	Judging
6. Create	
6.1 Generating	Hypothesizing
6.2 Planning	Designing
6.2 Producing	Constructing

3. Workshop Design

Every game starts as an idea. An educator decides to create an educational game based on a curriculum or learning goal. The challenge is to turn this vision into an effective game design.

This workshop has 4 phases: Instruction, Learning Goal Atomizing, Game Design Pattern Exploration, and Game Conceptualization.

Walking through these phases educators can map learning goals they wish to gamify to game design mechanics and patterns which are fitting their goals. The output of the Process is not only a better understanding of what the game could be, but a better communication between educators and game developers.

3.1 Instruction

Instructing the participants to the method used. As we use Anderson's revision of Blooms taxonomy (Anderson and Krathwohl, 2001) for structuring atomic learning goals, a short recap of this taxonomy is explained. All the instructor needs is a poster or 1-2 presentation slides to show the agenda and blooms taxonomy.

The general principles of game design patterns are explained and what the method targets to enable: Communication with game developers and consequently a better game concept.

Participants can use any tool they prefer, including digital and physical whiteboards, pen and paper, notepads, or other tools that assist in capturing their thought process. The chosen tools should be familiar to them and not impede their creativity due to handling difficulties during the workshop.

3.2 Learning Goal Atomization

Educators start this method with the idea of teaching learning content with a game, but this content may vary in size. Many teaching goals can be broken down into smaller goals. So, in this step educators will start to "atomize" their initial learning goal.

Educators break down main goals into smaller sub-goals, forming a tree view (see Figure 1). This continues until sub-goals can no longer be divided. The aim is to create atomic learning goals. Finally, action verbs from

Anderson's learning taxonomy are added as child nodes to each goal, resulting in a tree with action verbs as leaves. For instance, the tree in Figure 1 includes "recall objectivity" as a learning goal with its action verb in the applied pilot of this workshop (see chapter 4).

Educators should decide when to stop breaking down learning goals into smaller parts before they become too small. A tree view is useful for tracking this process, allowing educators to merge overly atomized goals back into larger ones if needed.

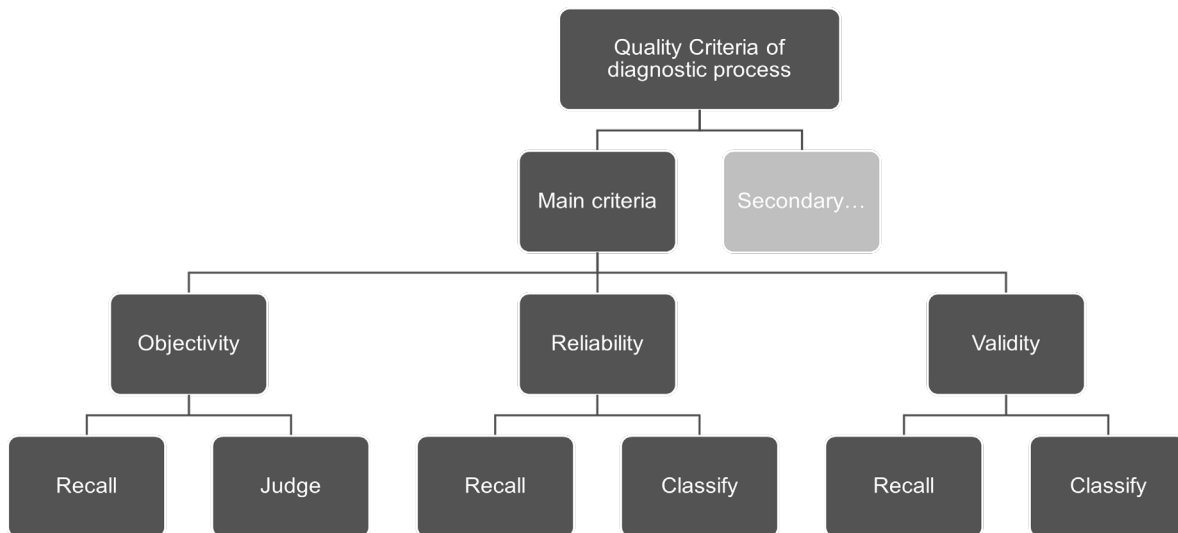


Figure 1: Tree View of a sample learning goal atomization

3.3 Pattern Exploration

Once we have the tree view of the atomizing step, we take all leaves into consideration. In this step we will design game elements based on atomic learning goals by using Björk et al.'s (2003) game design patterns.

We assigned each pattern one or more action verbs relating to Anderson's learning taxonomy while pruning Björk et al.'s patterns in a way, that we combined very similar pattern into one.

The mapping of pattern onto action verbs creates a look-up table for participants. This method allows educators to substitute for any lack of game design knowledge and boosts creativity. With action verbs assigned in step 2, educators can now find suitable game elements and patterns for their learning goals.

To enhance this process, we implemented a companion app (see Figure 2) in which one can choose an action verb and only browse patterns that have this action verb assigned. The workflow would be to choose an action verb on the left of the app and get three sample patterns fitting for this action verb. Participants can now take a closer look at one of the patterns (see Figure 3), request three alternative patterns if the shown patterns do not meet their needs or select a suitable pattern and proceed to the next learning goal.

Via this browsing process educators get already ideas of what is possible and has potential to benefit the learning goal.

For each leaf (from the learning goal atomization) a pattern can now be chosen, while by no means for everything another distinct pattern must be chosen. It can absolutely be beneficial to have the same pattern for many learning goals. This way a more compact and coherent game design can be made.

Choose Action Verb to get 3 random patterns	Random Pattern 1	Random Pattern 2	Random Pattern 3
Remember ^	Short description of the pattern.	Short description of the pattern.	Short description of the pattern.
Recognizing			
Identifying	Short description of the pattern effects within a game.	Short description of the pattern effects within a game.	Short description of the pattern effects within a game.
Understand v			
Apply v			
Analyze v			
Evaluate v			
Create v			

Figure 2: Simplified view of the companion app. Left: overview of alle Action Verbs. Right: Short description of sample Patterns in the chosen Action Verb Group

Pattern	Pattern used for:
Short description of the pattern.	Recognizing
Short description of the pattern effects within a game.	Identifying
Examples	Recalling
Elaboration of one or two examples of the pattern used in a game.	Retreiving
Using the pattern	Interpreting
Explanation of how the pattern can be integrated into a game.	Clarifying
Consequences	Paraphrasing
Positive and negative consequences using this pattern	Representing
	Translating
	Exemplifying
	Illustrating
	Instantiating
	Classifying
	Categorizing
	Subsuming
	Summarizing
	Abtracting
	Generalizing
	Inferring
	Concluding
	Extrapolating
	Interpolating
	Predicting
	Comparing
	Contrasing
	...
	...

Figure 3: Simplified view of the companion app with detailed view of a pattern. Left: detailed explanation of the pattern. (Björk et al., 2003) Right: Action Verbs fitting for this pattern

3.4 Game Design and Reflection

At this stage, each atomic learning goal is assigned a game design pattern. If all leaves of a parent node have the same pattern, one can assign this pattern to the parent node and remove the leaves to simplify the process.

Next, the actual game design begins. Educators can define, visualize, etc., their ideas regarding game content, player actions, and narrative challenges.

This step is characterized by its flexibility and potential for creativity. The aim is to produce an output that enables a game developer to create a game design and development plan aligned with the educators' vision.

Figure 4 illustrates the difference in outputs between two groups following the creative phase. Each group gained a clearer understanding of their game concepts and effectively presented their ideas to peers and the authors (see Chapter 4: Pilot Workshop).

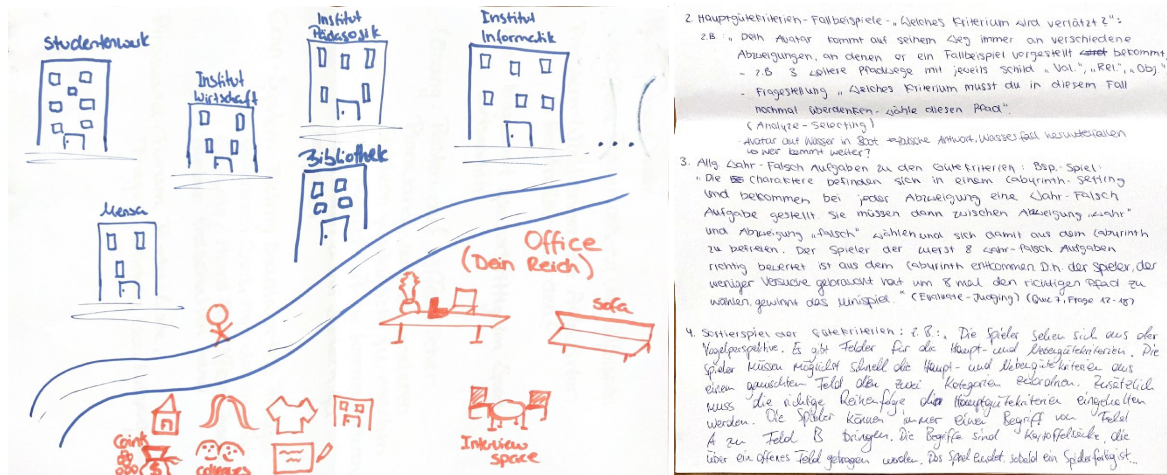


Figure 4: Output styles of 2 different groups after the workshop, see chapter 4

4. Pilot Workshop

In the project “The Analyst” funded by “Stiftung Innovation in der Hochschullehre” this method is utilized to lead students through the process of developing game design concepts for an educational game aimed at diagnostics in sports sciences. This approach resulted in a variety of gameplay mechanics now used in the further development of the game.

The goal to use the proposed method in this project was to not only generate ideas in a participative way, but to see if the creativity from the participants would benefit from this approach.

The workshop was held with overall 40 students at the technical University of Darmstadt at three different times and let them assign themselves into groups of 2-4 students. As the students would take on the role of an educator in this scenario they got access to learning materials prior to the workshop day. From the given-out materials they were told they can choose one topic which will be relevant to them during the workshop.

Participants were initially briefed on the method ("Instruction") and introduced to the project where their ideas would be used in.

After that they had 2 hours for the next steps up to the presentation of their results. This way each group could time their own process accordingly to their speed. We didn't have to limit their time on learning goal atomization or pattern exploration.

We (the authors) were present during the workshop for further (re-)explanation, guiding through the process or explaining the game design patterns found by the companion app.

After the two hours all participants returned and presented their results in front of all other participants.

During the workshop participants were allowed to choose to go to another room and had the ability to choose to use paper, whiteboards or online tools to write down their process and results.

After the workshop participants could rate their overall experience during the workshop on a 5-point Likert scale ranging from very poor to very good and had the chance to give freeform feedback. This feedback was given as explicit positive or negative feedback.

4.1 Analysis of the Feedback

As seen in Figure 5, 37 of the 40 participants rated the method as either good or very good ending in a mean (counting very good as 4 and very poor as 0) overall experience of 3.25. This reflects our impression during the workshop as all participants were concentrated and eager to exchange with their peers.

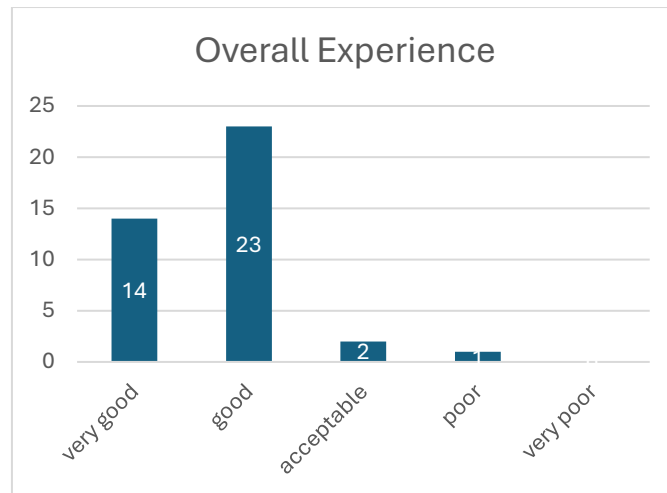


Figure 5: Overall Experience of Participants

Using the method and tools developed by Arlinghaus et al.(2024) we combined both positive and negative feedback statements and started to categorize these inductive into categories. The output categories from the tool provided by Arlinghaus et al. were pruned in a way that we erased duplicates and merged categories too similar to another into one.

We also erased all statements that either are just general feedback like the answer “Nothing” for the negative Feedback and all statements that are in no regard to the workshop itself like the overall positive feedback on edibles we had prepared for all participants (apples and pretzels).

After that step, eight categories were left, and all statements were assigned to at least one category.

The categories are:

1. Creativity and Freedom: Everything related to the creative process
2. Group Work and Interaction: How the peers interacted with each other
3. Atmosphere and Environment: Everything related to the feeling of the environment the workshop was held in
4. Learning and Knowledge Application: Here the statements are clustered that relate to the idea of educational games per se.
5. Motivation and engagement: How motivated the participants were or became during the workshop
6. Time Management: everything timing related
7. Clarity of Instructions and Guidance: If the instructions were clear and the guiding through the workshop was sufficient
8. Preparation and Materials: Given the nature that we had students take the role of an educator, they had preparation time and materials given out prior to the workshop

Every statement that fits into more than one category was split into smaller statements, so each statement was assigned to exactly one category.

In Table 3 Freeform categorization overview we show an overview of the categorized statements sorted by the overall number of statements in each category.

Table 3: Freeform categorization overview

Category	Positive Statements	Negative Statements	positive %	negative %	#statements
Creativity and Freedom	19	1	95,00%	5,00%	20
Group Work and Interaction	14	6	70,00%	30,00%	20
Clarity of Instructions and Guidance	3	12	20,00%	80,00%	15
Atmosphere and Environment	10	3	76,92%	23,08%	13

Category	Positive Statements	Negative Statements	positive %	negative %	#statements
Learning and Knowledge Application	9	2	81,82%	18,18%	11
Time Management	3	6	33,33%	66,67%	9
Motivation and Engagement	7	0	100,00%	0,00%	7
Preparation and Materials	1	6	14,29%	85,71%	7

For our method the most valuable categories are “Creativity and Freedom”, “Clarity of Instructions and Guidance” and “Motivation and Engagement” since these are the primary points we tried to tackle with the method.

Overwhelmingly positive are the two categories “Creativity and Freedom” and “Motivation and Engagement”.

In the Creativity and Freedom Category the statements were mostly very short and just stated, that they liked the freedom they got and that they could use all their creativity they had. Some more detailed statements were: “I liked: The creative approach to the task stimulates creative thinking and continuous improvement processes for your own ideas” and “I liked: You had a lot of freedom to come up with (creative) things and didn't have many restrictions”.

The only negative statement was ironically the same many others stated in the positive feedback: “The freedom”.

With 19 positive statements and one negative, the method clearly achieves its goal by enhancing creativity and freedom.

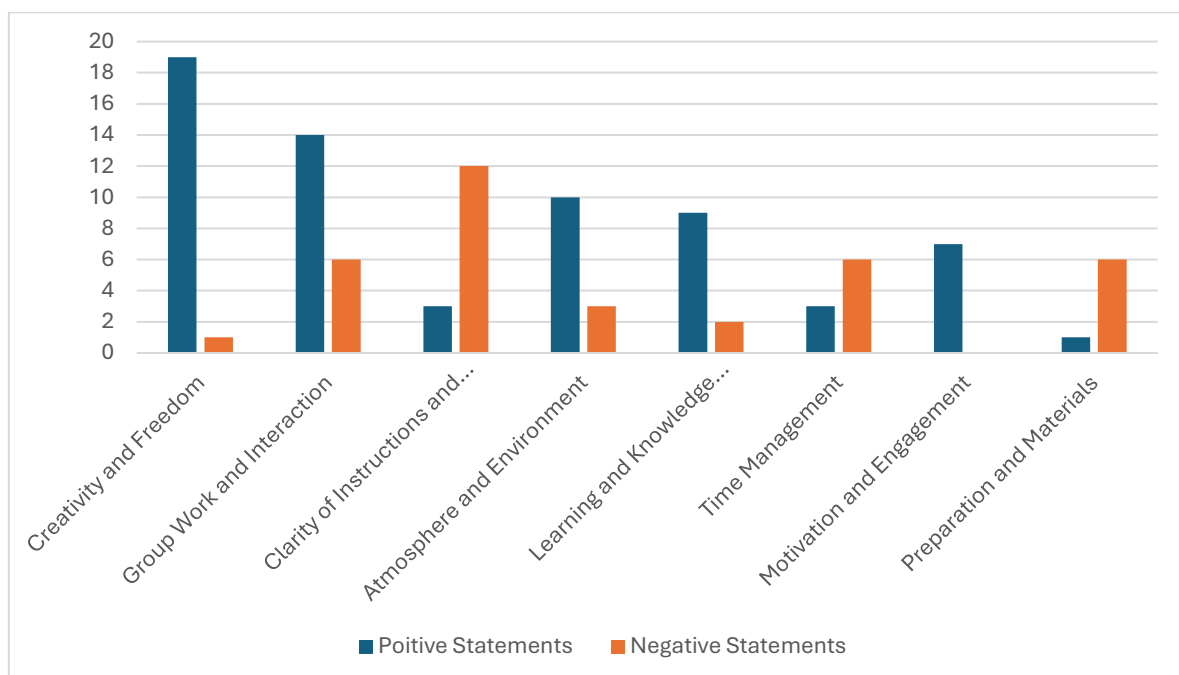


Figure 6: Breakdown of the positive and negative statements sorted (left to right) by the total amount of statements in the corresponding category

The category “Motivation and Engagement” had less statements overall but only positives. Mainly the statements were about that the project itself and game-based learning as an approach was motivating to brainstorm ideas. The fact that the participants were students assigned to develop ideas for an educational game that could be used later for their own courses was motivating too. Overall, this category was heavily influenced by the fact that the participants were students, so this category is not meaningful with the target group of teachers.

The third of the most valuable categories “Clarity of Instructions and Guidance” had mainly negative feedback with 7 negative statements and only 3 positive statements. So here it is essential to review the detailed statements to improve the workshop.

The main negative point was that the task given wasn't clear to all participants. Some wish to have a more narrowed down task like at least a game genre or a demonstration of a prototype their ideas would be integrated to have better starting point.

Examples of these statements are:

“It wasn't clear to me at the beginning what the exact procedure should be. The invitation to work creatively should have been more prominent in the introduction. “

“What could be improved: the game idea could have been explained better or what computer games look like and what is possible here could have been explained better. not all of us are gamers. „

“I didn't like it very much: Unfortunately, it was a bit difficult at the beginning to come up with a topic or a concrete approach. It might help to limit the task for the groups a little or to be more specific. “

On the other hand, the positive statements mentioned availability during the workshop, so we had the possibility to guide them through the process.

The main takeaway from this category is that the initial instructions should be clearer and a brief introduction to (serious) games would be helpful to tackle the negative statements, but the guiding through the workshop was perceived positive.

In the category Management and Preparation, the most common statement was that time was limited. While participants had insufficient time, this also indicates their desire for more time to work on their game concepts, which can be seen as a positive aspect.

5. Limitations

While the workshops provided valuable insights, some limitations should be considered. One potential challenge is the differing levels of familiarity among educators with foundational concepts like Bloom's taxonomy. This workshop currently expects participants to have at least a basic understanding of Bloom's taxonomy, or to acquire this understanding at the start of the workshop. As indicated in Figure 6, the preparation and materials were annotated accordingly, suggesting that the taxonomy could be included in the preparation or distributed during or before the workshop.

Additionally, narrative and aesthetic considerations in game design were not explicitly addressed during the workshops. These elements are crucial for fostering engagement and ensuring the seamless integration of educational content into game-based learning environments. Although this workshop emphasizes gameplay mechanics, future initiatives may explore these aspects further to assist participants in balancing the functional and experiential dimensions of their designs.

6. Future Work

Currently we're working to enhance the given game design patterns and develop more specific educational game design patterns which are targeted on educators, so they [the educators] can intuitively understand the pattern and the possibilities those patterns have. These educational game design patterns will become the primary patterns to explore during the exploration phase with the game design patterns by Björk et al. (2003) remaining a fallback and additional resource for educators.

The results from the reflection phase of the performed workshops are currently undergoing a deep screening and are involved in further development of the game “The Analyst”.

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Ethics declaration: No ethical clearance was required for the research of this paper.

AI declaration: AI has been used in two cases in the development of this paper: As the authors of this paper are not native English speakers, Microsoft Copilot has been used to rephrase chosen sentences for a better understanding. As stated in Chapter 4, an LLM² has been used in the process of inductive categorization of the free form statements of the probands. (Arlinghaus et al., 2024)

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Preparing the eLuna Visual Language for Human-AI Co-Specification and Code Automation

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Abstract: This paper presents the application and refinement of the eLuna Framework. The framework includes a two-phase collaborative method for designing and specifying narrative game-based learning (GBL) systems using a visual language. Researchers tested the framework through a real-world project that developed the Super Climate Model Game, a mobile game that explores learning objectives in climate science. Participatory action research and heuristic usability inspection methods were used to evaluate the eLuna Visual Language. The goal was to determine whether it could create unambiguous and expressively complete blueprints for narrative GBL development, and subsequently to rectify uncovered ambiguities and expressive shortcomings to enable future AI agent collaboration and code automation in development of narrative GBL using eLuna. Confirming previous research, the eLuna co-design phase was found to be highly usable. It effectively structured narrative GBL elements, supported collaboration between educators and developers, and ensured compliance with characteristics enforcing positive learning outcomes. However, the visual language lacked the expressive completeness and unambiguity required for AI agent collaboration and automated code generation. Seven modifications were proposed to address these issues while preserving the framework's empowering co-design properties alongside its originally targeted characteristics that are associated with positive effects on engagement, motivation, and learning. These seven changes improve human readability and computational parsing. They also bring the visual language closer to supporting automated coding processes. The Super Climate Model Game was developed using a hybrid approach that combined eLuna and SCRUM. This approach was necessary due to real-world constraints. The project demonstrated the flexibility of the eLuna Method and its relevance in practical development scenarios. This research moves the eLuna Visual Language closer to enabling multiagent human-AI collaboration and automated code generation. Future work will focus on creating an online visual editor for collaboration between human and AI agents. A semantic parser will also be developed to translate eLuna blueprints into structured data formats for automated code generation. These advancements will support scalable and effective narrative GBL development, delivering positive learning outcomes to diverse learner demographics.

Keywords: Narrative game-based learning, Human-AI collaboration, Code automation, Visual design languages, Modular development methodologies, Climate science

1. Introduction and Background

While previous research (e.g., Novak, 2015; Clark, et al., 2016) has reported narrative Game-Based Learning (GBL) to have the potential to enforce positive learning effects, the findings in these reports have been mixed and contradictory. Questions have been posed about what a narrative is in a game (Aarseth 2012), and about whether learning effects attributed to them comes from the narratives at all (Armstrong & Landers, 2017). Following up on Aarseth's (2012) work, defining video games as a dominant narrative media that requires its own models for analysis and design, Breien and Wasson (2021) presented the extended Ludo Narrative Variable Model (eLNVM), an ontological model to describe all games as narratives. Categorizing 15 narrative GBL on the eLNVM and sorting them by their self-reported effects, Breien and Wasson (2021) revealed a set of characteristics that are associated with positive effects on engagement, motivation, and learning. Answering calls to contribute collaborative design methods that empowers both educators and developers in the creation of effective narrative GBL, Breien and Wasson (2022) applied the positive effects characteristics and contributed the eLuna Framework. The eLuna Framework comprise four phases, accompanied by a visual language that is initially used flexibly to generate a game design from a synopsis, and later strictly, to transform this game design to a technical blueprint for narrative GBL that can be developed and deployed to learners. Figure 1 shows the eLuna Framework's four phases, and the application of the visual language in the co-design and co-specification phases. These two phases are together referred to as the eLuna Method.

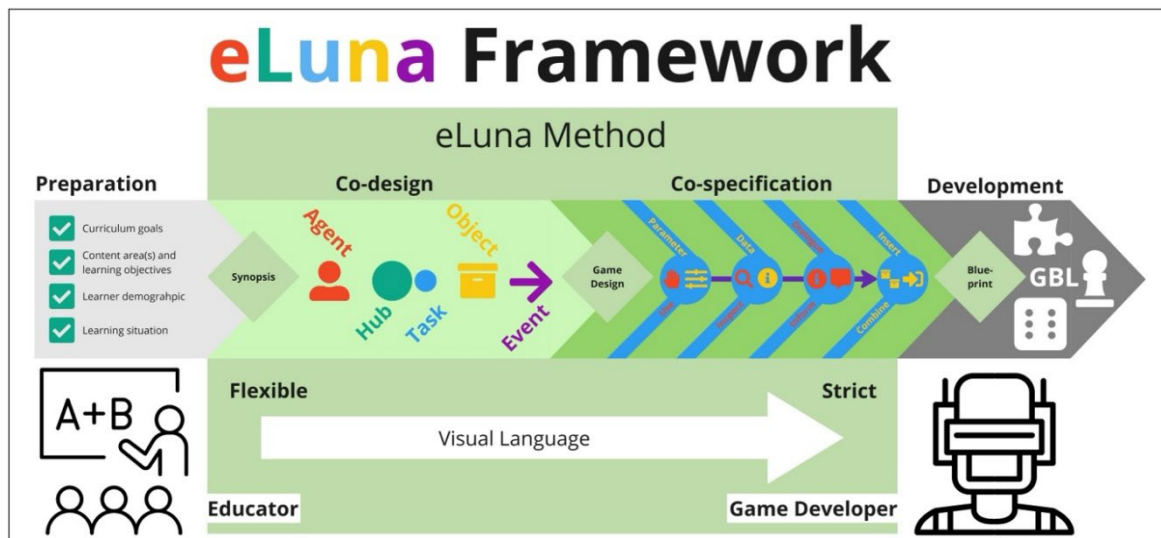


Figure 1: The eLuna Framework (adapted from Breien and Wasson, 2022). During the co-design phase the visual language is used flexibly to arrive at a game design supporting the goals defined by educators in the preparation phase. During the co-specification phase, the visual language is used strictly to arrive at a narrative GBL blueprint that can be developed in the development phase. Please refer to the original research (Breien and Wasson, 2022) for detailed descriptions and visualizations of the visual language elements and the blueprints that can be specified using them

Multiagent hybrid intelligence systems have been explored for human-AI collaborative creation of narratives (Li, et al., 2024), game mechanics (Yang, et al., 2024), and programming code (Pu, et al., 2025). Moreover, recent advances in the field of generative AI support the introduction of AI agents that can assist humans in the collaborative design of all types of games, including narrative GBL (Alvarez, 2022). Furthermore, Cheng et al., (2024) demonstrates that recent advances in AI assisted software development facilitate automated code generation based on visual schematics. The eLuna Method uses a formal visual language to specify blueprints for narrative GBL development through collaborative design and specification conducted by human agents. Therefore, it has the potential to capitalize on both AI assisted narrative and game mechanical design, as well as automated code generation. The advantages of adding these AI augmentations to eLuna are many:

- It allows for semantic AI assistance during design and specification, to ensure character consistency, aid dialogue development and editing, upkeep learning objective terminology compliance, track learning objective focus, integrate learning analytics, ensure sequencing of narrative learning content based on learning theories, and more.
- It offloads code work through AI construction and instantiating of programming classes and algorithmic structures based on blueprints, leaving human agents to focus time and resources on content.
- It affords pre-development debugging, and syntactic and semantic parsing of blueprints to generate pre-coding warnings, detect errors, and propose optimizations via language models trained on the GBL subject matter and game mechanical constraints and logic.
- It enables online and co-located narrative GBL design and specification to be conducted synchronously and asynchronously among human agents through implementation of AI guided online collaborative tools.

These improvements require visual language iconographic notations that are semantically unambiguous, and that can semantically express the characteristics targeted by eLuna. The visual language must also remain usable for human stakeholders, to conserve the original affordances of the eLuna Framework; empowering stakeholders in collaborative design processes. During the development of the eLuna Framework, only one narrative GBL was specified into an eLuna blueprint. This was the Idun's Apples prototype that was developed to evaluate the eLuna Method and to describe its visual language iconographies (Breien and Wasson, 2022). The eLuna Method has yet to be utilised in a real-world scenario, and several issues and shortcomings are expected to present themselves when applying the theoretical design framework in a real-world setting.

This paper presents a full eLuna project from preparation to development. Educators and game developers worked together using action research methods, to create a feature complete narrative GBL. This research focuses on presenting how the eLuna Method was practically applied in a real-world project, and more particularly exploring to what extent the visual language iconographies are useable for unambiguously expressing the characteristics of eLuna narrative GBL. This research presents clarifications to the eLuna Visual Language that enables unambiguous and expressive feature compliance when specifying eLuna blueprints.

2. Research Questions

This paper aims to test and then extend the visual language used in eLuna for the specification of blueprint deliverables, adhering to the demand that the syntax of iconographies, as well as the semantics that can be read from them, is unambiguous. The visual language must enable expression of all narrative and game mechanical features defined in the eLuna Method target characteristics. Furthermore, the visual language must comply with the design deliverables from the eLuna design phase and remain easy to read for both human and machine agents working with them. Two research questions (RQs) guide the work:

RQ1: How usable is the current eLuna Visual Language in practitioner specification work to create an unambiguous blueprint of a narrative GBL?

RQ2: How can ambiguities and expressive shortcomings found when applying the eLuna Visual Language to a real-world GBL development project be rectified while retaining its existing characteristics and co-design properties?

The resulting visual language will serve two purposes in future research: 1) It will lay basis for an online visual editor in which human and AI agents can work in collaborative and cross disciplinary teams to create eLuna specifications, and 2) It will lay basis for a semantic parser, that can interpret the specification blueprints into (semi) structured data (e.g. JSON, XML or SQL), and thereby enable automated code generation of narrative and game mechanical elements.

3. Methods

This research applied mixed methods. RQ1 was examined using participatory action research conducted using the practical guidelines set forth by Kemmis (2013). That is, the researchers were active participants in a real-world development project targeted at delivering a feature complete narrative GBL with learning goals set by a climate science context. Author 1 served as lead game designer and producer for the development project and moderated the eLuna design phase according to the eLuna Method, before introducing the collaborative team to the eLuna specification phase, inspecting its usefulness to produce a blueprint useable for the developers' creation of the game. Author 2 served as an educator with domain knowledge about climate science through the eLuna design and specification phases, and aided author 1 in documenting the process, including participating in evaluations. Two developers and five educators participated in the design phase, a number that was reduced to two developers and two educators in the specification phase. The development phase was conducted by the game developers alone, consulting author 1 to clarify the eLuna blueprint semantics when needed. Presented results focus on the authors' observations after working with the practitioners during the specification phase and are based on reflections put forth through mainly verbal communication in work settings. These included workshops, work sessions (usually one half to one day long), and status meetings of varying frequency from biweekly to every day, depending on project phases, over a 12-month period.

RQ2 was explored using iterations of Design-Based Research (DBR) as specified by Nieveen and Folmer (2013). The eLuna Visual Language was taken as the artifact in an Information System Research Framework (Hevner, et al., 2004) to inspect it for compliance, and to propose alterations that would mitigate identified shortcomings while remaining true to previously set requirements. To inspect compliance, the finished narrative GBL was reengineered back to eLuna Visual Language iconographies. This step was completed after going through expert usability inspection using Heuristic Usability Inspection Methods (Nielsen, 1994).

Ambiguities and expressive shortcomings were identified, before solutions were proposed that adhered to the principles of the eLuna Method.

4. Results

The Super Climate Model Game was developed and used as the testbed to explore the two RQs. The game teaches research topics in climate modelling. In the Super Climate Model Game, a feral spacefaring alien species has wreaked havoc upon a peaceful solar system, leaving myriads of animals stranded on planets incapable of

sustaining them. As part of the BAO (Benign Alien Overlord) Emergency Response Team, the player uncovers the animals' sustainability bounds, then perform climate model predictions to pair animals with planets that can sustain them before transporting the animals to safety. The goal of the game is to use as little energy as possible. Figure 2 shows selected screenshots from the developed game.

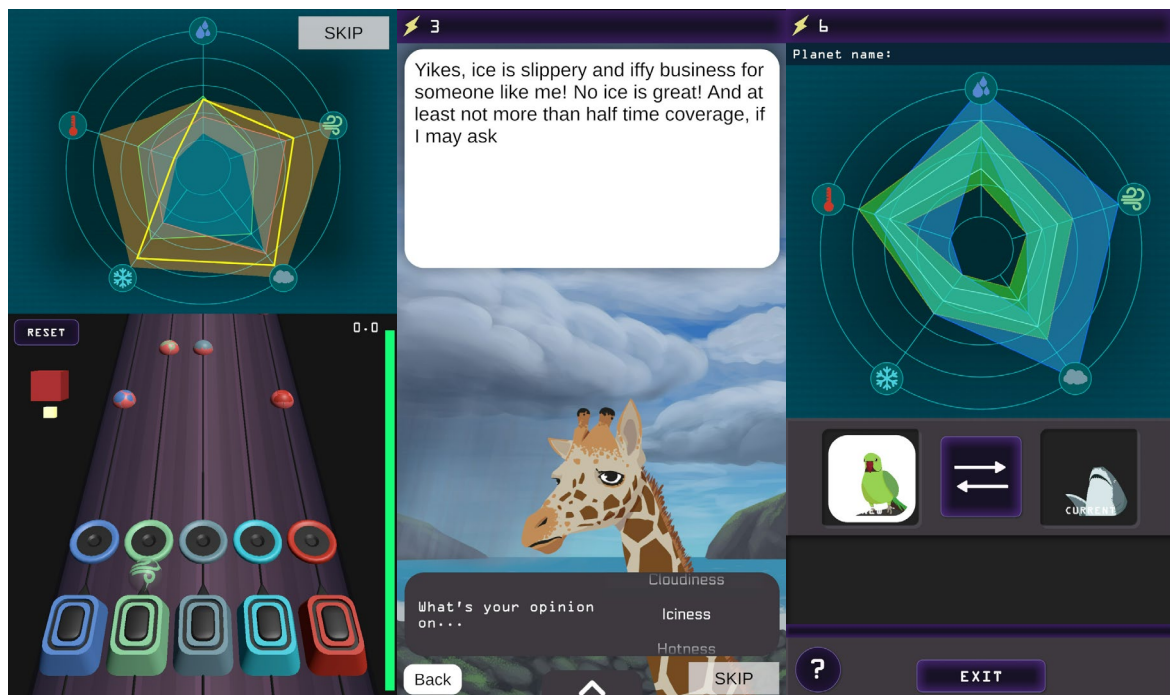


Figure 2: Screenshots from the Super Climate Model Game, climate prediction is done as a reaction game, based on time and climate models' parameters (left), animals' sustainability bounds are discovered through communication (centre), and animals are paired with habitable planets through model comparison (right)

4.1 Answering RQ1: The eLuna Visual Language could not unambiguously express elements

As expected by the researchers, the eLuna Visual Language failed when scrutinized for its ability to specify unambiguous narrative GBL blueprints. The practitioners confirmed previous results showing that eLuna is a usable and effective method to collaboratively design narrative GBL. They also added that the eLuna blueprints, when ignoring their lack of accuracy, are good references in practical development and as communication tools between educators and developers. However, the answer to RQ1 is that the eLuna Visual Language is unable to present unambiguous blueprints of narrative GBL that can be semantically parsed and coded without frequent clarifications about elements that are inexpressible or ambiguous when using the eLuna Visual Language.

Since this was a real-world project with budgets and milestone constraints, the practitioners abandoned attempts to specify the game fully using eLuna. They reverted to a known SCRUM development process as described by e.g., Schwaber (1997), using the eLuna design deliverables and the partial blueprints as useful references throughout the development.

While the narrative GBL was developed using SCRUM, it still resulted in a game that employed all elements that were defined in the eLuna co-design phase without adding anything new. This resulted in a game that is compliant to the initial eLuna vision and demonstrates that the eLuna co-design phase holds relevance even when resorting to specification using another method. Thus, incomplete eLuna blueprints can be used as guiding and communication tools in a mixed method development process that still results in eLuna games that target positive learning outcomes. However, eLuna is insufficient for use in both AI agent systems, and for code generation, since these both require unambiguous and completely expressive iconographies. Seeing the Super Climate Model Game in an eLuna categorical perspective reveals the following:

- **The agents** are the BAO, the feral aliens, and the animals (in the first version a Giraffe, a Shark, and a Parrot).
- **The hubs** are the planets' orbits and the planets' surfaces.

- **The objects** are the climate models (sustainability bounds (for animals), and sustainability models (for planets)), the energy reserve, the spaceship, and the space transport elevator.
- **The events** are the catastrophic event caused by the feral aliens, the making of climate models for planets and with animals, the comparison of climate models, and the transporting of animals and BAO representatives between the spaceship and the planets' surfaces, all of which consume energy when initiated.

4.1.1 Inspecting the Super Climate Model Game – second iteration design

The Super Climate Model Game was usability inspected after the first development iteration. This inspection was not directed at inspecting the eLuna Visual Language, however, the results of the inspection – the changes proposed by the inspectors for the next development iteration – are still considered when working towards answering RQ2 and are therefore reported here in brief.

The game was inspected by six experts, all having experience with games and interactive media to entertain, teach, or inform. The experts held the following positions: 1) Senior researcher in Human-Computer Interaction, 2) Pedagogue at a natural scientific museum, 3) Postdoctoral fellow in technology and learning sciences, 4) Lead game designer in a game development company, 5) Climate physics engineer at an energy company, and 6) Communications coordinator at a media and communications higher education unit. All inspectors were given an identical 20-minute introduction to the game, including a fully guided walkthrough of all its features. They were then given 40 minutes to play the game and were encouraged to articulate every time they were uncertain about anything: what they believed something meant; where they expected actions to lead them; what they thought the consequences of actions would be; and so on. Together with the researchers, they formulated each identified issue as a usability problem, which was recorded after the expert agreed that it reflected the issue completely and correctly. Experts were also given the opportunity to formulate possible solutions to the issue, if they could think of any. Finally, they consulted a list of 10 heuristic usability principles and related the issue to one or more of those, before ranking the issue on a severity scale from 0 (not a problem) to 3 (a system breaking problem).

The inspection resulted in 22 unique usability issues with proposed solutions, clustered together from 53 individual reports. The issues were inspected for their compliance to the eLuna target characteristics, to ensure that rectifying them would not alter the eLNVM category to one that is not associated with positive learning effects. This was done by inspecting each cluster's solution to determine whether any alterations it made to an agent, hub, object, or event complied to the target characteristic. There were three alterations: 1) Events could be looped based on object and/or agent parameters; 2) Objects' states could be stored or not stored based on status; and 3) Hubs could be clustered based on classes. These are all related to behaviours and manipulations of elements and comply with the eLuna target characteristics. However, they represent expressive requirements that should be available in the eLuna Visual Language and are thus of high relevance for answering RQ2.

4.2 Answering RQ2: Enhancements to eLuna

The final narrative GBL and the alterations introduced through the usability inspection, were reverse engineered back into eLuna specification format to identify ways in which it could be enhanced. The result was presented to the game developers participating in the project who then reconsidered the game flow and identified any remaining issues of ambiguity or expression. The group then used their experience and knowledge to propose a revised eLuna Visual Language, applying the same empowering co-design principles that is the foundation of the eLuna Framework. A total of 7 modifications were made to the eLuna Visual Language iconographies. These were organized as either ambiguity (Amb) or expressive (Exp) modifications and are summarized in table 1.

Table 1: Ambiguity and expressive modifications to the eLuna Visual Language that was originally presented in Breien and Wasson (2022)

Mod #	Type	Short name	Description
1	Amb	Connecting a quest to a hub does not constitute an event.	Quests are originally attached to hubs using purple event lines. However, starting a quest does not initiate an event before the first quest task is completed. Since the hub is green, and the line is there to indicate which hub the quest is attached to, using green lines from hub to quest is recommended.

Mod #	Type	Short name	Description
2	Exp	Hubs and the events that their quests' tasks trigger can be identical, only replacing or altering parameters belonging to it.	World hubs may exist in multiple instances, only changing the ID of the hub, and either replacing or altering the agents and objects involved in tasks, like moving from one planet orbit to another, to find a new planet with a new name and a climate model with individual parameters describing it. In the Super Climate Model Game, 42 planets are envisioned. Drawing all these on a blueprint would take a lot of time and moreover would leave the specification cluttered and illegible at least for human agents. It is therefore proposed to enable nesting of hubs visualized as intersecting dotted line hubs and several instances.
3	Amb	No distinction of quests availability qualifiers.	The original visual language attach quests to hubs using purple lines, which #1 alters to green. The semantics of eLuna however also states that quests belonging to hubs may have qualifiers that must be completed as tasks in other quests before they are enabled. A solid line makes it seems like all quests are always available to players. It is possible to traverse quest tasks in a hub to find out, but that is not technically efficient, nor simple for humans. Distinguishing quests that have external qualifiers using dotted lines is recommended to improve computational parsing and human overview.
4	Exp	Events can loop back repetitively to the same hub quest task.	It should be possible to show repeatable tasks, and the repetitions should be in types of being repeatable until reaching a condition, like matching up two climate models that overlap to some criteria or matching a set number of overlaps between climate models over time. This can be visualized by an event line looping back to the task, using finite number repetitions or an infinity marker, depending on game semantics.
5	Exp	Repetitive event loops can be forced based on task outcome assessment.	Some quests' tasks' may be assessed towards a criterion, such as presenting a correct climate model to an animal after a conversation. Successful assessment incurs an event that moves the game narrative onward, in this example allowing for the transfer of the animal to the spaceship using the space lift after verifying storage capacity. Unsuccessful assessment incurs a reinitiation of the quest from the start or from a previous task. This is visualized by using dotted event lines that fork out from the assessed task, with a simple Boolean expression added to the event lines, 1 for successful and 0 for unsuccessful assessment.
6	Amb	CRUD (Create, Read, Update, Delete) procedures that occur after the last task in a quest cannot be attached to event lines.	CRUD procedures are attached to events that precede a task that has instigated a change to the game. However, tasks that constitute the end of a quest, and that does not initiate any other quests will not have such event lines following them, leaving no place to visualize the CRUD procedure. CRUD procedures should therefore be attached to the task that instigates the change, and not the event following it, since CRUD procedures always follow the completion of the related task.
7	Exp	Some CRUD procedures are only triggered if the task result is within parameters	Following game mechanical logic, CRUD procedures are sometimes dependant on task results being within certain parameters or criteria, like when showing a sustainability climate model to an animal for assessment and only saving it if the model conforms to the animal's sustainability bounds. To distinguish between CRUD procedures that always happen and ones that have dependencies, a dotted line is used for the latter, and a solid line is kept for the former.

Figure 3 shows the resulting modified iconographies listed in table 1, using the Super Climate Model Game eLuna blueprint as example.

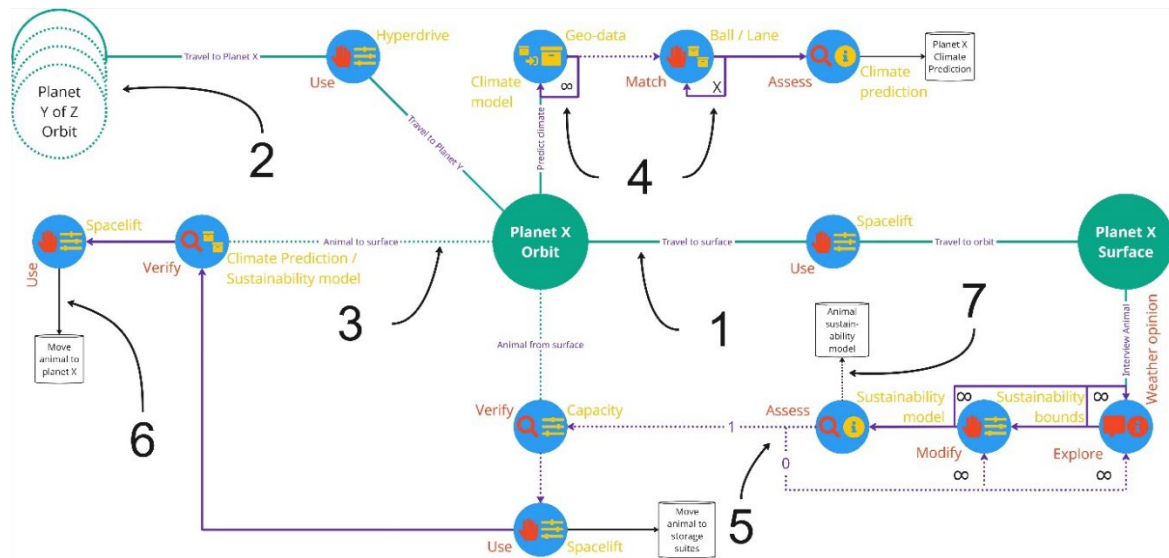


Figure 3: The Super Climate Model Game eLuna specification blueprint, numbers on blueprint references modifications as described in Table 1

5. Discussion

Our results demonstrate that the eLuna Visual Language is currently not usable to unambiguously express all relevant elements of a narrative GBL. This means that it is currently impossible to use it to either implement AI agent assistants, or to parse it into code based on its blueprints. Despite these shortcomings, we have reconfirmed previous results showing that the eLuna co-design phase is highly useable for human stakeholders. Programmers working on this project also found the blueprints to be highly relevant and useful tools for communication, and useable as programming references, even with their shortcomings in expressivity and ambiguity. While the eLuna specification phase was quickly abandoned given the temporal constraints associated with delivering a real-world and functional game, our results still show that the game remained faithful to the detailed elements that were identified during co-design and adhered to the characteristics targeted by the eLuna Framework as a whole. The Super Climate Model Game was designed using eLuna, and completed using SCRUM with eLuna assets to guide the development, something which shows the eLuna Method to be a flexible and modularizable one. As such, the co-design phase has merit on its own, to generate ideas, structure game elements and their foundational relationships to one another, create game narratives, and to tie them together in a narrative GBL whole. The designs can later be realized using other, more traditional development methods, still ensuring compliance with the characteristics that are associated with positive learning effects. This can be seen as a strength of eLuna, meaning that it can be used to guide the development of effective narrative GBL. Importantly, in moving from the laboratory domain to a practical one, eLuna has been confirmed as having sufficient flexibility to be employed alongside established development methods. This is a significant benefit as such hybrid approaches are often likely to be required for business reasons.

The research presented here has taken significant steps towards making the eLuna Visual Language expressively complete and unambiguous. Future work towards implementing a human-AI editor system and an automated code parser should continue in full. However, we have shown that there is also room for further research on using eLuna co-design as a modular phase. We envisage that this program of work could include tying eLuna to other development methods such as SCRUM; making it relevant to use in real-world narrative GBL projects; adhering to methods that are already at the core of development organizations pipelines. Of course, this work should still ensure that the updated eLuna complies with its targeted characteristics. In future work, several narrative GBL could be co-designed using eLuna, and the output from those processes used both to further advance the eLuna specifications towards hybrid intelligence multiagent systems with code automation, and to test compliance with industry standard development methods. This would result in the delivery of actual learning games that support various learner demographics.

The Super Climate Model Game provides a solid example that this is possible, since it has been delivered in feature complete status while still adhering to the positive learning effects characteristics and the deliverables from the original co-design phase. At time of writing the Super Climate Model Game is being budgeted for content completion, with a business plan provided in cooperation with the UiB technology transfer organization

(TTO) VIS. With a real-world distribution partner, it will be possible to deliver more narrative GBL, and indeed feature rich complete learning games, that support positive learning outcomes.

6. Conclusion

While this research has found that the eLuna Visual Language is not currently complete enough to support human-AI agent co-design and the automatic generation of code from blueprints, it has shown that the eLuna Method is highly useful and flexible in real-world settings. It has been used to deliver a narrative GBL with positive learning effects in a real-world setting, and a scientific consideration of the process used has brought the eLuna Visual Language closer to completeness. Avenues for further research have been identified, and a proposal for the modularization of eLuna for use alongside industry standard development methods has been made that would help to support the at scale development of effective narrative GBL that can reach real learners in educational settings. Finally, the Super Climate Model Game is being prepared for real-world distribution to learners, and the methods deployed in delivering it will form the basis for future real-world game development scenarios. Our approach shows great promise for developing games that have a real impact on learners by inducing positive learning effects for well-defined learner demographics.

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AI declaration: A long version of the abstract was provided to the UiB AI (chat.uib.no) for synthesising, before it was revisited and completed by the authors.

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CiteSaga: Lessons Learned in Serious Game Development for Academic Integrity Education

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Abstract: CiteSaga, a serious game designed for academic integrity education, immerses students in interactive citation challenges. This pedagogical approach offers an engaging alternative to traditional methods in higher education. The development revealed key insights: the necessity of substantial institutional support, interdisciplinary collaboration (including library services for resources), and the persistent resource demands of serious game creation despite AI advancements. While AI can empower smaller teams for narrative richness, faculty engagement differed from students, necessitating targeted training. Prioritizing player engagement, community, and interactive playtesting, drawing from UGC and indie game strategies, proved essential. Moreover, modular design and creative funding addressed budget constraints. CiteSaga demonstrates the potential of serious games for academic integrity, underscoring the need for institutional alignment, stakeholder buy-in, and interactive design. Future research should explore longitudinal impacts, faculty onboarding, and curricular integration.

Keywords: Academic integrity, Game production, Citation education, Serious games, Lessons learned

1. Introduction

The increasing adoption of game-based learning (GBL) strategies worldwide has brought renewed attention to the role of engagement, motivation, and interaction in fostering effective educational experiences (Subhash & Cudney, 2018; Manzano-León et al., 2021). In the South African higher education context, GBL offers promise for addressing entrenched challenges such as large class sizes, multilingual student populations, infrastructural disparities, and varying degrees of academic preparedness (Hu, 2024; Chen, 2025). Yet while digital platforms often dominate GBL discussions globally, local realities necessitate more flexible and context-sensitive approaches, including analogue, low-tech interventions.

One area where traditional pedagogy has struggled to ignite student engagement is academic integrity education, particularly regarding citation practices and the attribution of intellectual work. Students often perceive citation not as a meaningful scholarly exercise but as an arbitrary compliance burden—a perception that undermines foundational academic skills and values. In response, the CiteSaga project was initiated to reframe citation practices as an integral part of knowledge construction, positioning proper attribution as a creative and communal scholarly act rather than a bureaucratic hurdle.

CiteSaga originated as an analogue tabletop serious game designed to bridge motivational gaps in citation education by offering an interactive, narrative-driven learning environment. Developed through interactive prototyping and evaluated with a heuristic framework tailored to serious games ("Play with Purpose"), the project emphasised modularity, accessibility, and the power of user-driven engagement. However, recognising the broader need for scalable, flexible deployment across varied educational contexts, the project later expanded into an experimental digital prototyping phase.

This paper presents critical lessons learned from both the analogue and digital development of CiteSaga. It explores how principles of interactive design, resource-conscious creativity, interdisciplinary collaboration, and emergent AI-assisted practices coalesced into a coherent approach to serious game creation in a resource-constrained higher education environment. In doing so, it offers reflexive insights into not merely the technical facets of serious game development, but also the pedagogical, institutional, and philosophical challenges of integrating GBL into academic integrity education.

2. Contextual Background

Globally, game-based learning (GBL) has demonstrated consistent success in enhancing student engagement, motivation, and academic performance across disciplines (Adam & van den Berg, 2022; Szilágyi et al., 2025). However, effective translation of these approaches into the South African higher education context requires significant adaptation. Large class sizes, multilingual student cohorts, infrastructural inequalities, and varying levels of digital literacy present substantial barriers to conventional digital GBL implementations (Hu, 2024; Chen, 2025). Consequently, there is a growing imperative for educational interventions that are both pedagogically innovative and infrastructurally sensitive.

Within this context, low-tech and analogue GBL strategies have gained prominence as accessible and impactful solutions. Tabletop serious games, in particular, offer unique advantages: they minimise reliance on costly technological infrastructure, encourage face-to-face collaboration, and provide tangible, embodied learning experiences that resonate with assorted student populations. Yet their application to complex academic practices, such as scholarly citation and integrity, remains relatively underexplored.

The CiteSaga project emerged at the intersection of these challenges and opportunities. Initiated in 2023 through interdisciplinary collaboration, the project sought to address a persistent disconnect observed among students regarding the purpose and practice of citation. Rather than framing citation as a mechanical compliance task, CiteSaga aimed to reimagine it as a dynamic and integral part of scholarly identity and knowledge production. Rooted in principles of serious game design, the project emphasised narrative immersion, interactive playtesting, modular construction, and purposeful integration of academic learning outcomes.

Critically, CiteSaga was conceived not as a static artefact but as a flexible pedagogical intervention, capable of evolving alongside institutional needs and technological possibilities. From its inception, the project team recognised the necessity of designing for both present constraints and future scalability—an ethos that would eventually underpin the transition from analogue to digital prototyping in the later stages of development.

3. Development and Evaluation of CiteSaga

The development of CiteSaga as an analogue serious game was intentionally grounded in both pedagogical theory and practical contextual considerations. Recognising the infrastructural limitations facing South African higher education, the project team adopted a low-tech, tabletop format to ensure broad accessibility across student populations. However, accessibility was only one axis of design. Equally critical was the need to embed the learning objectives—specifically, scholarly citation practices—directly into the mechanics and flow of gameplay, ensuring that academic integrity was not peripheral but intrinsic to player engagement.

CiteSaga's development was structured around an interactive prototyping process informed by participatory design principles. Early prototypes were subjected to structured playtesting sessions with student participants drawn from varying academic backgrounds. These sessions provided essential formative feedback, allowing the design team to identify and address points of confusion, disengagement, or misalignment with learning goals.

To guide the development systematically, the team employed the "Play with Purpose" heuristic framework (Bunt et al., 2023), specifically designed for evaluating serious games in educational contexts. This heuristic provided evaluative criteria across key domains such as accessibility, feedback mechanisms, adaptability to different learning contexts, and the quality of the learning experience. Early evaluations revealed, for instance, that players often failed to transfer in-game insights about citation to their formal academic writing unless explicit debriefing sessions were incorporated post-play. As a result, guided reflection activities were added as a standard component of the CiteSaga implementation protocol.

Throughout development, modularity and adaptability were prioritised. CiteSaga was constructed not as a rigid, single-use artefact, but as a flexible learning tool: its rule sets could be adjusted for different class sizes or disciplinary focuses, and its physical components (e.g., citation cards, resource tokens) were designed for easy replication and customization. This modular approach was crucial for ensuring the game's sustainability across variable institutional contexts, particularly in environments where ongoing resource support could not be assumed. Moreover, the development process underscored the critical role of interdisciplinary collaboration. Educational technologists, academic integrity specialists, librarians, and design practitioners all contributed to different facets of the project, reflecting the multifaceted nature of both serious game design and academic

integrity education. Such collaboration not only enriched the game's content but also helped align it with broader institutional priorities, thereby facilitating stakeholder buy-in and potential curricular integration.

Ultimately, the development and evaluation of CiteSaga illustrated the value of interactive, user-centred, and context-sensitive design processes in serious game creation. These foundations would later prove essential when the project expanded into digital prototyping, where similar principles of modularity, interaction, and empowerment through emerging technologies continued to guide the work.

4. Lessons Learned

The development of CiteSaga yielded several critical insights into the process of designing serious games for higher education, particularly within resource-constrained contexts. These lessons, emerging across both analogue and digital phases of the project, extend beyond technical execution to reflect broader principles of educational design, institutional alignment, and participatory pedagogy.

4.1 Learning-Aligned Mechanics

A central design insight was the importance of embedding learning outcomes directly into core gameplay mechanics. CiteSaga's citation challenges were not supplementary tasks but integral to player progress, reinforcing the idea that citation is not an external imposition but part of scholarly strategy. This alignment increased student buy-in and encouraged reflection on the purpose and function of citation practices. Learning was not merely adjacent to play—it was the mode through which players advanced, competed, and collaborated.

4.2 Interaction as Pedagogical Method

Interactive design proved indispensable, both as a technical necessity and as a pedagogical method. Through repeated playtests and feedback loops, misconceptions—such as confusion over citation types or resource use—were surfaced and corrected. These interactions reflected the adaptive learning processes educators aim to foster in students, modelling reflexive practice within the design itself. By embedding interaction into the game's development, the team also enabled ongoing responsiveness to learner needs, institutional contexts, and pedagogical opportunities.

4.3 Accessibility Through Analogue Design

The choice to begin with a physical tabletop format was not a limitation, but a strategic response to infrastructural inequality. Many South African students lack stable internet or personal devices, making digital-first approaches exclusionary. CiteSaga's analogue design ensured accessibility across campuses with varied resources, and encouraged social interaction among players, reinforcing the communal nature of academic practices. This decision underscores the value of low-tech innovation in contexts where digital equity cannot be assumed.

4.4 Structured Reflection and Transfer

Game-based experiences do not automatically translate into improved academic practice. CiteSaga's effectiveness increased significantly when followed by structured debriefing, in which facilitators linked in-game decisions to academic behaviours and institutional expectations. Without these reflection moments, many students failed to generalise from gameplay to their own writing practices. This lesson reinforces the need for deliberate scaffolding to support knowledge transfer—a known challenge in serious games that must be addressed through complementary pedagogical framing.

4.5 Real Costs and Invisible Labour

Despite increasing access to AI tools, the creation of high-quality serious games remains labour-intensive. CiteSaga's development demanded not only game design expertise, but also pedagogical sensitivity, domain knowledge, and interactive testing. The common assumption that AI will dramatically reduce effort obscures the invisible labour of design synthesis, narrative cohesion, interface testing, and institutional coordination. As noted by Colado et al. (2023), AI tools can accelerate processes, but do not replace the need for human insight, interaction, and oversight.

4.6 Empowering Small Teams Through AI

That said, AI tools did play an empowering role, especially in later phases. Generative models such as ChatGPT and image-generation tools allowed the team to rapidly produce narrative content, card art, and interface

mockups, significantly lowering the threshold for experimentation. This mirrors trends in educational development globally, where low-resource teams increasingly leverage AI to access capabilities that would otherwise require specialised skills (Humble, 2024). In this way, AI functioned not as a replacement, but as a creative collaborator.

4.7 Designing Small, Designing Smart

Attempting to create large-scale educational games often leads to inflated scope and diluted outcomes. CiteSaga's strength lay in its modest ambition: a tightly-scoped, well-polished intervention targeting a specific pedagogical need. Drawing inspiration from indie game development models, the project prioritised depth over breadth, interaction over expansion. In resource-constrained academic environments, this approach offers a more sustainable model than attempting to replicate AAA game features at institutional scale.

4.8 Engagement Before Expansion

A recurring insight was that player engagement—and the creation of a sense of community around the game—was more impactful than large-scale distribution. Playtests showed that students were more likely to recommend the game and internalise its lessons when they felt invested in its world and mechanics. This echoes lessons from digital communities: small, highly engaged user groups often generate more meaningful learning outcomes than passive, large-scale deployments (Carson, 2024). Co-design elements, player choice, and in-game reflection all contributed to sustained engagement.

4.9 Modular Design and Sustainable Expansion

Finally, modularity emerged as a key design affordance. By creating discrete, swappable components—such as citation decks, environment cards, or rule variations—CiteSaga could be customised across faculties and disciplines. This modular architecture also supports reusability, enabling different educators to adapt the game without overhauling its core. From a funding and sustainability perspective, such modularity allows components to be incrementally updated or expanded, while enabling the game to fit varying curricular needs.

4.10 Adapt to Funding Challenges

Educational game projects need modular design and creative financing. Often with tight budgets (university grants), maximizing development value is key. Modular, reusable design allows repurposing components across contexts (Carlier et al., 2023). Traditional bespoke games lack knowledge transfer (Carlier et al., 2023). Reusing components creates adaptable core engines, saving costs and easing updates (Sparks, 2019). For higher education, a well-designed platform can serve multiple courses, stretching funding. Creative funding includes government/research grants (NSF, NIH, Horizon Europe) and corporate/NGO partnerships aligning with social impact goals (Liberty, 2023). Sustainable development requires modularity and external funding.

5. Digital Development of CiteSaga

Following the analogue success of CiteSaga, the development team explored a digital extension of the game to increase reach, support asynchronous play, and experiment with new modes of engagement. This digital prototyping phase was guided by the same pedagogical principles underpinning the tabletop version: modularity, accessibility, and interactive design. What distinguished this phase, however, was its embrace of emerging AI-assisted development practices—most notably, the use of "vibe coding" as a novel, intuition-driven approach to rapid prototyping.

5.1 Vibe Coding as Interactive Practice

"Vibe coding," a term popularised by Karpathy (2024), refers to a development approach in which the programmer relies heavily on natural language prompts to co-create functional code with generative AI. Rather than following a rigid software specification, the developer interactively describes goals to the AI—receiving code snippets, testing them, and refining through conversational loops. In this model, the AI acts as a pair-programmer, accelerating development by handling low-level implementation while the human focuses on design intent and user experience.

For CiteSaga, this technique proved especially apt. The project's pedagogical design had already embraced interaction and modularity; vibe coding mirrored this ethos by enabling fast, incremental builds and user-driven interface adjustments. A single developer, equipped with working knowledge of JavaScript and access to ChatGPT, was able to construct a functional digital prototype of CiteSaga in a matter of weeks. Each

gameplay feature—movement, resource tracking, citation resolution—was implemented through successive AI-generated code interactions, interspersed with player feedback and testing.

5.2 Leveraging AI for Empowered Prototyping

The use of generative AI in this context reflected a broader lesson from the analogue phase: small teams can achieve meaningful design outcomes when empowered by the right tools. Where the analogue prototype used modular physical components, the digital version relied on AI to scaffold equivalent modular functions—pop-up prompts, inventory displays, and event handling systems. The developer described desired functionality in plain language, allowing the AI to generate and adapt code in response to playtest issues. This practice aligns with recent findings on AI's role in educational game development, particularly its ability to augment design capacity among non-specialist developers (Colado et al., 2023; Humble, 2024).

Notably, the rapid feedback loop enabled by vibe coding supported agile experimentation. For instance, when testers found it difficult to track resource changes on screen, the developer quickly implemented animated UI feedback by prompting ChatGPT for glowing visual cues. Similarly, when gameplay flow became ambiguous, the AI was instructed to introduce contextual pop-ups guiding player decisions. These features—standard in polished digital games—were integrated into the prototype within hours rather than weeks, demonstrating how vibe coding enhances responsiveness and creative interaction.

5.3 Pedagogical Integrity and AI Oversight

Despite these advantages, the process revealed important limitations. Most critically, AI-generated code does not understand pedagogical nuance. Several early implementations simplified or misrepresented game rules in ways that undermined the intended learning outcomes—for example, auto-completing citation tasks that were meant to provoke player reasoning. This necessitated continuous oversight and alignment with the original game design documents to ensure that the educational intent was preserved.

Moreover, the opaque nature of the AI-generated codebase introduced maintainability risks. Because the developer did not manually write or review every function, debugging complex interactions—such as turn-order logic or event triggers—became challenging. This echoes broader concerns in AI-assisted development literature, where speed gains are often counterbalanced by reduced code comprehension and technical debt (Taeb et al., 2024; Tosi, 2024). In response, the CiteSaga team treated the digital prototype not as a deployable application, but as an experimental proof-of-concept requiring reengineering before broader rollout.

5.4 Rapid Prototyping, Not Final Deployment

The final digital version of CiteSaga successfully replicated the core mechanics of the analogue game, offering single-player functionality, interactive feedback, and guided citation challenges. However, it remained a prototype: fast to build, flexible to test, but not yet production-ready. Its primary value lay in demonstrating how AI-assisted workflows could lower the threshold for educational innovation, particularly in institutions with limited development infrastructure. As such, the digital phase of CiteSaga reinforced the project's central theme: that meaningful educational games can emerge from small teams working interactively, responsively, and creatively—even when technical expertise is limited.

The experience suggests a viable hybrid model for future serious game projects: use AI-augmented prototyping to explore ideas and generate functional builds quickly, then transition to traditional engineering methods for refinement, documentation, and scalability. In this vision, AI is not a shortcut to avoid complexity, but a catalyst that accelerates the early stages of design—allowing educators and instructional designers to lead innovation, rather than remain dependent on specialised development teams.

6. Conclusion

The development of CiteSaga, from an analogue tabletop prototype to an AI-assisted digital interaction, offers a multi-layered case study in serious game design for academic integrity education. In both phases, the project demonstrated how pedagogical goals, contextual constraints, and design pragmatics can be meaningfully aligned through interactive, learner-centred development.

Crucially, the project foregrounded the importance of accessibility—not only in terms of technological reach, but in cognitive and pedagogical design. By embedding citation practices into game mechanics and using gameplay as a medium for conceptual engagement, CiteSaga reimaged citation as a meaningful scholarly act rather than an abstract academic requirement. This reframing proved especially valuable in a South African context, where traditional academic literacy interventions often struggle to connect with student cohorts.

The use of modular, scalable components allowed the game to flex across faculties and contexts, while structured debriefings ensured that in-game learning transferred to academic behaviours. These principles—modularity, reflection, interaction—were later carried forward into the digital phase, where AI-enabled "vibe coding" facilitated rapid prototyping and empowered a small team to extend the game's reach. While this approach raised new questions around oversight, quality, and sustainability, it also pointed to a future in which educators can lead game design initiatives with increasing autonomy and agility.

Taken together, the analogue and digital phases of CiteSaga suggest a coherent and repeatable model for serious game development in higher education: begin with tightly scoped, contextually responsive interventions; design interactively with clear learning goals; and embrace emerging tools not as replacements for expertise, but as catalysts for experimentation and access.

Future research should explore the long-term curricular integration of serious games like CiteSaga, including their effects on academic writing performance, metacognitive understanding of attribution, and institutional attitudes toward playful learning. In parallel, there is a growing need to develop design guidelines and ethical frameworks for AI-assisted game development, particularly in educational contexts where learning integrity is paramount.

Ethics statement: This study did not involve human participants, personal data, or interventions requiring formal ethical clearance. As such, institutional ethical approval was not required.

AI Declaration: AI tools were used to assist in the writing and editing process of this paper, specifically for drafting and refining prose in collaboration with the authors. All ideas, arguments, and scholarly interpretations remain the intellectual work of the authors, with AI serving as a language support and formatting aid. No AI-generated content was accepted without human oversight, critical review, and contextual alignment with the paper's aims.

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Evaluating Multiplayer Game-Based Training for Earthquake Evacuation: A Systematic Review

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Abstract: Earthquakes are the most devastating natural disasters, causing extensive loss of life and damage. Traditional methods, such as drills and instructional materials, focus on individual preparedness, overlooking group dynamics that shape real-world evacuations. In crowded settings like schools and hospitals, peer influence, leadership and collective decision-making significantly impact evacuation outcomes. Game-based learning offers an interactive approach to disaster preparedness, yet most serious games rely on single-player training or AI-driven simulations where non-player characters (NPCs) attempt to mimic human behavior. These models often fail to capture real-time social interactions, limiting their effectiveness in preparing individuals for group evacuations. This creates a critical research gap, as there is limited understanding of how multiplayer game-based training can improve collaborative decision-making and evacuation efficiency. This study conducts a systematic literature review using SCOPUS and Web of Science databases to examine the relationship between multiplayer game-based training and earthquake evacuation preparedness. The review aims to identify key findings, highlight existing research gaps and explore the role of multiplayer interaction in improving evacuation efficiency and adaptive decision-making. While previous studies have primarily focused on individual-centered evacuation training, few have examined the real-time impact of multiplayer interactions on group evacuation behavior and decision-making dynamics. Additionally, the influence of social factors—such as peer interactions, leadership roles and collective decision-making—on evacuation performance remains largely underexplored. Furthermore, the potential of multiplayer serious games to enhance engagement, situational awareness and collaborative problem-solving has received limited attention in existing research. Future studies should prioritize empirical investigations into the effectiveness of multiplayer serious games in enhancing group coordination, role differentiation and social influence during evacuations. Moreover, integrating multiplayer game-based training into official disaster preparedness programs could provide a more dynamic, interactive and socially realistic approach to emergency response education.

Keywords: Serious games, Game-based learning, Earthquake evacuation, Disaster preparedness, Emergency training, Human behaviour

1. Introduction

Earthquakes are one of the serious natural disasters in the world and it scales globally. Türkiye is located in a geographical area with important tectonic fault lines. In history, Türkiye witnessed 114 earthquakes greater than 5 and these earthquakes directly affected approximately 23.8 people and caused life loss for more than 144.000 people (EM-DAT, 2023). Researchers have some predictions about a major earthquake in the Marmara region with Mw 7.5. According to scenarios developed by the Kandilli Observatory and Earthquake Research Institute (2019), a possible earthquake with this magnitude could significantly affect this densely populated region. The spatial needs that may arise if these scenarios occur are determined.

Earthquake preparedness actions are divided into three classes: pre-earthquake, earthquake moment and post-earthquake stages. Learning and implementing basic safety measures during an earthquake is an effective and fundamental solution to prevent loss of life in this natural disaster (Rajabi et al., 2022). Given the complexity of human behavior during such disasters, especially in densely populated areas such as schools, hospitals and commercial facilities, traditional preparedness methods alone may not be sufficient. Training individuals for earthquake evacuation in public indoor spaces poses unique challenges, including panic management, route selection and coordinated decision-making. Traditional training methods, such as drills and instructional sessions often fail to adequately simulate the complexity of real-life scenarios. Game-based learning provides an alternative by immersing participants in virtual environments where they can practice responding to emergencies. Multiplayer serious games, in particular, add the element of collaborative behavior, which is critical during large-scale evacuations. Despite growing interest in serious games for safety training, the literature lacks comprehensive studies focusing on multiplayer systems for earthquake evacuation. This paper aims to review existing research from SCOPUS and Web of Science databases, investigate the potential and effectiveness of multiplayer serious games in earthquake evacuation preparedness, highlight gaps and propose future research directions.

The following section provides an overview about earthquake evacuation training and a comparison between traditional methods and game methods. The second section provides a comprehensive review of existing studies conducted at the intersection of earthquake evacuation and serious game methods. Last two sections summarize the key findings derived from these studies and future work suggestions.

2. Traditional vs. Game-Based Training Methods

Traditional evacuation training methods such as instructional materials, drills, seminars and videos are standard preparation tools for preparing people for disasters in a long time. These traditional evacuation training methods aim to teach basic safety protocols and evacuation procedures to the people for reducing the effects of a disaster. However, their effectiveness is questioned because of the limitations in engagement, realism, adaptability and scalability.

Game-based learning (GBL) offers an alternative model with more realistic and interactive environments for simulating emergency conditions. Traditional methods are mostly passive and focus on individual behavior but serious games enable learners to actively participate in scenarios, make decisions and solve problems in a team collaboration. These features make Game-based learning (GBL) a powerful tool for enhancing preparedness in complex, high-stress scenarios like earthquake evacuations.

Nowadays, evacuation training is mainly conducted by using traditional methods like drills and written instructions. However, there are multiple factors that restrict how effective these methods can be. These limitations can negatively affect the process of preparing people for real emergency situations. The limitations of traditional evacuation training can be grouped under three groups:

- **Lack of Realism and Participation:** Traditional methods are not effective in simulating the unpredictability and complexity of real-life emergencies. This limitation makes it difficult for people to improve critical thinking and decision-making skills (Gwynne et al., 2020; Mitsuhashi et al., 2023). Additionally, traditional methods usually focus on specific scenarios and cannot properly direct participants to real disaster conditions (Capuano et al., 2015; Rahouti et al., 2017).
- **Limited Scope and Adaptability:** Traditional methods generally focus on specific scenarios and have difficulty about adapting different types of emergencies or personal behavior differences. Since these methods do not get attention to the decisions and behaviors of people during the evacuation process, deficiencies may occur during a real evacuation (Haghani, 2020; Li et al., 2022).
- **Restricted Educational Impact:** Traditional methods may not be effective in environments with vulnerable populations, such as hospitals or schools. These methods disrupt operations and offer limited educational value for vulnerable populations (Rahouti et al., 2017).

2.1 Conceptual and Theoretical Background: Serious Games in Evacuation Training

Serious games are not just about entertainment, their purpose is mostly about education and training. They use immersive storytelling, rule based systems and player agency to achieve specific learning outcomes. For disaster preparedness, serious games provide experiential learning environments that mimic real-life scenarios, promoting both knowledge acquisition and behavioral training.

Serious games serve several critical functions to apply evacuation training. They simulate the time-sensitive and high-pressure conditions of an emergency, allowing players to rehearse decision making, spatial navigation and collaborative actions. Unlike traditional simulations or paper-based learning, serious games allow real-time feedback and adjustment based on player choices, fostering deeper cognitive engagement. Multiplayer serious games further enhance this by simulating social dynamics, such as leadership, group cohesion and peer influence factors central to real-world evacuations in collective environments like schools or hospitals.

The theoretical foundation of serious games in this field is grounded in experiential learning (Kolb, 1984), which highlights the importance of context, interaction and reflection in effective education. These games also align with the principles of constructivist pedagogy, enabling learners to build knowledge through active participation and critical thinking within meaningful scenarios. Thus, serious games—especially in multiplayer formats—hold strong potential for improving disaster training by integrating behavioral realism, emotional engagement and social complexity into educational frameworks.

3. Methodology

This study adopts a systematic literature review methodology to investigate the effectiveness and potential of multiplayer serious games in enhancing earthquake evacuation preparedness. During the initial phase of the

literature search, it was observed that while numerous studies address serious games for disaster education and evacuation training, research specifically examining multiplayer dynamics in earthquake evacuation scenarios remains limited. For this reason, the keywords were expanded such as “Serious Game”, “Game-based Learning”, “Educational Game”, “Earthquake”, “Earthquake Evacuation”, “Earthquake Training” and not limited to just multiplayer. The review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines with the input of these keywords.

A comprehensive search was conducted in two major academic databases, Scopus and Web of Science, selected for their extensive coverage of peer-reviewed studies in disaster research, education and game-based learning. The initial search was restricted to articles published between 2015 and 2025 to ensure the inclusion of contemporary developments in serious game technologies and disaster education practices. The initial screening identified 71 records. After applying predefined inclusion and exclusion criteria, such as relevance to earthquake-related evacuation training, incorporation of serious game interventions and exclusion of studies focused on other disaster types (e.g., floods, hurricanes) or unrelated applications (e.g., engineering simulations without educational components), a total of 14 articles remained. (Figure 1)

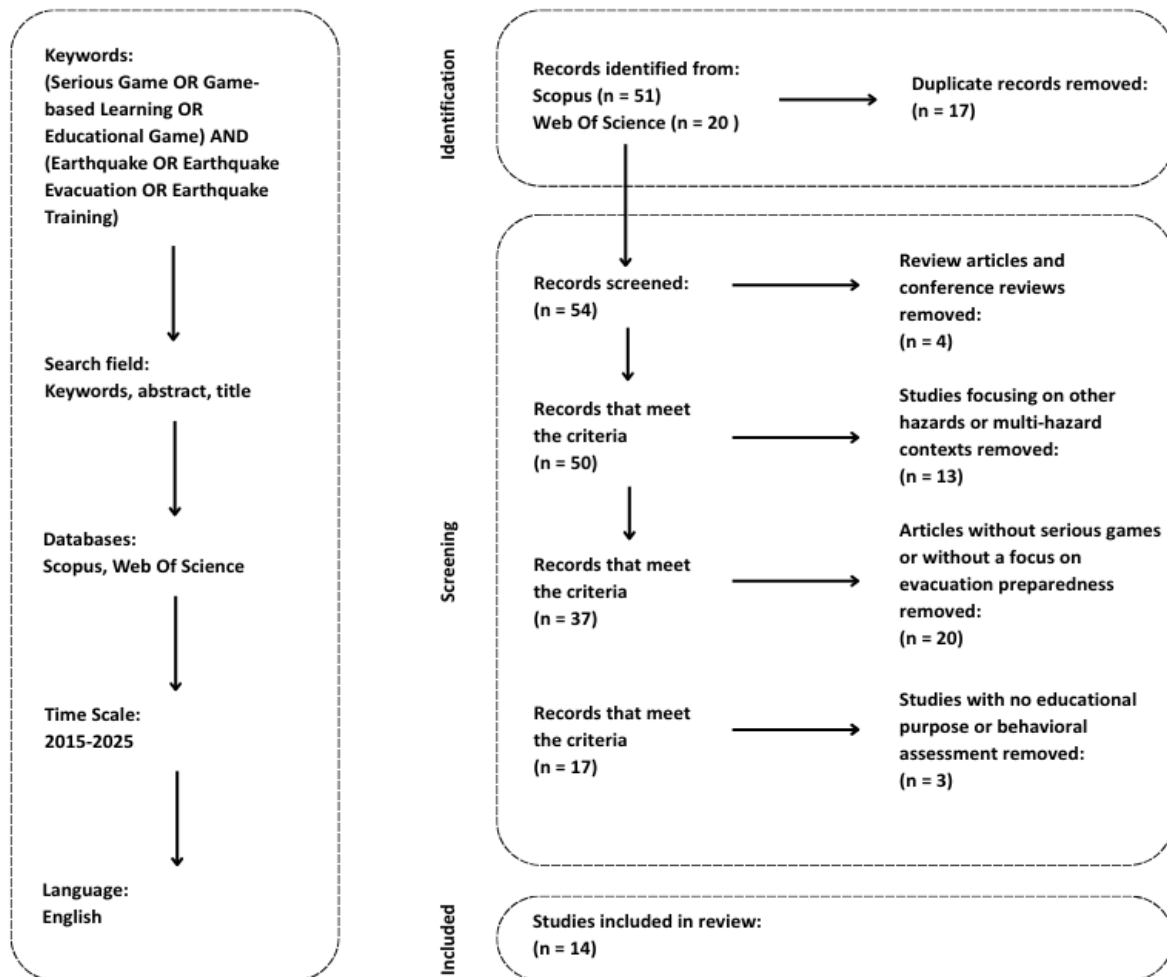


Figure 1: Literature search and screening based on PRISMA guidelines

Through further screening based on detailed eligibility criteria such as the presence of educational goals related to evacuation behavior 14 studies were finally included for final analysis. The table below shows the systematic review process of the selected resources. (Table 1)

Table 1: Literature review

N	Article Name	Year	Aim	Method	Findings
1	Improving post-earthquake evacuation preparedness for deaf and hard of hearing children: A conceptual framework	2021	Enhance evacuation preparedness for deaf and hard of hearing children using VR serious games	Systematic literature review	VR serious games should be adapted to deaf and hard of hearing needs within Disaster Risk Reduction frameworks
2	Exploring spiral narratives with immediate feedback in immersive virtual reality serious games for earthquake emergency training	2023	Investigate narrative structure and feedback impact in VR earthquake training games	Experimental VR game design and testing	Spiral narratives and immediate feedback improve learning outcomes
3	Instructional mechanisms in immersive virtual reality serious games: Earthquake emergency training for children	2020	Examine instructional strategies in VR games for earthquake training	Experimental study with children	Instructional scaffolding enhances preparedness learning
4	Mobile educational game for earthquake disaster preparedness in elementary school	2018	Develop a mobile game to teach earthquake mitigation to elementary students	Game development and pilot testing	Mobile games increased children's awareness and preparedness
5	An immersive virtual reality serious game to enhance earthquake behavioral responses and post-earthquake evacuation preparedness in buildings	2020	Create VR-based training to improve evacuation behaviors post-earthquake	Pilot study with hospital staff and visitors	VR training increased knowledge and self-efficacy significantly
6	Exploring the most effective feedback system for training people in Earthquake emergency preparedness using immersive virtual reality serious games	2024	Compare feedback types in VR earthquake training games	Controlled experimental study	Corrective feedback was most effective for behavior change
7	Educational Seismology through an Immersive Virtual Reality Game: Design, Development and Pilot Evaluation of User Experience	2023	Design a VR game for educational seismology and assess UX	Game design and pilot user evaluation	Positive usability and educational potential confirmed
8	Prototyping virtual reality serious games for building earthquake preparedness: The Auckland City Hospital case study	2018	Develop VR training prototypes for hospital earthquake preparedness	Prototype development and stakeholder testing	VR improved staff readiness for evacuation scenarios
9	Towards a customizable immersive virtual reality serious game for earthquake emergency training	2020	Create a customizable VR serious game for earthquake response	Design-based research approach	Customizable scenarios increased relevance and engagement
10	Prototyping of an earthquake evacuation learning game with VR reproducing the environment that is familiar to learners	2019	Prototype a VR earthquake evacuation game in familiar environments	Prototype testing with students	Familiar settings enhanced learning and realism
11	Human behavior and decision-making in earthquake emergencies: insights from virtual reality and serious games	2024	Understand human decisions during earthquakes via VR games	Observational VR study	Social factors critically influence evacuation decisions

N	Article Name	Year	Aim	Method	Findings
12	Which training method is more effective in earthquake training: Digital game, drill or traditional training?	2022	Compare the effectiveness of digital games, drills and traditional education	Controlled experimental comparison	Games improved motivation and drills better for skills acquisition
13	Playing games for risk prevention: Design, implementation and testing of serious games in recent European projects UPStrat-MAFA and knowRISK	2021	Use serious games for risk prevention education	Game design and public testing	Serious games enhanced seismic risk awareness
14	Comparison of the digital game, drills and traditional education methods in terms of motivation in earthquake education	2022	Evaluate impact of different methods on motivation in earthquake education	Experimental study with elementary students	Games increased motivation and drills were more effective for behavior

Following the systematic review and selection process, the 14 retained studies were thematically clustered to identify the dominant research focuses and methodological tendencies. The reviewed literature reveals five major thematic clusters: (1) the use of immersive virtual reality environments for evacuation preparedness, (2) mobile-based serious games for early disaster education, (3) instructional mechanisms and feedback systems in serious game design, (4) behavioral decision-making during evacuation and (5) accessibility and inclusion in game-based training for vulnerable populations. These clusters provide a structured foundation to analyze the strengths, limitations and research gaps in the field. (Table 2).

Table 2: Clustering of Articles

N	Thematic Clustering	Studies
1	Immersive VR for Earthquake Evacuation	5,7,8,9,14
2	Mobile-Based Disaster Education	4,13
3	Instructional Design & Feedback	2,3,6,12
4	Behavioral Decision-Making & Social Dynamics	11
5	Accessibility & Inclusive Design	1, 10

Several studies explored the use of immersive virtual reality (VR) environments to simulate earthquake scenarios and enhance behavioral preparedness. For instance, Feng et al. (2020) (Study 5), Lovreglio et al. (2018) (Study 8) (Figure 2) and Zhou et al. (2020) (Study 14) developed VR-based serious games to increase users' situational awareness and improve their evacuation responses through high-fidelity simulation. These applications often targeted adult populations such as hospital staff or university students and emphasized spatial realism and emotional engagement. Maragkou et al. (2023) (Study 7) focused on user experience within immersive systems, while another study by Feng et al. (2020) (Study 9) evaluated VR's role in reinforcing knowledge of evacuation procedures. Although these works highlight the value of VR in disaster training, they often lack consideration of multi-user dynamics and realistic social interactions.



Figure 2: A tester seated on the vibrating platform. (Lovreglio et al., 2018)

A smaller but significant group of studies examined mobile-based disaster education, particularly for younger learners. Winarni et al. (2018) (Study 4) developed an Android-based educational game to familiarize elementary students with earthquake preparedness through a multi-stage structure (before, during and after an earthquake). Similarly, Çoban and Göktaş (2022) (Study 13) compared digital games, traditional lessons and drills to assess their relative impact on motivation and learning. Both studies affirm the value of mobile serious games as accessible tools for early disaster education, though their behavioral complexity tends to be limited compared to immersive approaches.

Several studies emphasized instructional design and feedback mechanisms as core components of effective serious game-based learning. For example, Feng et al. (2023) (Study 2) investigated how spiral narratives and immediate feedback shaped users' understanding and performance. Another study by Feng et al. (2020) (Study 3) explored instructional scaffolding strategies in earthquake simulations. Yousefi et al. (2024) (Study 6) examined adaptive feedback systems and their impact on behavioral accuracy. Complementing these works, Çoban and Göktaş (2022) (Study 12) evaluated different instructional modalities and concluded that serious games can offer unique motivational advantages over traditional methods. Together, these studies suggest that pedagogical design elements are critical for shaping user engagement.



Figure 3: First training task. (Feng et al., 2023)

One study, Yousefi, Ahmadi and Ahmadi (2024) (Study 11), explored behavioral decision-making and social dynamics in simulated evacuation scenarios. This work investigated how individuals react to peer behavior, authority cues and spatial familiarity during earthquakes. The findings emphasize the importance of modeling realistic social interactions and behavioral variability in serious game environments—an area that remains underexplored in most existing training tools.

Finally, two studies focused on accessibility and inclusive design in evacuation training games. Abdulhalim et al. (2021) (Study 1) proposed a conceptual framework tailored to the needs of deaf and hard of hearing children, integrating visual cues and scenario-based learning to enhance preparedness. Yamamoto et al. (2019) (Study 10) stressed the importance of familiar spatial contexts in improving students' recognition and decision-making during VR-based training. These studies underscore the need for equity-oriented design approaches in serious game development to ensure that diverse populations can benefit from game-based disaster education.

4. Discussion and Conclusion

The findings of this review reveal that serious games have emerged as valuable tools for enhancing earthquake evacuation preparedness. Most of the reviewed studies demonstrated promising outcomes in terms of improving behavioral responses, increasing situational awareness and fostering disaster knowledge retention.

However, 3 critical gaps and limitations were consistently observed across the current body of research:

1. Limited Integration of Behavioral and Social Dynamics in VR Environments

A major limitation lies in the overreliance on architectural and environmental realism through immersive virtual reality (VR) technologies (Study 5, Study 7, Study 8, Study 9, Study 14). While these studies successfully employed high-fidelity VR environments to replicate post-earthquake conditions and stimulate emotional engagement, they often underexplored the behavioral and social dimensions of evacuation. Most simulations focused on spatial environments or individual responses, with limited incorporation of theoretical behavioral frameworks such as social influence theory, group coordination models or cognitive decision-making processes. The absence of a robust socio-cognitive layer in these game designs indicates a critical research gap, particularly in simulating complex human behavior during emergencies.

2. Lack of Multiplayer Functionality Reflecting Group-Based Evacuation Scenarios

All of the reviewed serious games were designed for single-player experiences. This widespread design choice neglects the essential role of peer interaction, leadership emergence and collective decision-making—elements that are fundamental to real-world evacuations. Earthquake response is inherently social and context-dependent, where individuals observe, follow or resist group behavior patterns. The lack of multiplayer mechanics results in a significant disconnect between the training environment and the reality of disaster scenarios. This suggests the urgent need for a paradigm shift toward multiplayer serious game formats that capture emergent group dynamics and foster collaborative learning experiences.

Despite the clear relevance of multiplayer dynamics in real-world earthquake evacuations, the reviewed literature mostly focused on single-player experiences. This trend may be attributed to several converging factors. From a technical perspective, implementing real-time multiplayer interactions in immersive environments—particularly VR—presents significant challenges, including synchronization of user behaviors, maintaining communication and preserving immersion across systems. Studies such as Lerner et al., (2020) and Freina et al., (2015) emphasize that multi-user VR systems demand advanced infrastructure and often encounter limitations in scalability and stability. Pedagogically, modeling collaborative decision-making and emergent group behavior under emergency conditions adds another layer of complexity, requiring interdisciplinary frameworks that integrate behavioral science, learning theory and interaction design. Consequently, many studies may have prioritized single-user designs for feasibility and experimental control, inadvertently reinforcing a gap in the literature. This disconnect between real-world social evacuation dynamics and current training game designs highlights the need for new approaches that can effectively integrate multiplayer capabilities into immersive serious games.

3. Limited Consideration of Role Allocation and Behavioral Pattern Formation

This limitation is not entirely independent; rather, it is closely interrelated with the two previously mentioned gaps. The limited consideration of dynamic aspects of evacuation behavior such as role allocation (e.g., leader, follower), timing of responses and behavioral pattern formation under stress further compounds the shortcomings of VR realism and single-player design (Study 11). While a few studies allude to the importance of

behavior adaptation during emergency conditions, the training scenarios rarely model the evolving interpersonal roles that naturally occur in evacuation settings. This gap is especially notable given that leadership, hesitation, following behavior or peer influence often determine the effectiveness of an evacuation. Role dynamics must be better represented in future game-based training tools particularly in multiplayer environments that can accommodate such complexity.

Based on these findings, future work should focus on designing a new generation of multiplayer serious games that integrate social behavioral theories, adaptive decision-making frameworks and dynamic evacuation modeling. Our next step will be to develop a prototype multiplayer serious game designed specifically for earthquake evacuation preparedness. This game will incorporate dynamic role differentiation, social influence mechanisms, and real-time group decision-making challenges. The design process will adopt an iterative development model involving continuous testing, player feedback collection, and refinement cycles to ensure both educational effectiveness and behavioral realism. By introducing this new multiplayer-focused approach, we aim to contribute to a paradigm shift in disaster preparedness training, bridging the current gap between environmental simulation and social behavior modeling in serious games.

Ethical Declaration: The ethical clearance was not required for this research as it involved a systematic review of published literature without direct involvement of human participants.

AI Declaration: AI tools (ChatGPT) were used during the preparation of this paper to assist with language refinement, content organization and academic writing support. All critical analysis, thematic synthesis and interpretations were conducted by the author.

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Bridging Theory and Practice: Evaluating a Game-Based VR Approach in Construction Education

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Abstract: Using Virtual Reality (VR) in design education has become a more popular and innovative way to teach. Learning environments that use VR can increase engagement, improve spatial awareness, and create immersive experiences that connect theoretical knowledge with practical application. However, even with these benefits, the usefulness of virtual reality in construction education is still an area that needs to be studied more. This study investigates the process of moving from concept to practice in the development and initial evaluation of a game-based virtual reality application that is intended to help interior architecture students learn the basic concepts of construction. The purpose of the research is to find out how students view the VR game in terms of usability, engagement, and instructional effectiveness, as well as to identify areas that could be improved. Five interior architecture students participated in a pilot study in which they played with the VR game and offered feedback using post-experience surveys and semi-structured interviews. Thematic analysis of responses from participants concluded that the use of VR enhanced interactive learning, spatial understanding, and learner motivation. Yet some limitations were found, namely the need for more explicit guidance in the game, improved readability of text, and clearer navigation flow. These findings are enlightening empirically regarding the actual application of VR in construction education, validating the need for iterative design cycles and user-centered development. The study highlights the role of student feedback in enhancing educational VR tools and offers insights to educators, instructional designers, and developers who are looking to integrate immersive technologies into construction education programs. By examining the educational potential and design limitation of this VR game-based method through analysis, this study aims to enhance the enhancement of interactive learning environments in the interior architecture courses.

Keywords: Virtual reality, Game-Based learning, Construction education, Interior architecture education

1. Introduction

Virtual Reality (VR) has emerged as a pioneering tool in design education, providing experiential learning that is generally unattainable through traditional techniques. It has been widely utilized across various disciplines to enhance students' spatial comprehension, augment engagement, and illustrate practical applications of theoretical concepts. By facilitating user interaction and navigation inside three-dimensional environments, VR allows students to bridge the divide between theory and practice, especially in fields like architecture and design, where spatial intelligence and practical expertise are paramount.

The utilization of VR in the instruction of construction, particularly in interior architecture, is garnering growing interest. Given that interior architecture necessitates both design and technical expertise, virtual reality offers a unique opportunity to enhance the understanding of construction materials, structural systems, and design principles in a way that traditional methods such as drawings or lectures cannot facilitate. Game-based VR applications possess the capacity to engage students actively, offering interactive experiences that allow them to navigate building structures, tactilely interact with materials, and imitate construction processes. Such experiences allow students to acquire theoretical knowledge and apply it in practical contexts, hence enhancing the learning process.

This study aims to assess interior architecture students' perceptions on the usability, engagement, and instructional efficacy of a game-based VR tool. This research seeks to evaluate the experiences of students who employed the VR tool to ascertain the strengths and limitations of the VR game, ultimately determining its potential to enhance construction education. The ultimate goal is to assess if this VR technique effectively bridges theory and practice in building education, providing a more immersive and engaging experience for aspiring interior architects.

Given the small sample and context-specific nature of the study, findings should not be interpreted as generalizable but rather constructed to provide intensive insights into early-stage development and usability of the VR tool. As a qualitative case study, richness of participants' perspectives takes priority over statistical representation. Future research should investigate the long-term impacts of VR-based learning on information retention and its comparison to conventional approaches. Extending the research to encompass a broader and more heterogeneous student demographic might yield more substantial data regarding the VR tool's efficacy across various educational contexts.

2. Method

This study takes a qualitative case study approach to evaluate a game-based virtual reality (VR) application for the improvement of learning basic construction principles among interior architecture students. The research design includes a pilot trial with semi-structured interviews to obtain rich data regarding the usability, user engagement, and teaching effectiveness of the application. Participants' comments were evaluated using thematic analysis to enable the identification of repeated themes and areas of improvement.

2.1 Research Design and Approach

A preliminary research was undertaken to assess the initial iteration of the VR game. Thematic analysis was utilized to understand participant feedback obtained from interviews and surveys. This enabled the researchers to discern patterns, difficulties, and recommendations concerning the VR tool's efficacy in achieving instructional objectives.

2.2 Participants and Data Collection Methods

Although the main study is to be carried out with second-year interior architecture students, the pilot study which is the main topic of this research, was done with five fourth-year students who volunteered to participate. This was selected because they were comparatively higher in their knowledge level regarding construction practices and course materials, which was expected to give more precise and constructive comments in the testing phase. Their prior experience with various aspects of design education well prepared them to critically examine the VR tool and its pedagogical potential. The outcomes of this pilot group were considered worthwhile for refining the tool before implementing it with the target group.

Data was gathered using a semi-structured interviews. Semi-structured interviews let researchers to investigate participants' experiences and feedback comprehensively and gathering data on certain dimensions such as usability, engagement, and instructional efficacy. These dimensions were designed based on the Attitudes toward Virtual Reality Technology Scale (AVRTS) by Bunz, Seibert, and Hendrickse (2021). To measure the attitudes of participants in relation to the VR tool, the items were categorized under three broad dimensions found in the AVRTS model: Ease of Use, Usefulness, and Enjoyment. The Ease of Use dimension assessed how intuitive and user-friendly the VR system was perceived to be; Usefulness evaluated the extent to which the students believed the tool supported the achievement of learning objectives; and Enjoyment evaluated the level of intrinsic motivation and enjoyment obtained from the VR activity. This categorization provided a structured framework for investigating the effectiveness and user acceptance of the VR-based learning tool.

2.3 Development of the VR Game

The VR game utilized in this study was developed as a game-based educational instrument for interior architecture students to investigate and comprehend essential construction materials and procedures. The game seeks to connect theoretical knowledge with practical application, enabling students to engage with virtual construction sites and materials. The program includes features such as 3D modeling of construction components, color-coded walls, interactive jobs, and a navigation system utilizing teleportation. The creation of the VR game involved several software processes and tools aimed at the precise presentation of design as well as complete integration into virtual space. First, precise 2D technical drawings for the construction parts were created through AutoCAD to form a working blueprint for digital models. Then, SketchUp was applied to convert these 2D drawings into 3D models, where more detailed structural pieces, materials, and spatial conditions were created. Finally, the 3D models were imported into Unreal Engine 5.5, where the game environment was built, the interaction was coded, and VR functionality was integrated in a way that provided users with an immersive and interactive learning experience. The primary objectives of the game were to:

- Augmenting students' spatial understanding of construction materials and structures.
- Creating an engaging environment consist of 8 different rooms, that allows students to interact with various construction materials, such as gypsum, brick, reinforced concrete, and Ytong.
- Promoting engagement using game-based learning methodologies while upholding educational integrity.

3. Literature Review

Literature review of this study will concentrate on three primary domains: game-based learning (GBL) in education, the function of virtual reality (VR) in design and construction education, and the obstacles related to the use of VR in educational environments. The discourse on GBL will emphasize its efficacy in enhancing student

engagement, motivation, and knowledge retention, especially within technical and design fields. This study will examine the incorporation of VR in construction education regarding its capacity to augment spatial awareness, promote experiential learning, and boost understanding of intricate architectural and structural principles. The limitations of virtual reality in education, including accessibility, usability concerns, cognitive overload, and the necessity for pedagogically robust content, will be addressed. This review will enhance the study by situating the VR-based building learning experience within current research, delineating its possible advantages and drawbacks, and establishing a basis for assessing its practical applications in interior architecture education.

3.1 Game-Based Learning in Education

Game-based learning (GBL) is increasingly acknowledged as an excellent educational method that improves student engagement, motivation, and knowledge retention. Research demonstrates that GBL utilizes interactive and immersive experiences to establish significant learning settings, especially in disciplines necessitating complex problem-solving and critical thinking abilities (Gee, 2003). Through the integration of game mechanisms including challenges, rewards, and progression systems, Game-Based Learning (GBL) cultivates intrinsic motivation and prolonged engagement, which are frequently challenging to attain in conventional educational environments (Malone & Lepper, 1987). Prensky (2001) contends that digital game-based learning corresponds effectively with the cognitive and behavioral tendencies of contemporary learners, who are familiar with interactive digital settings. This methodology has been extensively utilized across various fields, such as STEM education, language acquisition, and vocational training, exhibiting notable enhancements in both immediate engagement and sustained information retention.

The utilization of game-based learning in architectural and construction education is increasingly recognized, as it enables students to actively engage with spatial concepts, design principles, and structural problem-solving within a virtual context (Ebner & Holzinger, 2007). Research indicates that incorporating game aspects into virtual reality (VR)-based construction education improves spatial cognition and facilitates experiential learning, hence connecting theoretical knowledge with practical application (Rupp et al., 2019). Moreover, studies indicate that game-based learning (GBL) in virtual reality (VR) environments fosters active engagement and prompt feedback, both essential for skill enhancement in technical and design disciplines (Chang et al., 2017). Notwithstanding these benefits, difficulties persist in reconciling entertainment with educational goals, guaranteeing that the gaming elements enhance rather than detract from learning outcomes (Hamari et al., 2016). As GBL progresses, further research should concentrate on enhancing instructional design, evaluating long-term knowledge retention, and improving adaptive learning systems to tailor experiences for diverse learner profiles.

3.2 Virtual Reality in Design and Construction Education

Virtual Reality (VR) has emerged as a powerful tool in design and construction education, providing immersive, interactive, and experiential learning environments that enhance spatial awareness and practical understanding of architectural and structural concepts. Research has demonstrated that VR enables students to engage with complex spatial relationships and construction techniques that are difficult to grasp through traditional two-dimensional representations (Wojtowicz, 2001). Unlike conventional teaching methods, VR-based learning allows users to experience scaled environments, manipulate digital models, and simulate real-world construction processes, leading to improved comprehension and knowledge retention (Whyte, 2002). Moreover, VR fosters active learning by enabling students to visualize and experiment with structural designs before applying them in real-world scenarios, reducing errors and improving design efficiency (Bouchlaghem et al., 2005). This experiential aspect is particularly beneficial in architectural and construction education, where understanding spatial relationships, material properties, and construction sequences is critical (Sampaio et al., 2010).

The integration of VR into construction education has also been linked to increased student motivation and engagement, as interactive simulations provide a dynamic alternative to traditional classroom-based instruction (Le et al., 2015). Studies indicate that VR-based construction training enhances skill acquisition and safety awareness, offering students a risk-free environment to practice construction techniques and safety protocols (Li et al., 2018). Additionally, VR facilitates collaborative learning, allowing students and professionals to engage in real-time design modifications and problem-solving exercises within shared virtual spaces (Meža et al., 2015). Despite these advantages, challenges remain in terms of accessibility, hardware limitations, and the need for pedagogically sound VR content that aligns with curriculum objectives (Pedro et al., 2020). Future research should focus on optimizing VR applications for construction education by exploring adaptive learning models, improving user interfaces, and assessing long-term learning outcomes in real-world professional contexts.

3.3 Challenges and Limitations of VR in Education

Although Virtual Reality (VR) provides several benefits in education, its deployment entails multiple obstacles and constraints that must be resolved to enhance its efficacy. A primary challenge is accessibility, as virtual reality technology necessitates specialized hardware, such as head-mounted displays (HMDs), motion controllers, and high-performance processors, which can be expensive and impose financial obstacles for institutions and students (Radianti et al., 2020). The learning curve of VR interfaces may provide challenges, especially for students unaccustomed to immersive surroundings. Certain studies indicate that although younger students generally acclimate to virtual reality swiftly, others may encounter usability challenges, resulting in frustration and disengagement (Hew & Cheung, 2010). A significant difficulty is the potential for cognitive overload; when learners encounter excessive information or extremely intricate interactions, they may find it difficult to absorb and remember knowledge efficiently (Parong & Mayer, 2018).

4. Data Analysis

This section delineates the principal findings derived from the thematic analysis of participant input collected after VR experience, via semi-structured interviews (Figure 1). The examination concentrates on three primary domains: usability, engagement, and instructional efficacy. Furthermore, prevalent challenges and recommendations for enhancement derived from participant input are encapsulated.

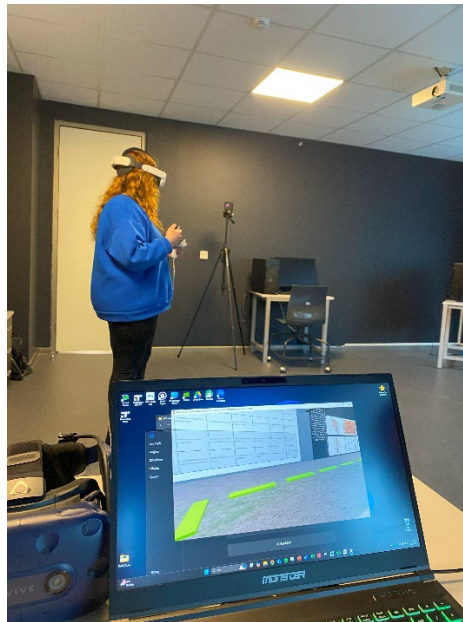


Figure 1: A Participant's experience during the study

4.1 Usability: Ease of Navigation, Interaction with Controls, and User Interface

Participants deemed the VR game user-friendly after acclimating to the controls. The navigation system, especially the teleportation function, was commonly perceived as user-friendly and straightforward. A participant remarked,

P1: "After familiarizing myself with the buttons and their functions, manipulating objects and navigating became rather instinctive." This signifies that the learning curve for utilizing the controls was comparatively brief, allowing participants to acclimate swiftly to the VR environment.

Nevertheless, certain individuals experienced slight difficulties concerning their accuracy in navigating the virtual environment. A participant stated,

P2: "I encountered challenges in comfortably attaining my desired position," indicating that while navigation was straightforward, there were intermittent difficulties in establishing precise control over movement. The interface design was largely regarded as clear; nevertheless, some users indicated a requirement for more explicit instructions concerning the movement mechanics, particularly during the initial phase of the experience (Figure 2).

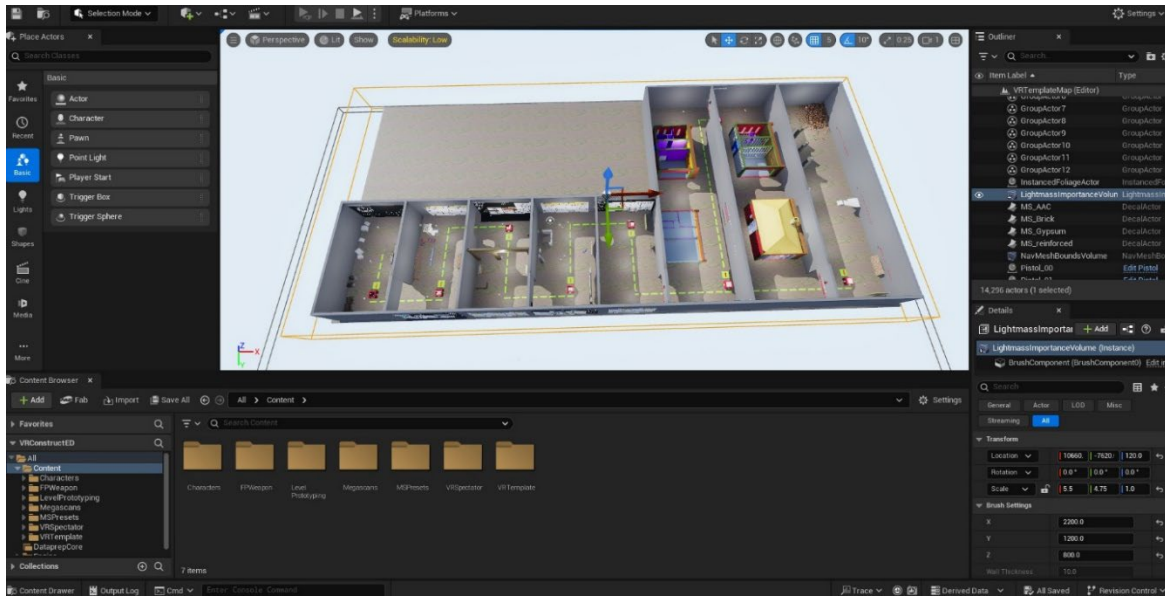


Figure 2: Screenshot from the VR game, Unreal Engine 5.5 editor

4.2 Engagement: Participant Motivation and Level of Immersion in the VR Game

The immersive quality of the VR environment significantly contributed to maintaining participant engagement throughout the encounter. A participant remarked,

P3: "I was fully engaged for the entire duration," emphasizing that the absence of phone access or interruptions facilitated continuous concentration. This demonstrates that the VR game effectively sustained player engagement and reduced external distractions. They also observed that the feeling of immersion improved their educational experience. The capacity to navigate the environment and interact with structural components enhanced engagement significantly. One attendee remarked,

P4: "Experiencing the plan and its elevation at full scale was genuinely impressive and uplifting." This indicates that the VR game successfully cultivated motivation by providing a dynamic and participatory experience that was both informative and pleasurable (Figure 3).



Figure 3: Screenshot from the VR game, Unreal Engine 5.5 editor

4.3 Instructional Effectiveness: Conveying Construction Concepts and Facilitating Learning

The VR game was widely regarded as an efficient medium for communicating construction principles. Participants valued the opportunity to examine materials and construction methods in three dimensions. A participant remarked,

P1: "Seeing how each structural element was constructed step by step was highly effective. Then, we examined two different building masses—one in the early construction phase and the other in a fully completed state. This transition process was particularly valuable as it made it easier to understand the different stages of construction." This suggests that the immersive quality of VR significantly improves the comprehension of construction concepts compared to conventional techniques.

Nonetheless, there were apprehensions over the comprehensiveness of the material presented. A participant remarked,

P2: "It requires greater detail, as the current information fails to adequately convey meaning, particularly for those unfamiliar with the topic." (Figure 4). This response indicates that although the VR tool effectively introduced construction materials and concepts, it required more comprehensive explanations, particularly for individuals less acquainted with the area.

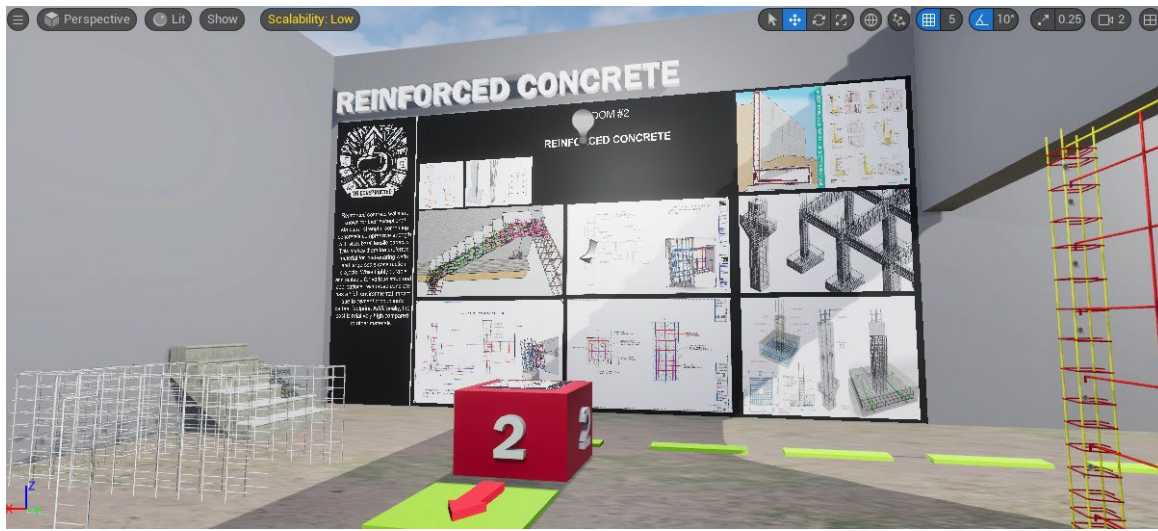


Figure 4: Screenshot from the VR game, Unreal Engine 5.5 editor

4.4 Specific Areas of Improvement Derived from Participant Feedback

There were some development areas that were identified by the participants. They include:

- **In-Game Instructions:** Players recommended providing more instructions and interactive features throughout the game. For instance, a player recommended, "I think that each room should have clear instructions on what is to be done there." (P3). This indicates that more formal in-game instruction would enable users to comprehend the task and navigate the experience more easily.
- **Text Readability:** A persistent issue was that text was difficult to read, particularly when seen from a distance. As one user commented, "I had trouble reading the text. This might have added to my eye strain." (P4). Better placement and sizing of text and more readable fonts would enhance the readability of the system and make it more usable.
- **Navigation Flow:** A few of the participants found the navigation flow confusing, especially where they needed to move from one area of the VR space to another. One participant commented, "I was wondering if there was going to be a final room where I could use the object that I was carrying." (P5). This indicates that a more structured path with more instructions on where to proceed next would enhance the flow of the experience and avoid confusion.
- **Interactive Tasks and Material Choice:** A number of participants recommended incorporating more interactive tasks to enhance the learning experience. For instance, one participant recommended, "Rather than a quiz at the end, little interactive tests or tasks could be inserted into each room in order to provide ongoing learning." (P1). This would work to keep students engaged throughout the experience and provide more interactive, hands-on learning (Figure 5).
- **Material Details:** The second key area of improvement was the addition of more information on material details. As one of the users put it, "The game has to include more detail when it comes to materials and use." (P3). Adding more in-depth material regarding the nature, durability, and use of various building materials can enhance the learning potential of the VR tool.

The findings indicate that although the VR game offered significant learning opportunities, there are aspects that require improvement to align the tool with educational goals and enhance the user experience.



Figure 5: Screenshot from the VR game, Unreal Engine 5.5 editor

5. Discussion and Conclusion

This study's findings offer significant insights into the efficacy of a game-based VR strategy in improving construction instruction, especially for interior architecture students. The VR game was created to connect theoretical knowledge with practical application through an immersive learning experience. Participant feedback underscores several critical elements pertinent to this purpose, revealing both the strengths and opportunities for enhancement in the VR tool.

5.1 How Does the VR Game Contribute to Bridging Theory and Practice in Construction Education?

The principal objective of this VR tool was to simulate an environment that accurately reflects real-world construction processes, allowing students to engage with construction materials and techniques in a virtual setting. The game effectively enabled students to envision and manipulate materials like as gypsum, brick, reinforced concrete and Ytong in three-dimensional space, a feat sometimes challenging to accomplish using conventional teaching techniques like textbooks or lectures. This immersive experience facilitated students in establishing concrete connections between theoretical knowledge and practical applications, corroborating previous studies that highlight the capacity of VR to improve spatial understanding and real-world application in design and construction education.

Participants observed that the capacity to examine construction materials at full scale and engage with them in real-time offered a deeper, more significant comprehension of construction processes than conventional teaching approaches. A participant remarked,

P2: "If presented with a construction textbook and the chance to engage with the same content in VR for 20 minutes, I would acquire considerably less knowledge from the book than from the VR experience." This finding supports research demonstrating that immersive VR environments improve learning outcomes by facilitating experiential learning opportunities.

5.2 The Effectiveness of Game-Based VR in Improving Spatial Comprehension and Motivating Students

Game-based virtual reality has demonstrated the enhancement of spatial understanding by allowing students to engage with a constructed environment in three dimensions. The participants in this study indicated that the VR game enabled them to perceive construction details with spatial accuracy, hence improving their capacity to conceptualize and comprehend the construction process. The color-coded walls, three-dimensional representations, and interactive components significantly aided students in comprehending scale and structure, hence enhancing their grasp of construction materials and techniques.

Moreover, the immersive quality of the VR game was important in sustaining student motivation. One participant remarked,

P3: "I was completely engaged throughout the entire duration... I was unable to check my phone, which guaranteed my full immersion in the experience." This supports existing evidence about the beneficial effects of VR's immersive features on student engagement and motivation. By eliminating prevalent distractions and offering an engaging educational setting, VR fosters student concentration and engagement during the learning experience.

5.3 Evaluation of the Usability of the VR Tool: What Worked Well?

The VR game was predominantly acclaimed for its usability. The teleportation system and intuitive interface design were commended for their user-friendliness, enabling students to traverse the virtual environment with minimal exertion. Participants reported feeling immersed and motivated throughout the experience, emphasizing that the interactive elements helped reinforce their understanding of construction concepts. One participant noted that "learning through doing" in the VR setting contributed to greater retention of information. Nonetheless, certain usability issues arose, especially concerning text legibility and interaction accuracy. Participants reported challenges in reading text, especially from a distance, with one individual stating,

P4: "I had difficulty reading the text...this might have contributed to my eye strain." Improving text clarity, font size, and accessibility may enhance the user experience, particularly for students with diverse visual abilities.

Moreover, although the movement and navigation technology was intuitive, certain participants encountered challenges in precisely situating themselves within the VR scene. This problem was particularly evident when trying to engage with specific materials or interact with finer details. The identified usability difficulties indicate that enhancing the user interface and interaction design would augment overall accessibility and user happiness with the VR game.

This study's findings indicate that VR tools can substantially improve the learning experience in construction education by offering an interactive, immersive, and engaging environment for students. Instructional designers can include these VR components into construction education curriculum, especially for elucidating spatially complex concepts such as material qualities, construction processes, and structural design.

To enhance the efficacy of VR technologies in construction education, it is imperative that designers prioritize the development of clear, structured experiences that systematically guide students through the learning process. This entails guaranteeing that in-game advice is readily accessible, offering explicit instructions and engaging exercises to enhance learning, and including real-time feedback systems to assist students in identifying errors and rectifying them.

Furthermore, VR tools need not to supplant conventional learning techniques totally. Participants emphasized that the integration of theoretical knowledge, practical application, and VR-based learning provides a more holistic educational experience. Consequently, VR need to be regarded as an ancillary instrument that augments, rather than supplants, conventional techniques such as lectures and illustrations.

5.4 Suggestions for Improving the VR Game Based on Student Feedback

The players identified several areas in which they felt there could be improvement within the VR experience, including a demand for more in-game guidance, particularly in the beginning, to help less skilled VR players navigate more easily. Text legibility was another area of concern, as presenting all material information in an easily readable format from a distance with improved font size, well-spaced text positions, and contrasting colors would ensure maximum accessibility. Navigation also had to be improved, and possibilities were to include a more structured process of advancement through color-coded instructions or signs so the learners proceeded in a more automatic manner. More interactive material with entertaining little quizzes or assignment types scattered in between rooms rather than the central final test also came in suggestion for maintaining learner interest as well as reinforcing learned material. They also requested detailed descriptions of building materials, suggesting additional information on the durability of the materials, sound insulation, and how they would be used in various building practices. Immediate feedback on building work was another suggestion, where the users would receive immediate feedback regarding the accuracy of their material positioning, thereby building up their skills in building practice. Designing the spatial structure of the VR environment was also considered significant, as changing room size and configurations could reduce disorientation and maximize focus. Finally, incorporating haptic feedback, e.g., vibrations during the manipulation of materials or tools, was proposed to increase immersion and provide a better three-dimensional understanding of construction procedures.

Iterative design processes and user testing are crucial in developing educational VR instruments. As this example illustrates, continuous testing and evaluation with real users are necessary for determining any problems and

making appropriate modifications. Incorporating user feedback in the design process enables developers to make sure that the VR experience is aligned with students' educational needs and maximize its impact. By continuously refining with the help of user feedback, VR tools can be made increasingly intuitive, interactive, and learning-oriented, enabling them to be as effective a learning aid as possible. Overall, though the VR app that has been examined is found to be promising for application in the context of construction education, ongoing development and creation of additional features will enable it to reach its full potential regarding learning. The incorporation of game-based learning and VR into curricula can have the potential to transform interior architecture and construction teaching by enabling students a better, more immersive understanding of the nature of construction concepts.

Ethics Declaration: This study involved voluntary participation from interior architecture students who provided feedback on a VR-based educational tool through semi-structured interviews. All participants were informed about the purpose of the study and gave their consent before taking part. No personal or sensitive data was collected, and responses were anonymized to protect participant privacy. As the study did not involve medical, psychological, or personally sensitive topics, formal ethical approval was not required according to the guidelines of Bahcesehir University. However, all research procedures were conducted in accordance with ethical principles for human subject research, ensuring transparency, confidentiality, and voluntary participation.

AI Declaration: This work utilized OpenAI's ChatGPT as a tool for language translation, content categorization, and topic synthesis. The AI tool facilitated the translation of participant responses from Turkish to English. Furthermore, although the thematic analysis of participant replies was performed manually, the AI technology was utilized to detect commonly referenced concepts and persistent motifs. The AI-generated content was not utilized directly in the final manuscript. It functioned as an initial framework for organizing the debate, pinpointing essential insights, and ensuring coherence in the presentation of participant comments. All interpretations, conclusions, and scholarly contributions were formulated by the authors based on the gathered data and pertinent literature.

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Implementing Tabletop Role-Playing Games for Workplace Learning: The ADVENTURE Framework in Practice

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Abstract: Organizations seek innovative approaches to develop collaborative competencies among knowledge workers, yet traditional corporate training often fails to address complex social and cognitive skills required in modern team-based work environments. This paper presents the practical implementation of the ADVENTURE framework, demonstrating how tabletop role-playing games (TTRPGs) can systematically enhance workplace learning through structured intervention design. TTRPGs offer unique advantages through cooperative storytelling, shared problem-solving, and reflective practice, creating immersive learning experiences that mirror real workplace challenges while maintaining high engagement levels. The absence of systematic implementation frameworks for professional contexts has constrained their adoption in organizational learning programs. The ADVENTURE framework addresses this gap by providing evidence-based methodology for designing, implementing, and evaluating TTRPG interventions in workplace settings. The framework integrates Self-Determination Theory with European LifeComp competencies through a three-level architecture encompassing theoretical foundations, operational implementation, and stakeholder engagement. This comprehensive approach ensures theoretical rigor while providing practical flexibility for diverse organizational contexts. The Adventurer's Diary assessment methodology captures learning processes and group dynamics through structured reflection prompts aligned with autonomy, competence, and relatedness needs, enabling systematic evaluation of competency development. Implementation involves knowledge worker teams engaging in four weekly TTRPG sessions designed to progressively mirror workplace challenges within fictional contexts that promote collaborative problem-solving and adaptive thinking. Game systems emphasizing collaborative narrative construction are selected using systematic criteria, with scenarios increasing in complexity and requiring sophisticated decision-making strategies. The five-phase implementation methodology guides practitioners from initial assessment through competency integration, ensuring systematic application while accommodating organizational constraints. Data collection integrates pre-post competency assessments, behavioral observations, and diary-based reflections using multiple methodologies to ensure comprehensive evaluation. Anticipated outcomes include improvements in LifeComp competencies, particularly collaboration, communication, and learning-to-learn skills, enhanced team dynamics, increased engagement, and measurable transfer of competencies to workplace contexts. Practical contributions include systematic game selection criteria, structured facilitation guidelines, comprehensive assessment protocols, and implementation guidance addressing organizational challenges. This work demonstrates that TTRPGs, when systematically implemented through frameworks such as ADVENTURE, may offer viable alternatives to traditional training methodologies while providing engaging approaches to developing workplace competencies, with implications for organizational learning and development practice.

Keywords: Workplace learning, Tabletop role-playing games, Competency development, Experiential learning, Team training, Implementation framework

1. Introduction

Contemporary organizations face unprecedented challenges in developing collaborative competencies among knowledge workers. Traditional corporate training approaches, while structured and measurable, often fail to address the complex social and cognitive skills required in modern team-based work environments. The need for innovative learning methodologies that can effectively develop collaboration, communication, and adaptive thinking skills has become critical for organizational success (Abersek et. al., 2023; Harari, 2018; Morin, 2008; Sim & Nicolaides, 2024).

Tabletop role-playing games (TTRPGs) present a unique opportunity to address these challenges through their inherent characteristics of cooperative storytelling, shared problem-solving, and reflective practice. However, the systematic implementation of TTRPGs in professional contexts requires structured frameworks that can bridge the gap between game-based learning theory and practical workplace application (Haarman, 2022; Markiewicz et al., 2024).

The ADVENTURE framework was developed to address this implementation gap by providing evidence-based methodology for designing, implementing, and evaluating TTRPG interventions in workplace settings. The theoretical foundations of the ADVENTURE framework, presented in detail elsewhere (Capobianco & Manganello, 2025), integrate four key theoretical perspectives

- Firstly, we consider Self-Determination Theory (autonomy, competence, relatedness) (Deci & Ryan, 2001), since in TTRPGs, these needs manifest through the ludic architecture's foundations. Players autonomously decide their character's behavior and influence the narrative (autonomy); overcome narrative challenges through individually or collectively conceived strategies requiring creativity (competence).
- Secondly, we introduce LifeComp Framework (personal, social, and learning-to-learn competences) (European Commission, 2020), which identifies essential life competencies for personal fulfillment, active citizenship, social inclusion, and employment (Pellegrini & Vitali, 2023). These competencies align naturally with TTRPG mechanics, where players must adapt to unexpected situations, collaborate effectively, and continuously learn from both successes and failures.
- Thirdly, we propose a pedagogical perspective articulated into three sub-dimensions, that are: 1) the heutagogical learning model (Hase & Kenyon, 2000) serving as our primary pedagogical reference. The heterogeneity of TTRPGs aligns with non-linear and personalized training possibilities. This creates superior engagement and intrinsic motivation, as individuals are free to solve problems according to their interests. This freedom has been readily associated with the creative liberty to manage one's learning that TTRPGs can provide; 2) TTRPGs propose "disorienting dilemmas" (Mezirow, 2003) that lead to critical reflections on one's assumptions, resulting in new configurations of interpretive systems. Players experience and make mistakes in complete autonomy, being challenged to find critically different approaches to ever-new situations. We operate between Bateson's second level and third (Bateson, 1973): modifications in decision-making processes are actuated, as subjects redefine reference schemas among which to choose their actions, questioning their methods. This is a profound redefinition of cognitive paradigms regulating reality perception and involves "epistemic learning" that implies changing the very way of knowing and basic meta-assumptions (Fahrenbach & Kragulj, 2022); 3) cooperative learning: TTRPGs are played in a relational decision-making context of exchanges and confrontations, where self-questioning is a reciprocal process. Everything happens in a cooperative context.
- Lastly, we considered neuroscience insights (neuronal patterns, neuroplasticity) and especially the game transfer phenomena), which describes how experiential game elements can influence perceptions and behaviors in daily life (Ali & Tan, 2022; Bowman & Schrier, 2018; Villalba, 2017). While the theoretical foundations of this framework are presented elsewhere (Author, 2025), this paper focuses on the practical implementation aspects, providing detailed guidance for practitioners seeking to integrate TTRPGs into organizational learning programs.

This paper presents the operational architecture of the ADVENTURE framework, with particular emphasis on intervention design, assessment protocols, and implementation guidelines. The contribution is primarily methodological, offering practitioners systematic approaches to TTRPG implementation that can be adapted across diverse organizational contexts.

2. The ADVENTURE Framework: Implementation Architecture

The ADVENTURE framework operates through a three-dimensional architecture that bridges theoretical foundations with practical implementation while addressing diverse stakeholder needs. This architecture encompasses the theoretical dimension, operational dimension, and stakeholder dimension, creating a comprehensive approach to TTRPG-based workplace learning.

2.1 Framework Overview

The theoretical foundations of the ADVENTURE framework, presented in detail elsewhere (Author, 2025), integrate four key theoretical perspectives: Self-Determination Theory (autonomy, competence, relatedness) (Deci & Ryan, 2001; Gupta & Goyal, 2022; Li et al., 2024), LifeComp Framework (personal, social, and learning-to-learn competences) (European Commission, 2020; Hoskins & Fredriksson, 2008; Pellegrini & Vitali, 2023), pedagogical approaches (heutagogy, transformative learning, cooperative learning) (Bateson, 1973; D'Souza, 2024; Fahrenbach & Kragulj, 2022; Hase & Kenyon, 2000; Mezirow, 2003; Stoten, 2020), and neuroscience insights (neuronal patterns, neuroplasticity, game transfer phenomena) (Ali & Tan, 2022; Bowman & Schrier, 2018; Villalba, 2017). These theoretical foundations inform all operational decisions while ensuring evidence-based implementation.

Game design principles embedded within the framework emphasize decision making, trial and error learning, and cooperation as core mechanisms for competency development. These principles translate into specific operational guidelines that inform scenario design, session facilitation, and assessment approaches.

Figure 1 illustrates the three-dimensional architecture of the ADVENTURE framework, showing the integration between theoretical foundations, operational components, and stakeholder considerations that guide practical implementation.

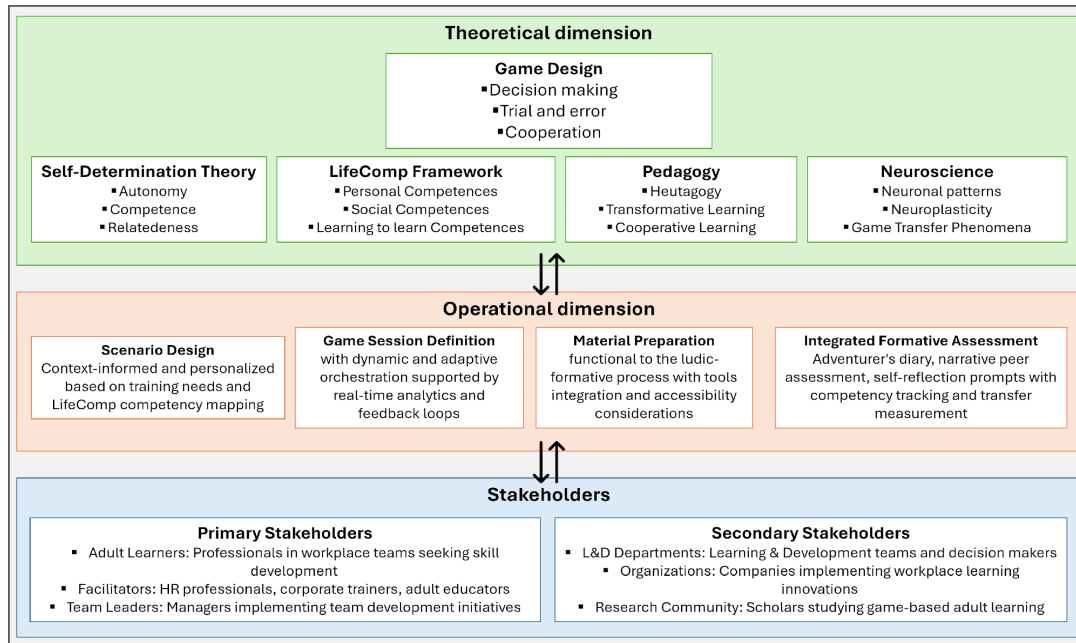


Figure 1: The ADVENTURE Framework Three-Dimensional Architecture

2.2 Three-Level Architecture

The operational dimension encompasses four core components that translate theoretical foundations into practical implementation. Scenario design involves context-informed and personalized approaches based on training needs and LifeComp competency mapping. Game session definition includes dynamic and adaptive orchestration supported by real-time analytics and feedback loops. Material preparation addresses functional requirements for the ludic-formative process with tools integration and accessibility considerations. Integrated formative assessment utilizes the Adventurer's Diary methodology, narrative peer assessment, and self-reflection prompts with competency tracking and transfer measurement.

The stakeholder dimension addresses both primary and secondary stakeholders essential for successful implementation. Primary stakeholders include adult learners (professionals in workplace teams seeking skill development), facilitators (HR professionals, corporate trainers, adult educators), and team leaders (managers implementing team development initiatives). Secondary stakeholders encompass Learning and Development departments, organizations implementing workplace learning innovations, and the research community studying game-based adult learning.

This three-dimensional approach ensures that implementation maintains theoretical rigor while providing practical flexibility for organizational adaptation and stakeholder engagement.

3. Systematic Game Selection and Preparation

3.1 Game Selection Criteria

The selection of appropriate TTRPG systems represents a critical implementation decision that significantly impacts learning outcomes. Dungeons & Dragons (D&D), for example, features complex gameplay divided by classes, species and abilities that deeply alter the experience with minimal variations. Players have an arsenal of solutions through parameters and narrative possibilities exploiting the game environment to solve complex situations. On the other side, Vampire - The Masquerade focuses heavily on social relations, political intrigue, and factional conflicts, rarely resolved through combat. There are no longer optimized statistics for creating characters with quantified characteristics, but abilities are registered in ten-sided dice pools whose successes

(6-10) give the Game Master an indication of action outcomes, not fixed resolution tied to numbers as in D&D. This makes combat and calculation-based strategies much less important, giving more space to player autonomy, their extradiegetic competencies and relationships among them. Yet another example could be *Fabula Ultima*, which encourages inexperienced users to intervene in narration and participate with the Game Master. It exploits the fabula points mechanic as a form of education in collective construction of diegetic environments and narrative elements (even during combat). Even bonds provide numerical bonuses, thus reinforcing cooperative dynamics.

Our framework establishes systematic criteria for game selection based on learning objectives, participant characteristics, and organizational context. Primary selection criteria include collaborative narrative emphasis, rules complexity appropriate for novice players, session duration compatibility with workplace scheduling, and thematic alignment with learning objectives. Game systems must prioritize cooperative storytelling over competitive elements, ensuring that learning occurs through shared narrative construction rather than individual achievement. Secondary criteria address practical implementation considerations including facilitator training requirements, material costs, and scalability across organizational units. The framework recommends game systems that require minimal specialized knowledge while providing sufficient structure to support meaningful learning experiences.

3.2 Scenario Development

Scenario development follows a structured approach that ensures alignment between fictional contexts and workplace learning objectives. Scenarios are designed to progressively increase in complexity while maintaining thematic coherence throughout the intervention period.

Each scenario incorporates specific competency development opportunities embedded within narrative challenges. The design process begins with competency mapping, identifying which LifeComp competencies will be addressed through particular narrative elements. Scenarios then integrate these competencies into storylines that require collaborative problem-solving and adaptive thinking.

The framework provides templates for scenario development that can be customized to organizational contexts while maintaining learning effectiveness. These templates include character development guidelines, conflict escalation patterns, and decision-making frameworks that facilitate competency development through gameplay.

3.3 Material Preparation

Implementation requires systematic preparation of learning materials that support both gameplay and assessment activities. Material preparation follows standardized protocols that ensure consistency across implementation sites while allowing for organizational customization.

Core materials include participant handbooks, facilitator guides, assessment instruments, and reflective practice tools. The participant handbook provides game rules, character development guidelines, and reflection prompts. The facilitator guide includes session plans, intervention protocols, and troubleshooting guidance.

Assessment materials encompass pre-intervention competency assessments, session observation forms, and post-intervention evaluation instruments. All materials are designed for ease of use by non-specialist facilitators while maintaining assessment rigor required for meaningful outcome evaluation.

4. Intervention Design and Session Structure

4.1 Five-Phase Implementation Methodology

The ADVENTURE framework follows a structured implementation process designed for workplace learning contexts, organized in five interconnected phases that ensure systematic application while maintaining flexibility for different organizational needs. The framework typically involves three to five workshop sessions of four to five hours each, allowing for deep engagement and meaningful competency development.

This flexible approach accommodates diverse organizational contexts, from intensive multi-day workshops to extended programs distributed over several weeks. The duration and frequency of sessions can be adapted based on participant availability, learning objectives, and organizational constraints while maintaining the integrity of the learning process.

The five phases ensure comprehensive implementation from initial assessment through long-term competency integration, with each phase building upon previous components while preparing for subsequent development activities.

4.1.1 Phase One: Pre-Assessment and game selection

The initial pre-assessment and game selection phase involves assessing team dynamics and learning objectives to establish a clear understanding of the target competencies and organizational context. This phase includes selecting the most appropriate TTRPG system based on organizational needs and participant experience levels, while establishing baseline measurements for target competencies that will serve as reference points for subsequent evaluation.

The assessment process examines existing team collaboration patterns, individual competency levels, and specific learning needs that will inform scenario design and facilitation approaches. Game selection follows systematic criteria that match system characteristics with learning objectives and participant characteristics.

4.1.2 Phase Two: Workshop series design

During the workshop series design phase, facilitators develop a comprehensive structure consisting of three to five workshop sessions. This phase encompasses creating scenarios aligned with learning objectives and workplace challenges, ensuring that the fictional elements resonate with real professional situations participants encounter. Simultaneously, facilitator materials and participant resources are prepared, including scenario guides, character creation templates, and assessment instruments.

Scenario development follows the framework's principles of progressive complexity increase while maintaining thematic coherence throughout the intervention period. Each workshop session is designed to build upon previous learning while introducing new collaborative challenges that require increasingly sophisticated problem-solving approaches.

4.1.3 Phase Three: Facilitated gameplay

The facilitated gameplay phase represents the core implementation period where sessions are conducted with trained facilitators who implement real-time observation protocols while supporting participant reflection through guided diary completion. This phase requires careful balance between maintaining game flow and capturing learning data, ensuring that assessment activities enhance rather than disrupt the immersive experience.

Sessions incorporate dynamic and adaptive orchestration supported by real-time analytics and feedback loops, allowing facilitators to adjust scenarios and challenges based on participant responses and learning progress. The gameplay experience emphasizes cooperative storytelling, shared problem-solving, and reflective practice as vehicles for competency development.

4.1.4 Phase Four: Assessment and reflection

The assessment and reflection phase involves systematic analysis of diary entries and observational data collected throughout the gameplay sessions. Focus group discussions are conducted to facilitate collective reflection and peer learning, while competency development is evaluated against baseline measures established in the initial phase. This comprehensive evaluation approach ensures both individual and group learning outcomes are captured and understood.

Multiple assessment methodologies are integrated including the Adventurer's Diary, narrative peer assessment, and self-reflection prompts with competency tracking. The assessment process addresses both formative learning during sessions and summative evaluation of competency development outcomes.

4.1.5 Phase Five: Transfer and integration

The final transfer and integration phase focuses on facilitating the transfer of learned competencies to actual workplace contexts through the development of concrete action plans for continued development. Follow-up assessment protocols are established to monitor long-term retention and application of developed competencies, ensuring that the learning experience produces lasting organizational value.

This phase includes specific activities designed to help participants identify workplace applications for developed competencies and establish support systems for ongoing skill enhancement. The transfer process is

supported by structured reflection on learning experiences and goal setting for continued competency development.

5. Assessment Protocols and Data Collection

5.1 Integrated Assessment Methodology

The ADVENTURE framework employs an integrated assessment methodology that captures learning processes and group dynamics through multiple interconnected approaches. This comprehensive system includes the Adventurer's Diary as the core methodology, complemented by narrative peer assessment, behavioral observations, and competency tracking measures that provide a holistic view of learning outcomes.

The integrated approach addresses both formative assessment during the learning process and summative evaluation of competency development. Multiple methodologies ensure triangulation of data sources while maintaining engagement through assessment approaches that align with the ludic-formative process characteristics of TTRPG experiences.

Assessment activities are designed to enhance rather than disrupt the immersive learning experience, utilizing tools that integrate naturally with gameplay while generating systematic data for both participant feedback and research evaluation purposes.

5.2 The Adventurer's Diary Component

The Adventurer's Diary serves as a central component within the integrated assessment methodology, capturing learning processes through structured reflection prompts aligned with Self-Determination Theory components. Based on diary study methodologies and reflective learning journals (Buranasinvattanukul, 2024; Miller, 2022; Rimmer, 2024), the diary serves as both a critical reflection tool for participants and an evaluation instrument for facilitators and researchers.

The diary methodology operates through reflection prompts structured according to SDT's three fundamental needs (autonomy, competence, and relatedness), ensuring systematic coverage of motivational aspects while maintaining connection to the ludic experience. Participants can autonomously choose when to complete diary sections, either during or after sessions, supporting the framework's emphasis on learner agency.

Reflection prompts are designed to be engaging and accessible while maintaining assessment rigor. Questions utilize gaming metaphors and narrative elements to encourage thoughtful reflection while generating data that can be systematically analyzed for learning outcomes and competency development patterns.

5.3 Narrative Peer Assessment and Competency Tracking

The framework incorporates narrative peer assessment as a complementary methodology that leverages the social and collaborative nature of TTRPG experiences. Participants provide structured feedback to peers about observed competency development, collaborative contributions, and learning growth throughout the intervention period.

Peer assessment protocols utilize narrative formats that align with the storytelling nature of TTRPGs while providing systematic data about social competencies and group dynamics. This approach captures perspectives that may not be visible through individual reflection or external observation alone.

Competency tracking integrates data from multiple sources including diary reflections, peer assessments, and facilitator observations to provide comprehensive monitoring of learning progress. The tracking system maps individual and group development against LifeComp competency frameworks while maintaining focus on learning transfer to workplace contexts.

5.4 Pre and Post-Intervention Assessment Protocols

Baseline assessment establishes initial competency levels and participant characteristics that inform both intervention customization and outcome evaluation. The protocol includes standardized LifeComp competency assessments that measure collaboration, communication, and learning-to-learn skills, providing quantitative baseline data that enable measurement of competency development throughout the intervention period.

Post-intervention evaluation includes competency reassessment using the same instruments administered at baseline, enabling measurement of competency development over the intervention period. Additional measures assess learning transfer intentions and self-reported application of developed competencies to workplace contexts.

The assessment protocol balances systematic data collection with practical feasibility for implementation in organizational settings, utilizing instruments that can be efficiently administered while generating data suitable for both individual feedback and program evaluation purposes.

6. Implementation Guidelines for Practitioners

6.1 Organizational Readiness Assessment

Successful implementation requires systematic assessment of organizational readiness for TTRPG-based learning interventions. This assessment addresses cultural factors, resource availability, and stakeholder support that influence implementation success.

Cultural readiness assessment examines organizational attitudes toward innovative learning approaches, acceptance of game-based learning, and support for collaborative competency development. Organizations with strong cultures of innovation and experimentation are more likely to successfully implement TTRPG interventions.

Resource assessment addresses facilitator availability, physical space requirements, and material costs associated with implementation. The framework provides guidelines for resource planning that help organizations prepare for successful intervention delivery.

6.2 Facilitator Preparation and Training

Facilitator preparation represents a critical success factor for ADVENTURE framework implementation. The framework provides comprehensive training protocols that prepare facilitators to effectively deliver TTRPG-based learning experiences.

Training addresses both technical game facilitation skills and learning facilitation competencies. Facilitators learn to manage game mechanics while maintaining focus on learning objectives and competency development. Training emphasizes the dual role of facilitators as both game masters and learning facilitators.

The training protocol includes practice sessions, mentoring relationships, and ongoing support systems that help facilitators develop confidence and competence in intervention delivery. Training materials are designed for use by organizational learning professionals without prior TTRPG experience.

6.3 Participant Preparation and Engagement

Participant preparation involves orientation to the learning approach, expectation setting, and motivation building for active engagement. The framework provides structured approaches to participant preparation that maximize engagement and learning outcomes.

Orientation sessions introduce participants to TTRPG concepts, explain learning objectives, and address potential concerns about game-based learning. These sessions help participants understand how gameplay connects to competency development and workplace application.

Engagement strategies address potential resistance to game-based learning while building enthusiasm for the collaborative learning experience. The framework provides techniques for maintaining participant motivation throughout the intervention period.

6.4 Organizational Integration Strategies

Successful implementation requires integration with existing organizational learning and development systems. The framework provides guidance for positioning TTRPG interventions within broader competency development programs.

Integration strategies address how TTRPG learning experiences complement traditional training approaches and support organizational learning objectives. The framework helps organizations understand how collaborative competency development through TTRPGs can enhance overall learning effectiveness.

Implementation guidance includes suggestions for scaling successful pilot implementations across organizational units and embedding TTRPG approaches into ongoing learning programs. These strategies help organizations maximize return on investment in innovative learning approaches.

7. Discussion and Future Directions

7.1 Implementation Challenges and Solutions

Practical implementation of the ADVENTURE framework reveals several common challenges that organizations must address to ensure successful outcomes. These challenges include participant resistance to game-based learning, facilitator confidence in managing both gameplay and learning objectives, and organizational skepticism about the effectiveness of TTRPG approaches.

Participant resistance often stems from misconceptions about gaming and concerns about professional appropriateness. The framework addresses this challenge through comprehensive orientation, clear connections between gameplay and workplace competencies, and emphasis on learning outcomes rather than gaming entertainment.

Facilitator confidence develops through structured training and ongoing support systems. The framework provides detailed facilitator guides, practice opportunities, and mentoring relationships that help facilitators develop competence in intervention delivery.

7.2 Scalability and Adaptation Considerations

The ADVENTURE framework is designed for adaptation across diverse organizational contexts while maintaining core learning effectiveness. Scalability considerations include resource requirements, cultural adaptation needs, and integration with existing learning systems.

Resource scalability addresses how organizations can implement TTRPG interventions efficiently while maintaining quality. The framework provides guidance for training multiple facilitators, adapting materials for organizational contexts, and managing implementation costs.

Cultural adaptation ensures that TTRPG interventions remain effective across different organizational cultures and participant populations. The framework provides guidelines for customizing scenarios, adjusting facilitation approaches, and modifying assessment methods to maintain cultural relevance.

7.3 Future Research Directions

Implementation of the ADVENTURE framework opens several promising research directions that can advance understanding of TTRPG-based workplace learning. These directions include longitudinal studies of competency development, comparative effectiveness research, and investigation of individual differences in learning outcomes.

Longitudinal research can examine how competencies developed through TTRPG interventions transfer to workplace performance and persist over time. Such research would provide valuable evidence about the long-term effectiveness of game-based learning approaches.

Comparative effectiveness research can examine how TTRPG interventions compare to traditional training approaches in developing collaborative competencies. This research would help organizations make informed decisions about learning methodology selection.

7.4 Technological Integration Opportunities

Future development of the ADVENTURE framework may benefit from integration with digital technologies that can enhance assessment, facilitate remote implementation, and provide ongoing support for competency development.

Digital assessment tools could automate data collection and provide real-time feedback to participants and facilitators. Such tools could reduce administrative burden while improving assessment accuracy and accessibility.

Remote implementation capabilities could extend the framework's reach to distributed teams and organizations with limited physical meeting space. Hybrid approaches combining in-person and digital elements could provide flexibility while maintaining the collaborative benefits of TTRPG learning experiences.

Ethics Declaration: Ethical clearance was not required for this research as it presents methodological frameworks and implementation guidelines rather than empirical research involving human participants. Future empirical implementation of the ADVENTURE framework will require appropriate ethical clearance from relevant institutional review boards.

AI Declaration: AI tools were used in the development of this paper to support formatting consistency and language refinement. The conceptual framework, implementation guidelines, and methodological contributions represent original work by the authors. AI assistance was limited to editorial support and did not influence the substantive content or conclusions of the research.

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Immersive Game-Based Experiential Learning for International Business Challenges

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Abstract: Higher education increasingly demands innovative instructional strategies that bridge the gap between academic theory and professional practice. In international business programs, access to real-world environments such as ports, customs facilities, and production centers has become progressively limited due to logistical and institutional constraints. As a result, educators are exploring alternatives that maintain experiential richness while adapting to evolving conditions. This paper presents an educational innovation that applies game-based learning and experiential learning frameworks through immersive virtual reality (VR). Two interactive VR simulations were developed to enhance student engagement and skill acquisition. The first experience focuses on individual decision-making in a global logistics scenario, requiring students to complete documentation, coordinate shipments, and solve operational challenges. The second emphasizes collaborative learning, guiding teams through the regulated production and export of a culturally significant product with protected designation of origin. Both simulations embed pedagogical objectives within dynamic, narrative-driven environments that reflect real-world complexity. By leveraging existing VR infrastructure across multiple campuses, the project aligns technological capability with curriculum needs to create scalable, high-impact educational experiences. These tools promote critical thinking, problem-solving, and communication while offering a viable substitute for traditional fieldwork. The paper concludes by outlining future research directions focused on implementation and impact evaluation. These efforts aim to contribute to broader conversations about the role of virtual reality and game-based methodologies in transforming experiential learning in higher education.

Keywords: Higher education, Educational innovation, Game-Based learning, Virtual reality, Experiential learning

1. Introduction

International business education increasingly requires innovative approaches to bridge the gap between theoretical instruction and real-world practice. However, access to operational environments such as ports, logistics hubs, and manufacturing facilities has become increasingly restricted due to institutional, logistical, and security-related constraints. These limitations have reduced opportunities for students to observe and engage with the complex systems that underpin global trade.

In response, educators are turning to immersive technologies that enable active, experiential learning beyond the physical classroom. Game-based learning (GBL) and experiential learning (EL) models provide a framework for students to develop decision-making, problem-solving, and collaborative skills through interactive scenarios. When combined with virtual reality (VR), these approaches can replicate key aspects of international trade environments in a controlled and scalable format.

This paper presents two VR learning experiences designed to support international business programs at Tecnológico de Monterrey. Each simulation integrates game mechanics with curriculum-relevant content, offering students the opportunity to engage in authentic logistical and regulatory challenges. These experiences aim to enhance engagement, reinforce conceptual knowledge, and offer viable alternatives to traditional field-based learning.

2. Context

Since 2023, the National Customs Agency of Mexico (ANAM) has militarized customs zones, effectively ending student visits to ports and customs facilities—once essential components of international business education in Mexico (Rionda, 2023). This shift has limited students' ability to understand critical operational procedures involved in international trade.

To address this gap, a virtual reality (VR) prototype is proposed, comprising two distinct experiences. The first is an individual, homework-style escape room where the student must facilitate the shipment of automotive parts from a factory in Puebla through the Interoceanic Corridor toward their final destination in Germany. Within the simulation, the student must make strategic decisions involving documentation, port procedures, and shipping

logistics. This experience leverages game-based learning to immerse students in real-world challenges otherwise inaccessible due to field visit restrictions.

The second experience is designed as a collaborative, in-class team activity. It focuses on the creation and export of a Caja de Olinalá, a handcrafted item with protected designation of origin from Guerrero, Mexico (Secretaría de Economía, 2016). In this scenario, one student navigates a VR environment using a headset and treadmill, while teammates—equipped with printed manuals—support the decision-making process. The objective is to select raw materials, prepare them according to traditional processes, comply with designation requirements, and complete the logistics for international shipment. Communication is essential, as only the student in VR can see the environment, and only the team can interpret the reference materials.

These immersive experiences offer a scalable and pedagogically grounded alternative to site visits, enabling students to engage with complex international trade operations and culturally significant logistics processes through experiential and game-based learning.

2.1 Game-Based Learning and Experiential Learning

Recent literature reviewed highlights the integration of game-based learning (GBL) and experiential learning (EL) to enhance student engagement, critical thinking, and knowledge retention across educational contexts. GBL emphasizes active learning through simulations and interaction, allowing students to “learn by doing.” This aligns with Kolb’s (1984) experiential learning cycle, which consists of four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation.

Audu and Asino (2024) demonstrate how embedding ethical content in game-based environments can influence student behavior, resonating with Kolb’s framework. Similarly, Spiteri and Vella (2024) show that simulation games in vocational education support formative assessments through experiential inputs. Mahunyag et al. (2024) and Varman et al. (2021) further reinforce how GBL promotes active experimentation and reflection, facilitating deeper understanding of theoretical content.

Mega-games represent a dynamic subset of GBL. These experiences fuse role-play, social interaction, simulations, rule-based systems, economic dynamics, political scenarios, and decision-making processes into immersive narratives (Castillo & Caudillo, 2024). Such complexity enhances analytical skills and real-world problem solving. Their versatility has been evidenced in multiple contexts: Ainul Nur Khusna et al. (2023) employed a Mega Monopoly Game to teach disaster preparedness to children, while Buenaño, Warner, and Moore (2024) found improved student confidence and practical competence through mega sporting event simulations.

Technological advancements have expanded experiential learning through emerging platforms. Gatsakou et al. (2025) explore the use of AI and VR in role-playing games to personalize learning based on student input. Emotional dynamics in gameplay, such as those studied by Sumi and Sato (2022), and collaborative mobile escape games (Trinh, 2021), illustrate how narrative and emotional engagement support reflective learning. This is echoed by Falk et al. (2023) and Stewart and Wang (2023), who emphasize the importance of feedback loops and shared experiences in professional training contexts.

Domain-specific applications also validate the adaptability of experiential GBL: Komaini et al. (2021) improved children’s motor skills through game-based interventions, and Tran (2021) demonstrated its value in hospitality education. Across these studies, a consistent theme emerges—when experiential principles are combined with interactive game mechanics, students develop practical and conceptual skills more effectively. Mega-games, in particular, illustrate how immersive, narrative-rich learning environments can simulate complex real-world challenges, making them especially relevant in international business education (Castillo & Caudillo, 2024).

2.2 Immersive Virtual Reality in Higher Education

This section reviews recent studies on immersive virtual reality (VR) in higher education, based on literature retrieved from Scopus and Web of Science databases. The findings highlight the growing use of VR to enhance teaching and learning across disciplines through interactive, multi-sensory environments.

Mallik and Aithal (2024) show that VR enables students to engage with complex academic scenarios by simulating real-world situations. Its multimodal features—visual, auditory, and kinesthetic—support deeper cognitive engagement and improved retention by allowing learners to interact with challenging content in a virtual setting.

Cai (2024) demonstrates how institutions use VR and artificial intelligence (AI) to support internationalization strategies. Immersive tools, such as virtual customer research platforms, allow institutions to design more globally relevant programs while improving students' cross-cultural communication and adaptability.

Tao (2024) focuses on human–computer interaction (HCI), emphasizing the importance of user-centered design in educational VR. Features like natural language processing and gesture-based interfaces help reduce cognitive load and enhance usability. These design elements are crucial for fostering collaboration and sustained engagement in diverse academic settings.

Overall, the reviewed studies suggest that VR offers substantial benefits for higher education by enabling experiential learning, increasing accessibility to complex content, and fostering collaboration. While challenges such as cost and infrastructure persist, VR represents a promising tool for enriching the educational experience across disciplines.

3. Rationale for the Virtual Reality Experience

The proposed virtual reality (VR) prototype consists of two distinct experiences designed to address the growing gap between classroom theory and real-world international trade practices. These immersive learning environments enable students to engage with complex logistics and cultural export scenarios through interactive, decision-driven simulations that promote experiential learning.

The first experience is a single-player, homework-style escape-room simulation set in a port logistics context. The student assumes responsibility for coordinating the export of automotive parts manufactured in Puebla, destined for Germany via the Interoceanic Corridor. Within the VR environment, the student must make time-sensitive decisions on documentation, customs procedures, shipment routes, and carrier selection. The objective is to “escape the port” by successfully completing the required trade operations without errors or delays. This simulation reflects real-world constraints, such as documentation errors, shipment bottlenecks, and schedule changes, offering students the chance to navigate dynamic logistics challenges that are no longer physically accessible.

This experience enhances students' strategic thinking and decision-making under pressure. It allows them to visualize cause-and-effect relationships in logistics, reinforces procedural knowledge, and offers repeated practice in a low-risk setting. By simulating what they cannot access in person, students gain operational insight, improved confidence, and a clearer understanding of the documentation and coordination required in international trade.

The second experience is a team-based, in-class simulation centered on the production and export of the Caja de Olinalá, a culturally significant wooden craft with a protected designation of origin (DO). In this activity, one student enters the VR environment using a headset and treadmill, interacting with virtual objects, locations, and decisions. The remaining team members, who cannot see the VR world, are given printed manuals containing critical information about the traditional crafting process, required materials, designation criteria, and logistics documentation.

The objective is to successfully produce and prepare the Caja de Olinalá for international shipment by guiding the VR participant through the correct sequence of actions—from selecting the appropriate wood and preparing it with natural treatments, to mixing traditional pigments and ensuring DO compliance. Success depends on precise communication between the student inside the VR and the team outside it. This experience fosters collaboration, reinforces verbal and written communication, and requires attention to complex procedural and regulatory steps—key skills in international business operations involving culturally protected goods.

Both VR experiences integrate game-based learning mechanics, such as progress feedback, reward systems, and challenge escalation. These features align with experiential learning theory, specifically Kolb's (1984) four stages: concrete experience (active simulation), reflective observation (feedback and team debriefing), abstract conceptualization (connecting actions to trade theory), and active experimentation (repeating and refining decisions). The result is a learning model that encourages deeper engagement, higher retention, and skill transfer to real-world business contexts.

Ultimately, these simulations provide scalable, immersive alternatives to field visits. They equip students with the critical thinking, procedural fluency, and collaborative problem-solving skills needed to navigate modern international business environments.

3.1 Challenges in Traditional International Business Education

Traditional methods of teaching international business increasingly struggle to prepare students for operational complexity. Access to key industrial settings—such as ports and customs facilities—has diminished due to security restrictions, reducing opportunities for direct observation and experiential learning.

Even when universities provide access to laboratories or simulation tools, these experiences are often fragmented. Students are typically exposed to isolated roles or processes without a holistic view of the system. Furthermore, these sessions are bound by limited schedules and cannot be easily repeated, weakening reinforcement and retention.

Online simulators offer theoretical training but often lack the visual and contextual elements necessary to simulate operational decision-making. When students encounter outcomes such as delivery delays or document errors, they receive alerts rather than experiencing how those failures unfold. This leads to reduced engagement and limits the development of applied problem-solving skills.

These constraints contribute to a growing disconnect between what is taught in the classroom and what students encounter in professional practice. To address this, alternative approaches must create space for interactive, repeatable, and context-rich learning—bridging academic content with the realities of international trade.

3.2 Technological Context and Feasibility

The technological infrastructure at Tecnológico de Monterrey provides a solid foundation for the integration of immersive virtual reality (VR) experiences in international business education. In 2017, the university established Mostla, an innovation space inaugurated during the International Congress of Innovation and Educational Research in December of that year. Although the inauguration was held at the end of 2017, Mostla officially opened its doors to students, faculty, and staff in January 2018. By October 2018, it had already served more than 5,000 members of the university community, demonstrating significant early engagement.

In subsequent years, Mostla expanded to 20 campuses of the Tecnológico de Monterrey, setting up dedicated VR Zones. Each VR Zone features four stations equipped with HTC Vive Pro headsets, enabling users to explore immersive digital environments. The name "Mostla," meaning "tomorrow" in Nahuatl, reflects its mission: to foster curiosity and digital fluency among students and professors, thereby strengthening a culture of innovation. This goal is pursued through four key strategies: facilitating the use of emerging technologies in learning activities and projects, supporting students in the use of technology for multidisciplinary projects, advising faculty and researchers on incorporating innovative technologies into their work, and integrating these tools into high-impact institutional projects.

Mostla offers a range of services, including group visits and explorations, consulting for academic and institutional projects, and the reservation and loan of VR equipment and spaces for academic purposes. This infrastructure has created an environment where emerging technologies are increasingly accessible for educational use across disciplines.

Building upon this foundation, in 2024 the Business School of Tecnológico de Monterrey made a significant investment in four of its campuses: Monterrey (Nuevo León), Guadalajara (Jalisco), Querétaro (Querétaro), and Estado de México (State of Mexico). These campuses now feature International Business Laboratories equipped with advanced immersive learning technologies. Each laboratory houses four VR stations with HTC Vive Pro 2 headsets and VR omnidirectional treadmills (KAT Walk C 2), allowing users to move freely, running, jumping, walking, and navigating as they would in a physical space. This level of physical immersion positions the institution to offer highly dynamic learning experiences.

However, despite the availability of innovative hardware, there is currently a gap in educational software tailored to international business courses. The existing VR application in use, a crane operation simulator for container management, while sophisticated, does not align with the learning objectives of international business programs. This situation presents a clear opportunity: while the hardware infrastructure is robust, the absence of appropriate software limits the educational value that can be derived from these investments. Developing or adapting VR content specifically for international business learning could thus significantly enhance the use of these technologies and maximize the impact of the resources already in place.

4. Discussion

The integration of immersive virtual reality into international business education at Tecnológico de Monterrey is both timely and feasible. The university has made significant infrastructure investments—through Mostla and the International Business Laboratories—that support the use of advanced VR equipment. However, a lack of curriculum-specific software has limited the pedagogical value of this hardware. The development of tailored VR content responds directly to this gap.

The proposed prototype includes two distinct learning environments. The first is a solo VR escape-room experience focused on port logistics. Students interact with a shipment scenario in which they must make real-time decisions involving documentation, transport coordination, and export protocols. The game mechanics allow learners to engage independently, reinforce procedural knowledge, and develop decision-making skills critical to international trade operations.

The second experience is a collaborative, classroom-based simulation involving the production and export of the Caja de Olinalá. This team-based task requires coordination between a student immersed in the VR world and peers navigating printed manuals. The activity is structured to simulate a complete supply chain, reinforcing teamwork, communication, and regulatory understanding in cultural goods exports.

These experiences leverage game-based learning to facilitate active experimentation and reflection—key stages in experiential learning. By aligning infrastructure with tailored content, the institution is positioned to bridge the divide between theoretical instruction and operational practice.

Future work will focus on implementing and evaluating these VR experiences in higher education classrooms. Subsequent studies can examine their impact on learning outcomes, skill acquisition, and student engagement. Publishing findings from these implementations will contribute to the growing body of research on immersive learning in international business education.

5. Conclusions

The development of immersive, game-based learning experiences offers a concrete response to the limitations faced in international business education today. By designing virtual reality simulations that integrate decision-making, collaboration, and regulatory processes, this initiative aligns innovative technology with pedagogical needs.

Rather than replicating field visits, these experiences aim to create new pathways for engagement—leveraging narrative, interactivity, and experiential structure to foster applied learning. The work presented here sets the foundation for evaluating how immersive tools can enhance conceptual understanding and operational thinking in academic contexts.

Continued efforts will focus on implementation and assessment, contributing to future research on immersive learning in higher education.

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Advanced Gamification to Enhance Lifelong Learning: A Second Hybrid Implementation

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Abstract: This paper presents a second iteration of a hybrid mega-game implementation within the sixth semester “New Realities” block of a Digital Art bachelor’s program at a Mexican university. Building on an earlier online-only model, this hybrid version combined mandatory face-to-face classes with optional, industry-led online sessions. Designed to mirror professional practice, the course challenged twelve students to develop professional-level competencies, visual creature design, 3D modelling, texturing, rigging, motion capture animation, and real-time video rendering for a transmedia campaign, while avoiding “crunch time” and refining self-management skills acquired in their fifth semester. Guided by Tracy Fullerton’s build–test–refine playtesting cycle and Jesse Schell’s Lenses framework, the implementation unfolded over three five-week periods from February to June 2025. Students earned virtual Prestige currency and experience points via the OASIS platform’s economy, which accounted for 20 percent of the final grade. Three assessment tracks accommodated diverse risk and scholarship requirements: Safe Mode secured a minimum passing grade; Normal Mode relied solely on three core deliverables weighted at 30 percent each; and Hero Mode unlocked Prestige-based Easter-egg rewards and elevated grades to 100 percent. In the final six weeks, each student partnered with one of twelve real clients, negotiated scope and resources, and orchestrated project teams in roles mirroring AAA studio workflows. Voluntary surveys administered at weeks five (n = 12) and ten (n = 10) captured quantitative ratings (1–10 scales and 5-point Likert items) and qualitative feedback on instructor effectiveness, motivational shifts, and self-directed learning behaviours. After five weeks, participants reported remarkable skill gains, strong motivation driven by narrative hooks and surprise mechanics, and high approval of Discord and recorded lectures; they also flagged the need for clearer coordination among instructors and more balanced scheduling. By week ten, the remaining cohort described measurable improvements in time management, a deeper willingness to research beyond class content, and heightened confidence in applying disciplinary concepts to real-world challenges—attributes essential for lifelong learning and imminent industry entry. Although episodes of burnout and stress persisted, students increasingly attributed these to personal organization and habits rather than the game’s design. These findings indicate that hybrid mega-games can simultaneously foster technical mastery and metacognitive practices. Embedding iterative playtesting into curriculum design empowers learners to assume responsibility for their own motivation and well-being. Future work should extend evaluation into the six-week mega-game simulation, examine long-term impacts on student resilience, and explore scalability across disciplines to refine hybrid gamification models that prepare students for sustained professional growth.

Keywords: Gamification, Mega-Games, Higher education, Lifelong learning, Educational innovation

1. Introduction

Gamification is increasingly recognized as a useful strategy to boost student motivation, improve skills, and foster teamwork. In a previous study, the use of mega-games in an online-only format was explored. In this document, the second iteration is described, which uses a hybrid model that combines mandatory face-to-face classes with recommended online sessions led by industry experts.

Mega-games are large-scale, interactive experiences that combine elements of board games, role-playing, and simulations, involving dozens to hundreds of participants assuming asymmetrical roles within complex scenarios. They emphasize strategy, negotiation, and dynamic narrative development, and have proven effective for educational purposes through immersive, collaborative engagement (Caudillo, 2024).

The switch to a hybrid format arises from lessons learned during the pandemic, where both strengths and limitations of remote learning were evident. The hybrid model aims to leverage the benefits of digital tools, such as flexibility and the inclusion of real-world knowledge, while maintaining the connection and interaction that face-to-face classes offer.

The previous study showed that mega-games can significantly increase student engagement; however, it also identified challenges related to scheduling and workload management. The innovative approach was designed to optimize the positive aspects and address these difficulties, creating a more balanced and attractive learning experience.

Inspired by the narrative of Ready Player One, the course uses a creative approach that connects theory to practice. Moreover, collaboration with professionals from the video game industry reinforces the relevance and

interactivity of the educational process. This approach aims to strengthen key skills such as critical thinking, self-management, communication, and collaboration, which are essential for lifelong learning.

2. Context

The implementation of this gamification and mega-game experience emerges from an evolutionary process in response to the changing conditions of higher education in Mexico. The first iteration was carried out from January to June 2022, during a period when the gradual return to on-campus classes in Mexican universities began. However, many students were residing in cities far from the campuses, making it unsustainable to require this generation of 35 participants to attend in person.

Consequently, in the following year, the implementation was conducted face-to-face at two campuses: Guadalajara and Querétaro. Although this modality fostered rich interaction, it limited opportunities for students unable to relocate, particularly those from the northern region and Mexico City. To address this issue, in the subsequent cycle additional face-to-face groups were opened in the Monterrey, Guadalajara, and Querétaro campuses, and by August 2024 a group was also established at the Mexico City campus.

The current implementation is carried out in the sixth semester of the Digital Art Bachelor's degree, specifically within the video game studies area, which spans two semesters. In the fifth semester, students learned to organize and self-manage their time through a deliberate practice diary. In this process, they set daily goals to work eight hours a day, five days a week, reviewing their accomplishments at the end of each day and reflecting on improvements for their next session. This graduated approach, progressing from daily goal-setting to a weekly format and finally to medium-term goals by semester's end, was designed to demonstrate that it is possible to develop video games while avoiding crunch time and managing time effectively. Results showed that 20% of the students reached the third level of mastery, 60% validated the competence at the weekly level, and the remaining 20% only achieved the basic level.

The self-management skills developed in the fifth semester are crucial for the current sixth-semester implementation, as students are now required to manage their time autonomously, facing direct consequences on their grades if they do not do so effectively. For this semester, the course and its activities were redesigned to clearly reflect the expected learning outcomes in a face-to-face format, which includes online elements outside regular class hours. These online sessions are optional but highly recommended and are taught by professionals with industry experience in video games who are located outside the Mexico City campus, where the class is held.

Moreover, this implementation aims for students to prepare for lifelong learning and to acquire an almost professional level in various areas of the discipline. These areas include the visual development of ultra-realistic creatures inspired by pre-existing narrative worlds, three-dimensional modelling, texturing, set-up or rigging, animation through motion capture, and the creation of real-time rendered videos focused on a transmedia campaign for social media.

The "New Realities" course is structured as a block with 24 hours of instruction and 24 hours of assignments per week, distributed over three 5-week periods, interspersed with one week during which students face short-term challenges requiring solutions in under 40 hours. In this semester, running from February to June 2025, the objective is to refine time management and achieve a balance between in-person instruction and complementary online activities, adapting to the needs and realities of sixth-semester students in the video game studies area.

2.1 Gamification in Higher Education on Hybrid Learning Models

Recent studies sourced from research databases over the last three years present a comprehensive picture of how gamification is applied to higher education, especially within hybrid learning models. Hybrid learning, which involves both online and face-to-face interactions, has prompted educators to explore gamified frameworks that support dynamic instructional designs. Thi Binh et al. (2024) offer a design science approach detailing a robust framework for incorporating gamification elements into hybrid course curricula, thereby validating positive student outcomes. Similarly, López Núñez et al. (2023) conducted a systematic review of b-learning contexts and found that integrating narrative, feedback, competition, and reward mechanisms is linked to increased student participation and motivation in higher education settings.

The practical application of gamification in hybrid learning is further underscored by Gironella (2023), who advocates for a student-centric course design that leverages motivational strategies to enhance engagement. This approach is particularly relevant in hybrid settings where a balance between traditional pedagogy and

technological tools is critical. In addition, Kosub et al. (2024) documented successful cases of integrating gamification elements within learning management systems, specifically Moodle, highlighting that thoughtful implementation leads to qualitative transformations in teaching through enhanced coaching, feedback, and interactive strategies.

Moreover, Alzahrani and Alhalafawy (2023) examine gamification through platforms such as Blackboard, identifying both motivational drivers and obstacles encountered by faculty when sustaining gamified interventions. Their work emphasizes the importance of aligning technology, pedagogical design, and gamified content to achieve long-term sustainability in hybrid learning models. Together, these studies support the notion that the intersection of gamification and higher education, particularly in hybrid environments, elevates student engagement and reinforces practical skills development and academic achievement.

Despite the widespread use of conventional gamification methods, characterized by elements like storytelling, rewards, and leaderboards, these strategies may not fully exploit the potential for deeper learning experiences. Advanced gamification techniques, such as the incorporation of mega-games, have begun to be explored to cultivate lifelong learning in higher education. Research over the past decade indicates that educational gamification can extend beyond conventional practices. For example, Franco (2022) reports an implementation in language learning for Brazilian students where popular elements like leaderboards were intentionally excluded to mitigate learner frustration, in favour of narrative techniques and tailored rewards. Similarly, Isa et al. (2022) describe the development of a mobile game-based learning application that embeds culturally relevant content and integrates a broader spectrum of game design strategies to address engagement and motivational challenges.

Collectively, these empirical studies provide a strong research basis for refining gamification strategies in hybrid learning models. They suggest that by integrating advanced gamification elements, such as mega-games, higher education can better meet the diverse needs of contemporary learners, supporting the development of both academic skills and lifelong learning competencies.

2.2 Mega-Games in Higher Education

Mega-games represent a novel trajectory in educational gamification, combining elements from board games, role-playing games, and simulations into large-scale, immersive experiences (Caudillo, 2024). Unlike conventional educational games that rely on points, badges, or leaderboards, mega-games involve dozens to hundreds of participants who assume asymmetrical roles within evolving narratives. Players engage in cooperative and competitive activities over extended periods, replicating complex real-world scenarios, such as geopolitical conflicts or economic systems, through structured rules, strategic decision-making, and resource management (Caudillo, 2024).

Empirical studies demonstrate the pedagogical value of these experiences. Caudillo's (2024) action-research investigation found that integrating advanced gamification elements with mega-games significantly increases student motivation and sustained engagement, although issues such as economic disparities and occasional burnout must be managed. Castillo and Caudillo (2024) further illustrate how role-play, interactive storytelling, and decision-making processes within mega-games catalyse deep experiential learning, fostering both cognitive and affective outcomes. Their work underscores that the scale and interactivity unique to mega-games create a dynamic environment for collaborative problem-solving and critical thinking.

Practical implementations reinforce these findings. Martínez et al. (2023) describe "Kuxtal," a mega-game designed for design students, which yielded marked improvements in collaboration, creative thinking, and real-world application skills. By situating learners in complex, simulated contexts, Kuxtal and similar initiatives demonstrate how mega-games can transcend traditional hybrid models, offering higher education a robust strategy to prepare students for lifelong learning and professional practice.

2.3 Relevant Theories in Game Design

Two foundational frameworks guided the design of this implementation: Jesse Schell's Lenses (2019) and Tracy Fullerton's Playcentric Approach (2018). Schell's Lenses present over a hundred focused heuristics that encourage designers to examine every aspect of a game from multiple perspectives, such as the lens of essential experience, the lens of the player's perspective, and the lens of the play space (Schell, 2019). By systematically applying these lenses, designers can ensure that mechanics, aesthetics, and narrative coalesce into a cohesive whole that delivers the intended emotional and cognitive experience.

Complementing this, Fullerton's playcentric methodology emphasizes iterative prototyping and empirical playtesting as the core of game development (Fullerton, 2018). In her model, each prototype undergoes cycles of testing with real players, gathering feedback on what works, what frustrates, and what delights—then refining the design accordingly. This cycle of build–test–refine not only uncovers usability issues but also reveals emergent behaviours and unanticipated learning moments.

In the current implementation, these theories converge in a three-period, five-week cycle within the “New Realities” course. At the end of each period, student complete surveys to formal playtests: they evaluate instructor effectiveness, identify which game elements or activities functioned as intended, and highlight problematic features. This structured feedback loop mirrors Fullerton's playtesting phases, allowing the design team to apply Schell's Lenses selectively, focusing each iteration on lenses most relevant to the issues raised. Over successive cycles, the course evolves responsively, ensuring that the mega-game remains immersive, pedagogically sound, and aligned with lifelong learning objectives.

3. Methodology

The study adopted Tracy Fullerton's playtesting cycle, build, test, refine, as its guiding framework. Data were gathered at the end of each five-week period within the New Realities block through an online survey completed by the twelve sixth-semester Digital Arts students specializing in video game studies. The first section of the survey evaluated instructor performance using three numerical items on a 1–10 scale: subject mastery, the degree to which the instructor challenged students to develop new skills, and the overall learning experience. Two open-ended questions then invited students to share feedback directly with the instructor and to suggest areas for improvement in confidence that their critiques would remain confidential.

In the same survey, a period review section asked students to reflect on what had gone well, what had gone wrong, and what should be improved during the previous five weeks. Students also provided comments for the course coordinator, offering insight into the overall direction of the immersive experience. During the first period, the survey included a motivational-tracking module in which students rated, on a five-point Likert scale, how motivated they felt before the semester began, during the initial five weeks, and as they looked ahead to subsequent periods. This section also probed specific elements of the experience—storytelling, the utility of Discord, game mechanics such as fun and curiosity, the innovation of challenges, the evolution of difficulty, hidden secrets, random events, communication channels, reward systems, parallel challenges, and key-collection mechanics tied to the Easter-egg reward.

Additionally, students rated their motivation for various course activities, face-to-face lectures, optional online sessions, recorded classes, upcoming challenges, key-gathering tasks, earning Prestige and experience points, extra Oasis activities, autonomous learning, and mastering new software platforms. In the second period, the survey shifted focus to deeper dimensions of student-driven learning: the extent to which participants researched beyond class content, assumed responsibility for their own progress, explored career-related topics, applied disciplinary concepts, felt confident solving domain-specific problems, engaged in situational learning, prepared for lifelong learning, and managed their learning independently in anticipation of new challenges.

Surveys were distributed at the close of weeks five and ten and were both voluntary and anonymous. Quantitative responses were analysed by calculating means and standard deviations for each item, while qualitative feedback was coded thematically into strengths, issues, and suggestions. Each period's findings informed adjustments to the course design, ensuring that the hybrid format and mega-game elements evolved in response to student data and maintained alignment with the learning objectives of fostering autonomy, collaboration, and professional-level skill development.

3.1 Course Design

The course, designed by Carlos Astengo, Lorena Martínez, and Mario Caudillo, offered an immersive experience that combined gamification elements with mega-games to cultivate collaboration skills. Its structure was inspired by the narrative world of Ernest Cline's Ready Player One, reflecting the thematic links between the novel and course content.

The 2025 version built on the successes of the original design, uniting the best practices from both implementations under the guidance of twelve instructors, coordinated by Mario Caudillo. It was organized into three modules.

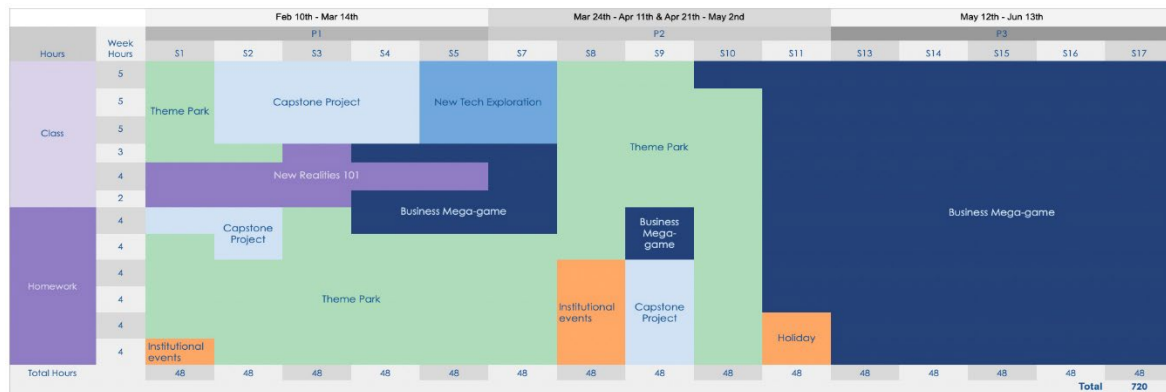


Figure 1: New Realities Course modules organization

The Theme Park Planet module emphasized professional discipline skills by challenging students to create a photorealistic creature based on existing narrative intellectual property, developing its psychology, visual design, 3D modelling, textures, rigging, and motion-capture animation for a transmedia theme-park campaign.

The Video Game Planet, shown in Figure 1 as Capstone Project, module focused on documenting and experimenting with students' capstone projects, which they continued refining over the next two semesters until submission as their final degree projects.

The Sector 18: Planet Doom module functioned as a business mega-game, simulating a professional work environment in which students assumed three distinct roles across three projects, earned virtual Prestige currency, and engaged in mechanics such as tax payments and freelance negotiation. A major difference from first implementation is that there are 12 different clients which needs to be contacted by students as producers of their own new realities game ideas.

3.2 Gamification and Mega-game Design

The OASIS platform enabled students, during the first nine weeks, to amass a virtual currency called Prestige, which governed the Mega-game's economy. As they participated, students also earned experience points that unlocked additional features. Unlike the prior implementation, the course offered three grading tracks: Safe Mode, which guaranteed a passing grade of 70 as long as deliverables were submitted on time at a basic level; Normal Mode, which excluded Prestige from the grade calculation and weighted each of the three main deliverables (Theme Park, Capstone, Planet Doom) at 30 percent each, sufficient to maintain the 90 percent threshold required for academic scholarships; and Hero Mode, the only track allowing students to earn Prestige, collect keys, and ultimately claim an Easter-egg bonus that elevated their grade to 100. In Hero Mode, the Capstone project counted for 30 percent, reflecting its role in developing individual game-design competencies and documentation skills; the Planet Doom deliverable accounted for another 30 percent, representing production skills such as scheduling, budgeting, and resource planning; and the Theme Park assignment carried 20 percent, recognizing ongoing disciplinary skill development; and finally the Prestige accounted for 20 percent of the final grade.

To simulate real-world accountability, students logged their class hours with the "/work" command within the Mega-game. Each entry triggered a notification to administrators, who could verify the activity or impose Prestige fines for false reports. In the final six weeks, the Mega-game shifted into a professional simulation: each student was paired with an actual client, conducting initial meetings to gather requirements and learn professional communication. Producers selected projects from a Job Board containing client contact details, negotiated scope, resources, budgets, payment terms, and timelines, and then presented their proposals to a board composed of three professors and the client. Upon approval, the board released 50 percent of the required Prestige, enabling the producer to recruit teammates, artists, developers, or producer-designers, in roles mirroring AAA studio workflows. Projects concluded with a formal closure and post-mortem review to assess outcomes and lessons learned, thereby reinforcing both technical skills and professional practices.

4. Results

Twelve students completed the first survey at the end of week five. Based on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree), most participants, 10 out of 12, reported remarkable gains in their skills and appreciated working alongside peers with varied perspectives. However, they also noted confusion arising from

overlapping instructions among instructors and the tight scheduling of optional online sessions, which often left little time for restful breaks or deeper focus on projects. To address these concerns, students recommended clearer guidelines for deliverables and more balanced class and online activity scheduling.

In the motivation module of the first survey, students rated their enthusiasm for the “New Realities” block as extremely high before and during the first five weeks (mean = 4.6) and remained optimistic about the upcoming period (mean = 4.7). All agreed that the storytelling elements drawn from Ready Player One stirred positive emotions and curiosity, and that Discord received a satisfaction score of 4.7 out of 5. 9 out of 12 found the surprise mechanics and prestige currency engaging, though a few expressed neutral views on specific game elements. While motivation for face-to-face sessions varied, optional online classes and recorded lectures consistently received strong approval, as did the chance to earn experience points and collect virtual keys.

By week eight, two students faced significant risk of failing and were advised to withdraw, reducing the second survey cohort to ten. These remaining students still described an overall improvement in their time management (mean self-rating increased from 4.0 to 4.5) compared to the first period yet continued to seek ways to optimize deadlines and information gathering. All ten, agreed that the mega-game format encouraged them to research beyond class content, take ownership of their learning, and explore new career-related topics. Confidence in applying disciplinary concepts and linking theory to real-world scenarios remained high, and most felt better prepared for lifelong learning and future academic challenges.

When asked about stress and burnout, several students acknowledged periods of anxiety, especially around platform transitions and team coordination. Feedback highlighted the need for deeper alignment among instructors to smooth out handoffs between course modules. Nevertheless, students praised the professional insights they gained, particularly in pipeline organization, budgeting, and client interaction, and many credited fifth semester’s deliberate-practice diary with preparing them to juggle semester-long projects.

Comments to the course coordinator expressed gratitude for the immersive experience and the chance to work with industry-seasoned professors. Students recommended earlier communication about extra online sessions and finer coordination of platform workflows to prevent bottlenecks. Despite these challenges, the overall sentiment was one of pride in their accomplishments, increased motivation for autonomous learning, and confidence in applying their newly acquired skills.

5. Conclusions

The findings from both surveys demonstrate that embedding a hybrid mega-game within a face-to-face block can meaningfully boost student engagement, self-management, and professional readiness. After five weeks, all twelve participants reported strong motivation driven by narrative hooks, surprise mechanics, and a flexible blend of in-person and online sessions. At the same time, they highlighted the need for clearer coordination among instructors and more balanced scheduling to prevent workload bottlenecks.

By week ten, the ten remaining students described measurable improvements in their time management, a deeper willingness to research beyond class content, and heightened confidence in applying disciplinary concepts to real-world tasks. These two abilities, independent inquiry and practical application, are vital for preparing students for lifelong learning and will prove indispensable when they join the industry in a year’s time.

This iteration built on the previous online-only model by offering three assessment tracks, Safe, Normal, and Hero, that accommodate different risk tolerances and scholarship requirements. Assigning each student a distinct client project demanded professional communication, scope negotiation, and resource planning. The playtesting framework ensured that each five-week cycle responded directly to student feedback, keeping the experience both immersive and pedagogically sound.

Together, these design choices reinforced essential lifelong-learning skills such as critical thinking, self-direction, and collaboration, while guiding students toward near-professional mastery in creature design, 3D modelling, rigging, motion capture, and real-time rendering.

In both the online-only and the hybrid implementations, students reported episodes of burnout, anxiety, and stress. Yet whereas participants in the first iteration attributed these feelings to the mechanics of advanced gamification and the scale of the mega-game, in the hybrid model they instead cited personal factors such as time management, goal setting, and healthy habits. This shift, from externalizing pressure to owning one’s role in sustaining motivation, underscores a maturation in student self-awareness. It suggests that, by embedding structured reflection and iterative playtesting into the curriculum, learners are better equipped to recognize and address their own challenges rather than blame the implementation’s design.

Such self-regulatory skills, taking responsibility for one's workload, planning, and seeking balance between ambition and well-being, are crucial for lifelong learning. As these students prepare to enter the industry within a year, their capacity to monitor stress levels, adapt their strategies, and maintain resilience will be as important as any technical competency. In this way, the hybrid mega-game not only advances disciplinary mastery but also models the self-directed, reflective practice that drives sustained professional growth.

5.1 Implications for Future Implementation

Because this paper focuses on the advanced gamification phase and the preparatory work leading into the mega-game, it captures only the first half of the semester's hybrid experience. Future implementations should extend the evaluative framework to include the six-week mega-game simulation, using the same quantitative and qualitative instruments to measure outcomes such as collaborative problem-solving, professional role competence, and client-interaction skills. Tracking those final weeks will reveal whether early gains in motivation, autonomy, and time management translate into sustained engagement and effective project delivery under simulated industry pressures.

Moreover, longitudinal research is needed to assess lasting effects on student well-being and professional readiness. While participants in this hybrid model assumed responsibility for stress and burnout, an encouraging sign of self-regulation, it remains unclear how the intensity of the mega-game impacts resilience over time. Future studies might incorporate periodic well-being check-ins, reflective journals, or physiological stress metrics to balance ambition with healthy habits.

Finally, scaling this approach across different disciplines and institutional contexts will test its generalizability. Researchers and practitioners should explore variations in narrative themes, client-project structures, and assessment tracks to identify the core design principles that drive deep learning. By closing the loop on the full implementation—from advanced gamification through to mega-game completion—educators can refine hybrid models that not only equip students with near-professional technical skills but also focus in the reflective, self-directed practices essential for lifelong learning.

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Immersive Virtual Reality Experience for Informed Career Decision-making

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Abstract: Tecnológico de Monterrey's Tec21 framework structures student development through Exploration, Focus, and Specialization phases, supported by a triad of peer mentors, program directors, and student mentors. Despite this robust design, two decision points, leaving the Exploration phase and selecting a specialization, emerge as peaks of stress and anxiety, driven by fears of irreversible mistakes, financial uncertainty, and external pressures. A mixed-methods survey of 78 sixth-semester students revealed that while most report low stress when choosing a university or major, a significant minority experiences moderate to severe anxiety. Open responses highlighted concerns about costly tuition, heavy course loads, confusing curricular options, and worry over disappointing family or peers. Traditional interventions, detailed program overviews, mindfulness exercises, and proactive advising, provide some relief but may not fully engage Generation Z learners, who gravitate toward immediate, immersive experiences. Simultaneously, Tec's Mostla innovation hub has established VR Zones on twenty campuses, each equipped with HTC Vive Pro stations and a proven track record of five thousand visits within the first ten months. Yet, existing VR applications do not address the specific decision-making challenges faced by students. Anchored by the university's 2030 vision, "education not just for work but for life, and continuously", and its credo of "leadership, innovation, and entrepreneurship for human flourishing," a tailored VR prototype offers a compelling solution. By recreating campus tours, career pathways, and specialization scenarios in a controlled virtual environment, students can test outcomes without real-world stakes. This experiential rehearsal bridges information gaps, alleviates financial and logistical anxieties, and builds emotional resilience and self-efficacy, core components of human flourishing. Discussion of survey findings alongside VR's proven capacity for social-emotional learning suggests that immersive simulations can transform high-pressure academic choices into guided explorations. Students who feared choosing the wrong discipline or losing scholarships could, for instance, virtually navigate financial aid processes or "walk through" a corporate project before committing. By aligning Tec21's phased curriculum and well-being dimensions with interactive VR modules, the university can deliver decision-making workshops and in-simulation prompts that reinforce confidence at those pivotal junctures. In conclusion, implementing bespoke VR experiences, grounded in Tec21 pedagogy and deployed through Mostla's infrastructure, promises to convert moments of acute anxiety into opportunities for growth. Such an approach not only prepares students for professional success but also nurtures their capacity for continuous learning and balanced living, satisfying Tecnológico de Monterrey's aspiration to cultivate resilient individuals ready for the challenges of an ever-changing world.

Keywords: Virtual reality, Experiential learning, Game-Based learning, Higher education, Educational innovation

1. Introduction

Tecnológico de Monterrey's Tec21 framework guides learners through three stages, aiming to build foundational skills, deepen disciplinary expertise, and ultimately empower students to design bespoke specialties aligned with their aspirations. This phased curriculum is reinforced by a triad of people, peer mentor, program director, and student mentor, who support academic, professional, and personal development. Yet, critical transition points, exiting Exploration and choosing a specialty, coincide with elevated stress and anxiety, as students grapple with lifelong implications, financial uncertainty, and social expectations. Traditional remedies, including detailed program overviews and mindfulness exercises, offer some relief but may fall short for Generation Z learners accustomed to immersive, interactive experiences.

An innovation centre in the university mature VR infrastructure presents a unique opportunity. By situating decision-making scenarios within virtual simulations that replicate campus life, career pathways, and specialization options, students can rehearse choices in a low-stakes environment. Such an approach promises to bridge information gaps, bolster self-efficacy, and cultivate emotional resilience in line with the institution's 2030 vision of education "for life" and its ethos of "leadership, innovation, and entrepreneurship for human flourishing."

2. Context

The Tec21 educational framework at Tecnológico de Monterrey is structured around three progressive phases that guide students from broad exploration to personalized specialization. In the initial Exploration stage,

learners engage with competencies common to multiple disciplines, an approach that also serves to reinforce their confidence in choosing a career path. During the subsequent Focus phase, attention shifts toward the mastery of skills directly related to the student's selected field. Finally, in the Specialization stage, known as Semesters Tec, students gain the freedom to curate experiences aligned with their vocational interests, whether through disciplinary specializations, collaborative projects with industry partners, dual-degree programs, or international exchanges, all designed to broaden horizons and support well-rounded development.

Parallel to this curricular design, the Tec21 accompaniment model assigns each incoming student a dedicated support team consisting of a peer mentor, program director, and student mentor. The peer mentor, drawn from upper semesters in a related program, offers practical advice on campus life and helps newcomers navigate institutional practices, especially those transitioning from different preparatory systems. The program director assumes responsibility for professional academic guidance, ranging from career decisions and specializations to scheduling, international programs, and disciplinary specializations, ensuring that each student's academic trajectory aligns with their goals. The student mentor addresses personal growth by fostering the seven dimensions of well-being outlined in Tec21: self-awareness and management, innovative entrepreneurship, social intelligence, ethics and citizenship, complex reasoning, communication, and digital transformation.

Drawing on three years of mentoring experience that follow students from their first semester through the seventh of eight, two pivotal decision points have emerged: exiting the Exploration phase and selecting a specialization. These junctures coincide with the ongoing maturation of the prefrontal cortex, a brain region vital for reasoning, planning, and decision-making, which neuroscientific research indicates continues developing into the mid-twenties (Steinberg, 2005). Recognizing that such moments often trigger anxiety, mentors collaborate closely with the university's Well-Being Department to offer timely support. This combined effort ensures that students approach critical academic choices from a position of informed calm rather than heightened stress.

2.1 Stress and Anxiety in Decision-Making in Higher Education

Research into how stress and anxiety influence decision-making among university students uncovers a dynamic interaction between emotional states, mental processes, and situational pressures. A recurring observation is that academic stress and indecision reinforce one another. Flores-Buils and Mateu-Pérez (2025) found that students experiencing vocational uncertainty often report heightened academic stress, with attentional lapses and anxious feelings intensifying their career-related doubts. Anghel and Gati (2019) reached similar conclusions, showing significant associations between career decision difficulties and negative emotions such as stress, anxiety, and depression. Extending this perspective, Lee and Park (2016) observed that anxiety linked to practical training and low confidence in career decision-making contribute to procrastination and less favourable vocational outcomes.

Studies examining decision-making under uncertain conditions further highlight anxiety's role in shaping choices. Yan et al. (2022) noted that during the COVID-19 pandemic, elevated anxiety prompted students to seek quick cognitive closure, at times leading to precipitous or irrational judgments. McKian (2015) demonstrated impaired inhibitory control in students with greater anxiety and stress symptoms, making them more inclined toward risky options. In a focused study on domain-specific fears, Buelow and Barnhart (2016) reported that math anxiety undermines performance on tasks requiring careful risk-reward evaluation, suggesting both general and subject-related anxieties can skew decision strategies toward suboptimal paths.

Attention has also turned to interventions aimed at easing the cognitive burden of stress and anxiety. Eshet, Grinautsky, and Steinberger (2024) showed that mindfulness exercises can lower statistical anxiety and reduce tendencies toward unethical decision-making under risky conditions. Parallel findings from Thomas, Kamath, and Joseph (2024) indicate that mindfulness-based stress reduction programs bolster self-confidence and diminish academic test anxiety. Together, these studies imply that cultivating mindful awareness may enhance decision-making by lessening emotional interference and improving focus.

Such evidence underscores the importance of addressing stress and anxiety to support effective decision-making in higher education. Academic pressure and negative affect undermine clarity and self-assurance, sometimes provoking hasty or risky choices. Mindfulness practices offer a viable countermeasure, and future research would benefit from longitudinal and experimental designs to unravel the mechanisms at play and to assess intervention outcomes across diverse academic contexts.

2.2 Social-Emotional Development in Higher Education

Recent research highlights a shift toward hands-on learning approaches that nurture social-emotional capacities in university contexts. Experiential pedagogies, from community service to gamified coursework, are reshaping curricula and equipping students with empathy, resilience, and collaboration skills vital for personal and professional areas.

Service learning and community engagement stand out as powerful drivers of social-emotional growth. Rodríguez-Zurita et al. (2024) found that students involved in sustainability-focused service projects report stronger social responsibility, improved emotional resilience, and heightened empathy. By confronting real-world challenges, learners engage in reflective practices that reinforce emotional awareness and foster key socio-emotional learning (SEL) outcomes (Rodríguez-Zurita et al., 2024).

Leadership education similarly relies on immersive experiences to develop affective and interpersonal competencies. K  pyl   and Palvalin (2023) outline a model in which management principles are taught through practice-oriented exercises, prompting students to navigate uncertainty and examine their emotional responses. Sandberg (2024) adds that art-based leadership modules, integrating aesthetic and embodied activities, promote self-reflection and elevate emotional intelligence among emerging leaders.

Active learning methods such as flipped classrooms and gamification further illustrate this connection. Pellu, et al. (2023) observed that flipped-classroom environments enhance listening, problem-solving, and collaboration, driven by deeper emotional engagement. In business management courses, Skritsovali (2023) demonstrated that gamified elements boost motivation while cultivating resilience and creative teamwork, underscoring the capacity of game mechanics to support SEL.

The move to remote and hybrid instruction has inspired digital experiential formats. Thier, Mason, and Mattice (2023) describe virtual study-abroad and NGO partnership projects that build global awareness, adaptability, and intercultural communication in online settings. Brodie et al. (2022) argue that post-pandemic educational reforms must address socio-emotional well-being directly, recommending digitally mediated experiential initiatives to sustain autonomy, self-regulation, and community across dispersed learning environments.

Instructional support plays a crucial role in embedding SEL within higher education. Collie (2021) shows that student-centred teaching strategies enhance emotional regulation and social competence. Mart  nez, et al. (2023) demonstrate that incorporating active methodologies into teacher training creates conditions where academic achievement and socio-emotional development reinforce one another, highlighting the importance of educator preparation in sustaining SEL.

Together, these studies illustrate that experiential learning, through service projects, leadership simulations, active approaches, and digital adaptations, offers multiple pathways to cultivate social-emotional skills in higher education.

2.3 Immersive Virtual Reality Experiences in Higher Education

Recent academic literature highlights the growing use of immersive virtual reality (VR) technologies in higher education to support not only cognitive development but also SEL. These immersive environments offer opportunities for students to engage with emotionally charged, simulated contexts that stimulate authentic affective responses and interpersonal reflection.

A notable body of work centres on VR's potential to foster empathy and emotional understanding. For instance, Beverly et al. (2022) describe how 360   cinematic VR experiences in healthcare education enhance not only technical competencies but also emotional engagement through an increased sense of presence. Similarly, Aguirre-Calan et al. (2024) examine a VR intervention tailored to university students, finding that when integrated into courses addressing ethical and social issues, immersive VR significantly enhances empathic awareness. These findings suggest that VR simulations can function as experiential platforms for confronting complex interpersonal scenarios, thereby contributing to the emotional development of learners.

Qualitative studies provide further evidence of VR's impact on non-technical skills relevant to SEL. Helle et al. (2023) conducted focus group sessions with healthcare and social work students, revealing that VR-based simulations promote ethical reflection, communication, and decision-making. In parallel, Lie et al. (2023) report on the development of a VR educational tool intended to elicit emotional responses, noting increased empathy among participants as a direct outcome of interacting with virtual characters in emotionally realistic settings.

Systematic reviews reinforce these findings within professional education. Juan and O’Connell (2024) synthesize a range of studies on simulation-based learning in nursing education, concluding that immersive VR scenarios help cultivate empathy and emotional responsiveness critical for clinical practice. Dhiman (2023) extends this perspective by highlighting VR’s ability to expose students to diverse worldviews and emotionally charged environments, effectively bridging the empathy gap.

Further research explores VR’s role in supporting self-efficacy and learner motivation, both key factors in socio-emotional development. Hsiao (2021) shows that immersive experiential education strengthens social work students’ confidence and engagement. Blair et al. (2021) add that 360° VR content in health and social care education generates emotionally immersive learning spaces that encourage active emotional participation. Farley and Herrera (2023) also document the benefits of trauma-sensitive VR environments, noting their potential to build empathy and emotional readiness for real-world challenges.

Together, these studies suggest that immersive VR, when thoughtfully integrated into higher education curricula, can serve as a powerful medium for socio-emotional learning. By simulating emotionally resonant experiences, VR supports the development of empathy, self-awareness, and interpersonal competence—skills essential for personal and professional growth.

3. Rationale for the Virtual Reality Experience

Anchored in the institution’s 2030 ambition to deliver an education “not just for work but for life, and continuously,” and guided by the motto “leadership, innovation, and entrepreneurship for human flourishing,” a dedicated VR prototype can extend this vision by immersing students in lifelike scenarios at key decision moments. Rather than confronting abstract uncertainties alone, learners step into virtual simulations that mirror campus environments, career pathways, and specialization choices, allowing them to experiment with outcomes without real-world stakes. In doing so, the experience cultivates emotional resilience and self-efficacy, core ingredients of human flourishing, while bridging information gaps and reducing financial or logistical anxieties. This alignment of pedagogical purpose with Mostla’s technological capacity transforms high-pressure academic choices into an exploratory journey that prepares students not only for professional success but for a balanced, flourishing life.

3.1 Analysis of Student Stressors in Decision-Making

A mixed-methods instrument comprising Likert-scale items and open-ended questions was administered to 78 sixth semester students to explore stress and anxiety at three critical decision points in their higher-education trajectories. Participants first rated their emotional response to choosing a university on a five-point scale (1 = not at all stressed/anxious; 5 = severe anxiety or physical symptoms). Although the plurality (37.2 %) selected “2,” a notable 17.9 %–14.1 % of students reported moderate to high stress (ratings of 3 or 4) and 5.1 % rated their anxiety at the highest level. When asked to elaborate on ratings of 3 or above, many described fear of irreversible mistakes (“I didn’t want to pick the wrong program and waste time”), financial uncertainty (“I wasn’t sure I could afford tuition”), and personal crises that magnified indecision (“a personal crisis made me question my motives”). Others cited academic workload concerns, short, content-heavy courses and rapid deadlines that threatened both grades and well-being, and the pressure of family expectations or disappointing others.

In the second decision phase, selecting a major in the second or third semester, stress levels eased slightly, with 43.6 % at “1” and 32.1 % at “2,” yet 24.4 % still reported moderate to severe anxiety (ratings 3–5). Open responses illuminated anxiety around changing fields: students recounted lengthy, worrisome processes of switching majors, reluctance to disappoint parents, and doubts about their own aptitude in the newly chosen discipline. Uncertainty around similar program options, unclear curricular descriptions, and a lack of guidance exacerbated these fears. One student remarked that engineering disciplines “felt too similar” on paper, amplifying indecision, while another noted anxiety over confessing a change of heart to their family.

By the sixth semester, when choosing a specialization experience, stress was more evenly distributed: 35.5 % of respondents rated “1,” 25.8 % “2,” and 25.8 % “3,” with only 11.3 % selecting “4” and 1.6 % a “5.” Students who rated their stress at 3 or higher described conflicting opportunities, such as deciding between an exchange program and a local internship, short planning windows for researching requirements, and worries about long-term career impact. One participant explained that fear of choosing a specialization “that wouldn’t lead to a job” loomed large, while another worried about adapting to a new campus environment. Social pressures also surfaced, with several students admitting they felt judged by peers or family for their choices.

Together, the quantitative and qualitative data reveal that, although the majority of students experience mild stress across these decision points, a substantial minority endure moderate to severe anxiety driven by uncertainty, fear of error, financial concerns, information gaps, and external expectations. These findings suggest that targeted interventions, such as comprehensive decision-making workshops, detailed program overviews, and proactive advising, should be concentrated at the transition from broad Exploration to Focus and throughout the specialization planning phase, enabling students to approach these pivotal choices with confidence and reduced distress.

3.2 Technological Context and Feasibility

Tecnológico de Monterrey already possesses a mature technological backbone that enables the deployment of immersive virtual reality (VR) solutions across its campuses. In late 2017, the institution unveiled Mostla, a dedicated innovation hub, during the International Congress of Innovation and Educational Research; the facility then began serving students, faculty, and staff in January 2018. Within ten months, Mostla recorded over 5,000 visits, signalling strong institutional uptake and community enthusiasm.

Over the following years, Mostla's footprint grew to encompass twenty campuses, each hosting a VR Zone outfitted with four HTC Vive Pro stations. These zones empower users to navigate richly detailed virtual spaces and engage with interactive simulations. The choice of the name "Mostla", derived from the Nahuatl word for "tomorrow", speaks to its aspiration to nurture a spirit of exploration and digital competence among learners and educators alike. To realize this vision, Mostla pursues four core objectives: embedding cutting-edge technology in curricular and extracurricular projects; guiding students in leveraging VR for cross-disciplinary initiatives; advising academic staff on the thoughtful incorporation of immersive tools; and aligning these technologies with large-scale institutional priorities.

Mostla also provides structured group demos, tailored consulting services, and a reservation system for VR hardware and spaces, making advanced immersive tools readily available across fields of study. Despite this well-developed hardware network, a notable absence persists in software solutions designed specifically for higher education contexts. Current VR titles often fail to align closely with course objectives or institutional goals, limiting their pedagogical value. This gap reveals a clear opportunity: by creating or customizing VR applications that address the unique needs of university students, the institution can fully capitalize on its existing infrastructure and enhance educational outcomes through immersive, game-based experiences.

4. Discussion

The Tec21 model's phased progression, from Exploration through Focus to Specialization, intends to scaffold students' academic and personal growth. Yet our findings reveal that the transition points where learners exit broad exploration and select specialization often coincide with spikes in stress and anxiety. Flores-Buils and Mateu-Pérez (2025) identify a reciprocal relationship between vocational uncertainty and academic stress, an insight borne out by students' reports of fear of irreversible mistakes and financial worries during their initial choice of university. Likewise, Anghel and Gati (2019) link career indecision with heightened negative emotions, a pattern reflected in our participants' anxiety when contemplating program changes in early semesters.

Although stress diminishes somewhat during the major-selection phase, with 43.6 % reporting minimal anxiety, the persistence of moderate to severe stress in 24.4 % of students underscores Lee and Park's (2016) observation that low confidence in decision-making can foster procrastination and emotional strain. By the sixth semester, stress levels become more evenly distributed; yet 27.4 % still describe moderate to severe anxiety when choosing a specialization, echoing Yan et al.'s (2022) finding that uncertainty can drive hasty, ill-considered choices, and McKian's (2015) evidence of impaired inhibitory control under stress.

Mindfulness interventions have shown promise in reducing decision-related anxiety (Eshet, Grinautsky, & Steinberger, 2024; Thomas, Kamath, & Joseph, 2024). However, their reliance on sustained practice may limit uptake among Generation Z learners who favour immediate, interactive engagement. Here, immersive VR offers a contextually relevant alternative: by simulating campus environments, career pathways, and specialization options, students encounter lifelike scenarios that allow safe experimentation without real-world stakes. This virtual rehearsal can reduce informational gaps and financial or logistical anxieties, directly addressing the stressors our mixed-methods data uncovered.

Mostla's well-established network of VR Zones across twenty campuses provides the necessary hardware backbone for such an intervention. Yet, as the rationale highlights, the absence of bespoke software tailored to decision-making hinders pedagogical impact. By developing dedicated VR prototypes aligned with Tec21's

phases and Tec21's well-being dimensions, the institution can leverage its technological capacity to cultivate emotional resilience and self-efficacy at critical junctures. This approach transforms high-pressure academic choices into guided exploratory experiences, thus bridging theory and practice in service of a more balanced, flourishing student journey.

5. Conclusions

The convergence of Tec21's structured phases, the documented stressors at pivotal academic junctures, and Mostla's VR capabilities points to a practical, context-sensitive intervention. Immersive prototypes that mirror real-world decision points can transform abstract anxieties into concrete explorations, enabling students to experiment, reflect, and build confidence before committing to life-shaping choices. By harnessing game-inspired interactions and emotionally responsive design, these VR experiences align with Generation Z's learning preferences while addressing the root causes of decision-related distress.

Implementing tailored VR applications, grounded in Tec21's pedagogical pillars and accompanied by targeted workshops and advisement, will allow Tecnológico de Monterrey to leverage existing resources for maximal impact. In doing so, the institution can satisfy its ambition to nurture not only capable professionals, but emotionally resilient individuals equipped for continuous growth and flourishing throughout their lives.

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Using VR as a New Pedagogical Approach for Food Science and Technology Education in Hong Kong

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Abstract: This study explores the potential of Virtual Reality (VR) as a pedagogical tool for teaching Food Science and Technology to junior secondary students in Hong Kong. Traditional cooking education faces significant challenges including safety risks, resource constraints, and limited hands-on practice opportunities, issues particularly acute in Hong Kong where teacher shortages and lack of standardized textbooks compound these difficulties. The VR game was designed specifically for entry-level junior secondary students, incorporating scaffolded learning of both theoretical food science concepts and practical cookery skills aligned with Hong Kong's Technology and Living curriculum. Unlike traditional digital games, the VR environment enables three-dimensional spatial visualization of cooking processes, hand-tracking for motor skill development, and immersive procedural learning that closely mimics real kitchen experiences. This teaching experiment compared learning outcomes between students using a custom-developed VR cooking game ("Food Science Academy VR") and those watching video recordings of the same content. Four Secondary 1 (Grade 7 / K7) students participated in the experiment, with two engaging in VR gameplay and two viewing recorded gameplay videos. Assessment included both written tests and practical cooking tasks. Preliminary results indicated that VR users demonstrated superior knowledge retention and practical performance, though the study acknowledges significant limitations including the small sample size and the artificial nature of the video control condition, which does not represent actual traditional teaching practices in Hong Kong schools. While findings are preliminary, they suggest VR's unique affordances—particularly spatial visualization and embodied interaction, may offer advantages over both passive video instruction and potentially traditional methods for teaching procedural cooking skills. However, questions remain about the resource feasibility of implementing such technology in Hong Kong's educational context.

Keywords: Virtual reality, Food science and technology education, Junior secondary education, Cooking skills training, Immersive learning, Hong Kong curriculum

1. Introduction

The teaching and learning of cookery, consisting of both practical skills and theoretical knowledge, holds significant value not only within educational settings, but also in professional culinary contexts and everyday life. However, traditional approaches to Food Science and Technology education face persistent challenges, including ensuring student safety during practical sessions and managing substantial time requirements associated with hands-on practice, preparation, and cleanup activities.

The situation is particularly acute in Hong Kong, where the Technology and Living (T&L) curriculum faces critical resource shortages. According to recent legislative council data, only 430 Home Economics or Technology and Living teachers serve across 440 secondary schools, representing a severe personnel shortage (Inmedia, 2025). This has led to widespread subject discontinuation, with only 13 schools offering Technology and Living (Food Science and Technology) at senior secondary level, enrolling merely 524 students in 2023/24—a decrease from the previous year. The Hong Kong Diploma of Secondary Education examination saw only 113 candidates in this subject, representing a 40-person decrease from the previous year (Inmedia, 2025).

A 2017 survey by the Hong Kong Federation of Education Workers revealed the systemic nature of these challenges. While 87.8% of 288 responding schools offered junior secondary Home Economics, only 20.2% provided senior secondary Technology and Living (HKFEW, 2017). The primary barriers were lack of qualified teachers (74.9%) and absence of appropriate facilities (54%). Many schools reported having only one professionally trained teacher, with 195 schools having no teachers with relevant professional training for senior secondary Technology and Living subjects (HKFEW, 2017).

The hardware infrastructure challenges include inadequate cookery facilities and specialized equipment costs. The software challenges refer to insufficient human expertise, with 99% of survey respondents believing teachers require professional training, yet many schools lack adequately trained personnel (HKFEW, 2017). Legislative Council member Leung Tze-wing has expressed concerns that continued decline may affect talent

supply in food science industries, potentially requiring imported specialists to address gaps in local expertise (Inmedia, 2025).

These challenges are compounded by Hong Kong's specific educational context, where junior secondary students often have minimal cooking experience due to many households employing domestic helpers for meal preparation. This unfamiliarity with basic kitchen equipment reflects broader societal patterns and creates additional pedagogical challenges. Moreover, the T&L curriculum's emphasis on developing "positive values and attitudes for the well-being of families and society" (EDB, 2017) suggests that cooking education serves broader purposes beyond skill acquisition, including social and cultural dimensions that traditional classroom cooking provides through shared experiences.

Despite these challenges, educators recognize substantial benefits these subjects provide. The survey indicated 92.3% of respondents believed the subjects enhance students' self-care abilities, while 88.9% noted improvements in healthy living awareness (HKFEW, 2017). Remarkably, 98% of schools indicated they would offer these subjects if adequate equipment and teaching staff were available.

To address these issues, this paper proposes integrating Virtual Reality (VR) as an innovative pedagogical tool within the Food Science and Technology strand of Hong Kong's T&L curriculum. VR could provide students with foundational exposure to kitchen environments and equipment before engaging in actual practice, potentially serving as a preparatory tool. Gamified learning has been widely recognized for enhancing student motivation, engagement, and knowledge retention. Recent research by Gordillo et al. (2022) demonstrated that students learning through educational video games achieved significantly higher learning gains and motivation compared to video-based learning.

VR games extend gamified learning possibilities by providing immersive three-dimensional environments, haptic feedback, and embodied interaction that closely mimics real kitchen experiences. This creates safe, controlled environments where students can practice culinary techniques without physical risks, effectively addressing both hardware limitations of inadequate facilities and software constraints of insufficient trained personnel. VR eliminates safety concerns, provides access for schools without cookery facilities, and minimizes preparation and cleanup time while offering personalized feedback and adaptive learning pathways.

The subsequent sections will review literature on gamified learning, explore VR integration advantages in Food Science and Technology education, and investigate how VR-based learning might enhance practical competency while addressing Hong Kong's documented hardware and software challenges.

2. Literature Review

Traditional food science and technology education faces significant systemic challenges that impede effective instruction delivery. In New Zealand schools, practical food-based education encounters substantial barriers including inadequate cooking facilities, persistent teacher shortages, and prohibitive infrastructure costs (Gorman et al., 2022). The cost of providing and maintaining cooking facilities is significant, with many facilities experiencing limited utilization of approximately 20 hours weekly, creating economic inefficiencies for educational institutions. The Hong Kong context presents additional complexities, with the Technology and Living curriculum encompassing diverse domains beyond food science, making it challenging to assess students' specific cooking abilities accurately (Gorman et al., 2022).

The evolution of food science education methodologies has progressed from traditional paper-based questionnaires to computer and mobile device-supported instruction (Gere et al., 2021). However, significant pedagogical challenges persist, including various cognitive biases that can influence student responses, such as acquiescence bias, demand characteristic bias, extreme responding bias, and desirability bias, all of which can compromise the validity of educational assessments and learning outcomes.

Extensive research demonstrates the substantial potential of gamification to enhance educational outcomes across diverse academic contexts. A comprehensive meta-analysis by Li, Ma and Shi (2023) involving 41 studies with 49 independent samples and over 5,071 participants revealed a significant large effect size ($g = 0.822$ [0.567 to 1.078]) for gamification's impact on student learning outcomes. The effectiveness of gamified learning varies considerably based on several key moderating factors, with elementary school learners and higher education users showing significantly larger effect sizes compared to secondary school users. Educational discipline also plays a crucial role, with science education showing the strongest effect size, followed by mathematics, engineering/computing, social science, and business (Li, Ma and Shi, 2023).

Design principles for educational gamification significantly influence learning outcomes, with the combination of "mechanics + dynamics + aesthetics" producing the largest effect size (Hedges' $g = 1.285$). This aligns with the MDA framework, which emphasizes the cohesive interplay between quantifiable game components, behavioural interactions over time, and emotional responses in generating successful learning outcomes. Food-related gamification research, while more limited, demonstrates similar positive trends across marketing, nutritional education, and healthcare applications, though research predominantly presents short-term empirical results with limited evidence of long-term effectiveness (Könnölä et al., 2016).

Virtual Reality technology offers unique affordances that distinguish it from traditional digital learning approaches. Gere et al. (2021) define VR as computer-generated stimulation creating immersive environments where users experience and interact as if in real-world situations. VR applications in food science demonstrate strong validity compared to real-life scenarios, with validation studies revealing significant correlations between VR and real-life consumer behaviours ($r = 0.91$, $P < 0.001$). VR environments enable manipulation of visual features without changing product composition, allowing for controlled experimentation with variables such as color, texture, and environmental context. Gorman et al. (2022) demonstrated VR's practical application in food technology education through a custom-developed VR Classroom, achieving a System Usability Scale score of 80.4 and high student engagement levels.

Comparative research examining video-based and game-based learning approaches employs sophisticated experimental designs to isolate the specific effects of different instructional modalities. Gordillo, López-Fernández and Tovar (2022) implemented a quasi-experimental design with 180 software engineering students, comparing video-based learning with teacher-authored educational video games. Their study revealed statistically significant differences in learning gains (p -value = 0.04, $r = 0.13$), with game-based learning proving more effective than video-based learning for both knowledge acquisition and motivation. Students in the experimental group rated the game-based learning experience significantly higher for motivation, fun, and overall opinion. Similarly, Gorman et al. (2022) employed user observation with questionnaire data collection from 12 middle school students, providing comprehensive assessment of both usability and educational effectiveness. The convergence of findings across these methodologically diverse studies provides robust evidence supporting the superiority of game-based approaches over traditional video-based instruction, particularly when enhanced through immersive technologies such as VR.

3. Methodology

This study aims to explore whether immersive VR experiences can enhance effectiveness in learning practical cookery skills compared to video-based instruction. The research employed a quasi-experimental design with control and experimental groups and pre- and post-tests to investigate the potential benefits of VR-based gamified learning in Food Science and Technology education. The methodology encompasses four key components: an overview of the research approach, detailed VR game design rationale, experimental procedures, and assessment methods.

3.1 Research Approach Overview

The research experiment was structured into three phases: a pre-experiment assessment, the experimental intervention, and a post-experiment evaluation. Students were randomly assigned to two groups - one engaging with a custom VR cooking game and another viewing video recordings of the same content. This comparison was designed to isolate the specific effects of VR's immersive and interactive features while controlling for content delivery.

Rationale for Video-Based Control Group: Video-based instruction was selected as the control condition for several practical and methodological reasons. First, video instruction offers standardized content delivery that is easily consumable and does not require specialized technical skills from participants, eliminating potential confounding variables related to technology familiarity. Second, video-based learning is widely used in Hong Kong's educational system and represents a realistic alternative to VR implementation. Third, using video recordings of the same VR gameplay ensures identical content exposure between groups, allowing for direct comparison of delivery methods rather than content differences. While acknowledging that this approach does not represent traditional hands-on cooking instruction, it provides a controlled comparison to evaluate VR's unique interactive and immersive advantages over passive content consumption.

3.2 VR Game Design

3.2.1 Focus on eggs: Curriculum and educational rationale

The custom-developed "Food Science Academy VR" game centres on egg-based recipes, a choice supported by multiple educational and practical considerations. According to the Hong Kong Education Bureau's Technology and Living curriculum guidelines (2017), proteins are typically introduced at the junior secondary level as fundamental macronutrients requiring practical understanding. Eggs serve as an ideal vehicle for teaching protein science concepts due to their versatility and clear demonstration of protein coagulation, denaturation, and functional properties.

Review of existing culinary education resources reveals that eggs are consistently featured as foundational ingredients in entry-level cooking instruction. Professional cookery textbooks and educational programs typically begin with egg preparation due to the ingredient's accessibility, safety profile, and clear visual demonstration of cooking principles. Furthermore, eggs allow for diverse cooking methods - from simple boiling to complex emulsification - enabling progressive skill development within a single ingredient category.

3.2.2 Scaffolding structure: Educational theory and practical implementation

The game's instructional content is organized using a scaffolding structure aligned with established educational theory and practical cooking pedagogy. This progression follows Vygotsky's zone of proximal development principles, where each level builds upon previous knowledge while introducing manageable new challenges. The scaffolding approach is further supported by analysis of existing cookery curricula and professional culinary training programs, which consistently employ progressive difficulty structures.

The level progression reflects both educational scaffolding principles and practical cooking complexity:

- Tool complexity: Early levels use simple tools (water, basic heat) progressing to more complex equipment (whisks, multiple cooking methods)
- Technique difficulty: Starting with passive cooking (boiling) advancing to active manipulation (whisking, emulsification)
- Safety considerations: Beginning with low-risk water-based cooking before introducing oil-based frying methods
- Curriculum alignment: Matching Hong Kong T&L curriculum emphasis on food safety, with progression from safer to more complex preparation methods

3.3 Game Content and Level Design

The VR game provides an integrative and immersive experience, guiding students through the entire cooking process from ingredient selection at a virtual supermarket to hands-on food preparation. The game presents multiple ingredient choices, with immediate feedback and pop-up explanations when incorrect selections are made, promoting learning through trial and error. In the cooking phase, students interact with various kitchen tools and reference a virtual tablet containing recipes and food science information. The game supports real-time correction by allowing players to reset levels and receive reminders when mistakes occur. Leveraging VR's motion-capturing capabilities, the simulation mirrors real-life cooking actions such as pouring liquids and whisking.

The following table outlines the progression of levels, detailing the key food science knowledge points and corresponding cookery techniques addressed at each stage:

Table 1: Level Design Structure

Level and Dish Name	Food Science Knowledge	Cookery Knowledge
Level 0 - Hard Boiled Egg	Protein coagulation, Protein denaturation under heat	Boiling (cooking with water)
Level 1 - Steamed Egg	Protein coagulation, Protein denaturation under heat, Protein unfolding / link loosening	Steaming (cooking with water), beating eggs

Level and Dish Name	Food Science Knowledge	Cookery Knowledge
Level 2 - Sunny Side-up	Protein coagulation, Protein denaturation under heat, Maillard Reaction	Pan-frying (cooking with oil)
Level 3 - Souffle Pancake	Protein coagulation, Protein denaturation under heat, Foaming (using egg white as a lightening agent)	Whisking, sieving
Level 4 - Eggs Benedict	Protein coagulation, Protein denaturation under heat, Emulsification (in Hollandaise sauce)	Whisking, Boiling (cooking with water)
Level 5 - Scotch Eggs	Cooking temperature of different proteins	Pan-frying (cooking with oil), mincing

3.4 Experimental Procedures

3.4.1 Participants and setting

The experiment was conducted in early April at the Arts and Technology Education Centre (ATEC). Four Grade 7 (Secondary 1) students were randomly selected to participate, ensuring no selection bias. To maintain fairness, two students were assigned to the VR game group (experimental group), while the other two formed the video group (control group). The content delivered to both groups was standardized, with the video group watching pre-recorded gameplay footage of the VR cooking game, ensuring exposure to identical instructional material. The said video could be found [here](#)

Student Profiles:

- Student A: Grade C+, Test Medium: Game
- Student B: Grade C, Test Medium: Game
- Student C: Grade B+, Test Medium: Video
- Student D: Grade A-, Test Medium: Video

Student grades reflect prior school performance in written and practical T&L assessments. These grades serve as indicators of general aptitude, though the T&L curriculum encompasses diverse domains including needlework and sewing, so grades may not fully represent specific cooking abilities.

3.4.2 Three-Phase experimental design

Phase 1: Pre-Experiment Assessment

Each student participated in a semi-structured interview designed to: assess perceived and actual subject performance, determine appropriate content difficulty level using school grading as reference, and gather background information for qualitative analysis.

Phase 2: Experimental Intervention

- VR Game Group: Students played the VR cooking game, following the intended game flow and interacting with the virtual environment to learn cooking processes.
- Video Group: Students watched video recordings of the same gameplay, with instructions to actively take notes on important methods, techniques, and observations.

Phase 3: Post-Experiment Evaluation

Immediately after the learning intervention, all students completed:

Written Test: Questions directly aligned with knowledge points addressed in the game/video

Practical Test: Students prepared cloud eggs, involving egg white and yolk separation and specific cooking methods demonstrated in the instructional materials, allowing direct evaluation of skill transfer and knowledge retention.

- Evaluation and Results
- a) Methodology

The primary evaluation method involved **comparing written and practical test scores** between the VR game and video groups, supplemented by qualitative observation of students' behaviour, confidence, and procedural accuracy during the cooking task. For the practical assessment, each step will be scored on a scale from 0 to 2: a score of 0 indicates the student was unable to complete the step correctly or performed with major mistakes, 1 reflects successful completion with minor mistakes, and 2 reflects the step was executed in a flawless manner.

- b) Experiment Results
- VR Game Group (Students A & B):

Table 2: Score of the VR Game Group students

Practical Test – Procedural Item:	Score:		Interpretation:	Other observations:
	A	B		
Pre heat oven to 230 °C	2	2	Both students had no trouble choosing the correct temperature	
Crack eggs and separate egg yolk and egg white	1	2	Student A broke the yolk when cracking the egg.	
Whip egg whites until stiff peaks are seen	2	1	Student B has trouble observing "stiff peak", has tried to proceed to the next step even there the egg white is not whipped well.	Student B has asked numerous times whether the egg white is beaten well.
Add salt and pepper into the egg white	2	2	No issue.	
Put parchment paper on backing tray and pour egg white onto the parchment paper	2	2	No issue	Both students were observed making a small dimple in the egg white for the yolk in the later step, despite not being indicated in the recipe
Bake for 8 minutes, or until the egg white appears golden brown	1	1	Both students nearly burned the egg white because they placed the baking tray on the top rack of the oven, where higher heat led to faster cooking.	Both students have paid close attention to the egg white, and have asked if it is normal for the egg white to appear a bit burnt.
Put egg yolk on top and bake for 3 more minutes	2	2	No issue	
Practical Test Total	12/14	12/14	/	/
Written Test	6.5/10	7/10	/	/
Total Score:	18.5/24	19/24	/	Both students demonstrated carefulness and attention to detail during the experiment, as evidenced by their frequent checks to the recipe.

- Video Group (Students C & D):

Table 3: Score of the VR Game Group students

Practical Test – Procedural Item:	Score:		Interpretation:	Other observations:
	C	D		
Pre heat oven to 230 °C	2	2	Both students have chosen the correct degree without issue.	
Crack eggs and separate egg yolk and egg white	1	0	Both students broke the egg yolk repeatedly. Student D incorrectly transferred the egg white to the small bowl.	Student D has redo step 2 after she realised she has put the egg white onto the wrong bowl
Whip egg whites until stiff peaks are seen	1	2	Due to insufficient whipping, Student C's egg white remained semi-liquid	
Add salt and pepper into the egg white	2	2	No issue.	
Put parchment paper on backing tray and pour egg white onto the parchment paper	1	2	Due to the mishap in step 3, Student C's egg white does not set firmly on the parchment paper	
Bake for 8 minutes, or until the egg white appears golden brown	1	1	Both students nearly burned the egg white because they placed the baking tray on the top rack of the oven, where higher heat led to faster cooking.	
Put egg yolk on top and bake for 3 more minutes	1	1	Both students' egg yolk fell on the parchment paper during baking.	
Practical Test Total	9/14	10/14	/	/
Written Test	1/10	1/10	/	/
Total Score:	10/24	11/24	/	

- c) Qualitative Analysis

The **VR game group** showed superior retention and application of both procedural and conceptual knowledge. The immersive, interactive experience appears to have facilitated better visualization and memory of the steps, as well as increased self-efficacy during practical execution. In contrast, the **video group** struggled to translate passive observation into practical skills, suggesting limitations in engagement and cognitive processing when learning solely through video.

Notably, the issues experienced by the video group did not stem from the content itself (which was identical) but rather from the **method of delivery**; passive video watching may have resulted in lower engagement and less effective encoding of procedural knowledge.

4. Discussions

- Control Condition Limitations and Implications

The most significant limitation of this study concerns the control condition design. Using video recordings of the VR game as a comparison does not represent traditional Food Science and Technology teaching practices in

Hong Kong schools, which typically involve direct instruction, demonstration, and supervised hands-on practice when resources permit. This artificial control condition essentially compared active VR engagement with passive video observation of the same content, making it unsurprising that the VR group outperformed. A more valid experimental design would have compared VR instruction with actual classroom teaching methods currently employed in Hong Kong schools. The absence of such comparison severely limits the transferability of findings and prevents meaningful conclusions about VR's effectiveness relative to existing pedagogical practices.

- VR's Unique Contributions versus Digital Games

While the VR group demonstrated superior performance, it remains unclear whether these benefits stem from VR's unique affordances or simply from active gameplay versus passive viewing. The scaffolding structure and real-time feedback highlighted in our findings are features common to many digital games, not exclusive to VR (Gorman et al., 2022). However, certain patterns emerged suggesting VR-specific advantages: students in the VR group demonstrated better spatial understanding of cooking processes (evidenced by creating dimples for egg yolks without instruction) and more accurate replication of hand movements. These observations align with literature suggesting VR's three-dimensional visualization and embodied interaction provide unique benefits for procedural learning (Tusher et al., 2024).

Nevertheless, this raises a critical question: could similar results be achieved with well-designed non-VR digital games at lower cost? Future research must isolate VR-specific features—such as depth perception, natural hand tracking, and spatial presence—to determine whether these justify the substantial resource investment required.

- Resource Paradox and Implementation Feasibility

This study presents an inherent paradox: proposing VR technology as a solution to resource constraints in Hong Kong schools, when VR itself demands significant technological infrastructure. With documented teacher shortages and absence of standardized textbooks in Technology and Living education (InMedia HK, 2023), introducing resource-intensive VR systems may seem counterintuitive. However, several factors could mitigate this concern:

1. Centralized resource model: VR equipment could be shared across multiple schools through education centers like ATEC, similar to existing arrangements for specialized facilities
2. Scalability: Once developed, VR content can be replicated indefinitely without consumable materials, unlike traditional cooking practice
3. Safety and supervision efficiency: One teacher can safely supervise more students in VR than in actual kitchens, partially addressing teacher shortage issues

Still, the practical feasibility of widespread VR implementation in Hong Kong's educational context remains questionable without substantial policy support and funding allocation.

- Patterns in Learning Outcomes

Analysis of performance differences reveals interesting patterns beyond simple score comparisons. The dramatic disparity in written test scores (VR group: 6.5-7/10; video group: 1/10) suggests VR may particularly enhance theoretical knowledge retention, possibly through the integration of pop-up explanations and immediate corrective feedback during gameplay. Conversely, practical test scores showed smaller differences, with both groups making similar errors (e.g., incorrect oven rack placement), indicating that certain tacit knowledge aspects of cooking may not transfer effectively through either medium.

The video group's difficulty translating observed procedures into practice—particularly Student C's semi-liquid egg whites and Student D's bowl confusion—suggests passive observation fails to build the procedural schemas necessary for practical execution. VR's requirement for active decision-making and physical engagement may facilitate stronger motor-cognitive connections, though this hypothesis requires further investigation with larger samples.

- Artifact Design Considerations

The VR game's limitations, particularly simplified gesture controls and unrealistic liquid physics, highlight the tension between educational objectives and technical feasibility. While features like scaffolded learning and curriculum alignment represent good educational design applicable to any digital platform, VR-specific elements like spatial manipulation and embodied interaction were underdeveloped due to technical constraints. This raises important questions about the minimum fidelity required for effective VR-based skill transfer. Future

iterations must balance realism with computational efficiency and development costs, potentially focusing on aspects where high fidelity most impacts learning outcomes.

5. Conclusion and Future Works

- Conclusion

This study has explored the integration of a VR-based gamified learning environment into the Food Science and Technology curriculum at the junior secondary level, evaluating its effectiveness in enhancing students' practical cookery skills and theoretical understanding compared to traditional video-based instruction. The findings tentatively support the notion that the VR game can foster improved procedural competency, engagement, and knowledge retention. Students in the VR group, despite initially expressing low confidence and limited cooking experience, generally demonstrated higher performance in both practical and written assessments. The immersive and interactive features of the VR game, such as real-time feedback and a scaffolding structure, appear to have contributed to these positive learning outcomes.

However, several limitations must be acknowledged. The experimental design was preliminary and qualitative in nature, with a small sample size and possible selection bias, limiting the generalizability of the results. The pre-assessment relied primarily on self-reported aptitude rather than objective, quantifiable measures, and thus did not provide a robust baseline for comparison. Additionally, some students' unfamiliarity with kitchen equipment, as well as the limitations of both the VR simulation (e.g., gesture realism and physics effects) and the video-based approach (e.g., lack of negative examples and passive learning), may have influenced the outcomes. These factors highlight the need for a more comprehensive and rigorous evaluation framework in future investigations.

- Future Works

Future research should aim to address the methodological and design limitations identified in this study. Specifically, it is recommended to:

- **Develop Stronger Pre- and Post-Assessment Tools:** Implement standardized, skills-based assessments and objective performance metrics to accurately measure learning gains and provide a reliable framework for comparing pre- and post-intervention results.
- **Expand Sample Size and Diversity:** Involve a larger and more diverse group of participants to enhance the robustness and generalizability of findings.
- **Enhance VR Artifact Realism:** Refine the VR simulation to better replicate real-world cooking gestures, equipment operation, and food physics (e.g., effects of viscosity and liquid handling), thus improving immersion and authenticity.
- **Iterative Design Based on Feedback:** Incorporate ongoing feedback from both teachers and students to iteratively improve the educational content, realism, and usability of the VR game.
- **Address Passive Learning in Video-Based Approaches:** Redesign the video intervention to include negative scenarios or common mistakes, and provide opportunities for active engagement or self-correction, thereby enhancing its instructional value.
- **Investigate Long-term Impact:** Conduct longitudinal studies to examine the sustained effects of VR-based cookery training on student confidence, engagement, and real-life application of practical skills.

By addressing these areas, future work can contribute clearer evidence for the effectiveness of immersive technologies in practical skill development and provide actionable guidance for the integration of VR and gamified learning into Food Science and Technology education.

Ethics Declaration: I declare that this research has undergone official and proper ethics declaration from the authors' university (The Hong Kong Polytechnic University). Moreover, the work in this report is my own work. No part of this assignment is taken from other people's work and/or other sources without giving them credit. All references have been clearly cited.

AI Declaration: I declare that Generative AI tools have not been used to produce the submitted work.

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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 context, 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	- 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.
	1.2 Business structure	
	4.1 The nature of operations	
	5.1 Business finance	
	6.2 Business strategy	
	7.3 Leadership	
Global Perspectives & Research – 9239	Component 1. Become effective researchers, using appropriate sources to support judgements and understanding of research processes.	- 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
	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	

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
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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 <i>Refer to Appendix 2: Voting Token</i>	- 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. (Niemic, 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

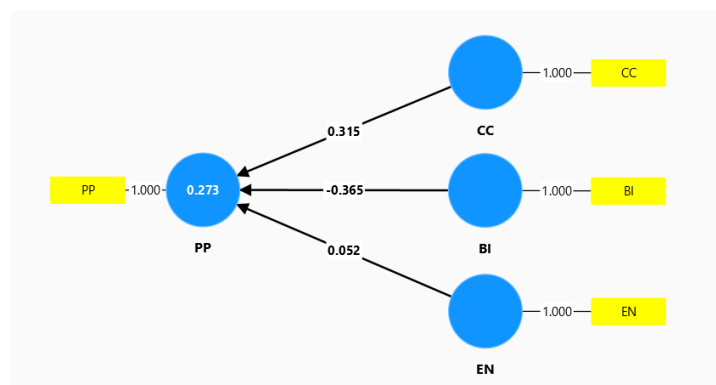
The author is honoured to implement this teaching plan for students from Hanyang University – Raya team. Following a two-week immersion program involving 24 participants, the students consistently expressed in their compositions and feedback that they had gained greater confidence.

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



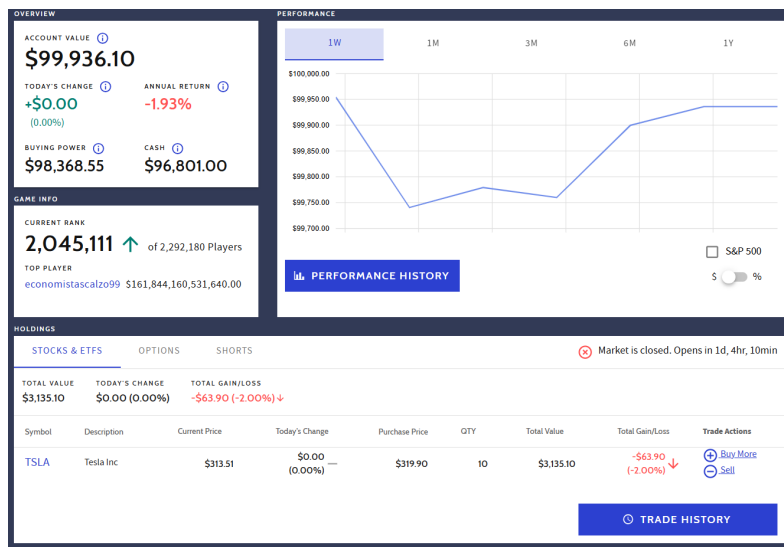
Appendix 2: Mock Token for Startup Voting Activity



Appendix 3: Sample Offer Letter from Prominent Enterprises



Appendix 4: Example of the Simulated Investment Platform



The Great Garbage Patch: The Bionauts' Challenge: An Educational Escape Room on Marine Plastic Pollution and on Possible Solutions

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Abstract: Marine plastic pollution is a critical environmental issue, with the Great Pacific Garbage Patch symbolizing its severity. To engage the public in understanding this crisis and exploring scientific solutions, we developed "The Great Garbage Patch: The Bionauts' Challenge", an educational escape room set in a biology lab aboard an oceanographic research vessel. Participants must solve challenges and puzzles to learn about marine pollution and the role of plastic-degrading bacteria in ocean cleanup. First presented at Maker Faire Rome 2024, the escape room attracted students, educators, and families. A tabletop version was later introduced to extend its reach at other events. Through gamified learning, participants explored the impact of plastic waste and the potential of biotechnology in mitigating pollution. This case study highlights the potential of educational escape rooms for informal science learning. While results were encouraging, they should be interpreted with caution due to methodological limitations such as self-selection and group-based evaluation. Still, the experience demonstrates how game-based learning can foster curiosity and deepen understanding of STEM subjects and environmental issues.

Keywords: Educational escape room, STEM education, Science communication, Marine pollution, Plastic-Degrading bacteria, Environmental awareness

1. Introduction

Escape rooms have emerged in recent years as powerful tools for active learning and public engagement in both formal and informal educational settings. Originally developed as recreational experiences, escape rooms have been adapted for educational purposes due to their ability to combine narrative immersion, collaborative problem solving, and time-constrained challenges, which foster motivation, critical thinking, and engagement (Veldkamp *et al.*, 2020). These features make them particularly well-suited for STEM education, where abstract or complex topics can be made more tangible and memorable through interactive, game-based learning (Borrego *et al.*, 2017; Fotaris and Mastoras, 2019). Educational escape rooms can improve knowledge retention, stimulate curiosity, and support the development of transversal skills such as communication and teamwork (Taraldsen *et al.*, 2022). Their flexibility also allows for contextualized learning, where content is embedded within real-world scenarios, thus enhancing relevance and learners' engagement. Moreover, escape rooms are increasingly being used in science communication and outreach initiatives to engage broader audiences — including families, students, and educators — by transforming complex scientific concepts into accessible and immersive experiences (Veldkamp, Knippels and van Joolingen, 2021). While the educational potential of escape rooms and game-based learning is well documented, it is also important to consider some critical perspectives. Challenges include the substantial resources required for design and implementation, potential superficial engagement if the narrative overtakes the educational content, and difficulties in assessing learning outcomes objectively. Moreover, game-based approaches may not equally suit all learners, and their effectiveness can vary depending on the alignment between game mechanics and pedagogical goals. Including such considerations helps to frame the method not as universally applicable, but as one that requires thoughtful adaptation to context and audience.

This study presents “The Great Garbage Patch: The Bionauts’ Challenge”, an educational escape room designed to promote STEM-based environmental awareness through a game-based narrative. The ideation and development were carried out by an interdisciplinary team of researchers with expertise in physics, chemistry, biology, and engineering. These diverse scientific competencies enriched the design process. They also ensured the scientific credibility of the educational content at every stage — from narrative construction to technical implementation. This collaborative approach made it possible to create an experience that is both educationally effective and scientifically sound. By examining its structure, implementation, and audience reception, we aim to contribute to the growing body of research on the pedagogical value of escape rooms in science communication.

2. Marine Plastic Pollution: Challenges, Emerging Solutions, and the Role of Public Awareness

Plastic pollution in the oceans represents a growing threat to marine ecosystems, biodiversity, and global food chains. An estimated 8 million metric tons of plastic waste enter the oceans annually, accumulating in large-scale convergence zones such as the Great Pacific Garbage Patch — an area between Hawaii and California where ocean currents trap floating debris (Jambeck *et al.*, 2015; Lebreton *et al.*, 2018). These garbage patches are made up mainly of microplastics and fragmented polymers, which are highly resistant to degradation and make cleanup efforts difficult.

Addressing this issue requires a combination of mitigation strategies, including reduction at the source, improvement of waste management systems, and the development of novel clean-up technologies. Among emerging solutions, the use of plastic-degrading microorganisms has attracted increasing scientific interest. Certain bacterial strains, such as *Ideonella sakaiensis*, can degrade and consume polyethylene terephthalate (PET), a plastic material that was previously considered non-biodegradable, offering promising biological solution to plastic pollution in marine environments (Yoshida *et al.*, 2016; Danso, Chow and Streit, 2019). However, these approaches are still in experimental stages and require further research to assess their ecological safety and effectiveness on a large scale.

Given the complexity of marine plastic pollution and the multidisciplinary nature of potential interventions, public understanding and awareness are essential. Effective science communication plays a critical role in bridging the gap between research and societal action, fostering informed decision-making, environmental responsibility, and behavioral change (Moser, 2010; Stoknes, 2015; Di Paolo *et al.*, 2024). Engaging educational tools, such as science-based games and immersive experiences, have the potential to make these challenges more relatable and actionable for diverse audiences.

3. Case Study: “The Great Garbage Patch: The Bionauts’ Challenge”

To explore the communicative potential of educational escape rooms in the context of marine plastic pollution and biotechnology, we developed *The Great Garbage Patch: The Bionauts’ Challenge*, an immersive, STEM-focused experience presented at Maker Faire Rome 2024 — a major European event for innovation and science outreach, which attracted approximately 45 000 visitors. The escape room was installed in a closed 16 m² space, designed to replicate a biology laboratory aboard a fictional oceanographic research vessel. The setting included authentic scientific instruments and custom-made visual materials such as posters, diagrams, and experimental data sheets.



Figure 1: Pictures of the escape room

Participants entered in small groups and were guided by a narrative scenario: a severe storm is approaching, and a team of scientists (the players) has only 20 minutes to retrieve crucial data, kept in the ship's laboratory protocols, describing the optimal conditions to allow the growth and viability of marine bacteria able to degrade harmful plastics. These bacteria might hold the key to ocean cleanup, but the conditions for their optimal activity must be verified before the lab is evacuated. Players had to solve a series of interconnected puzzles and scientific challenges embedded in the laboratory setting, requiring them to explore real instruments and interpret scientific information presented on posters. Clues were distributed spatially and semantically across the room, promoting inquiry-based learning and observational reasoning (Veldkamp *et al.*, 2020).

A key element of the experience was a dedicated computer interface, a large 55" monitor with a mouse controller, that served both as a narrative device and an interactive learning platform. By discovering and inputting specific codes, participants unlocked short video clips containing scientific explanations and hints, progressively unveiling the underlying biological principles and the environmental significance of the mission. This hybrid design, combining physical exploration with digital media, aligns with established best practices in immersive science education, which emphasize multisensory engagement and authentic context as drivers of conceptual understanding (Taraldsen *et al.*, 2022).

The structure of the escape room experience is outlined below. After a short introductory briefing, participants are provided with a data sheet containing essential information, such as the biological cell incubator working temperature (38°C), the name of a bacterial strain, and the indication of a type of plastic, along with other experimental information, not useful for the game but contributing to the scientific setting. A handwritten note asks players to enter the start code "AUG" into the lab computer as they begin the escape room. AUG is the starting codon of the messenger RNA (mRNA) coding for *Ideonella sakaiensis* enzymatic protein responsible for PET degradation. Below, we outline the key sequential steps of the activity:

1. Upon inputting the sequence "AUG" on the lab computer, a video is launched that introduces the environmental context and prompts players to determine the correct incubation temperature, initiating the countdown.
2. Temperature Clue: A second sheet, found on the table, displays a different temperature (30°C). Inputting this value on the computer reveals a clue: "Between yellow and blue, length is the key", referencing the visible light spectrum.
3. Light Spectrum Analysis: A nearby poster shows the light spectrum, indicating that green lies between yellow and blue, with a wavelength of 549 nm. This numerical value is used to open a locked box.
4. UV Light: Inside the box, participants find a UV torch and a note suggesting that fluorescence will reveal the next clue in a poster. The message also provides the first RNA triplet: UCU.
5. Fluorescent Tubes: Participants use the UV torch to examine test tubes labeled with numbers. Only three tubes contain a fluorescent solution (labeled 0, 1, 4), pointing to poster numbered 014.
6. Hidden Message Reveal: Using the UV light, players uncover a hidden message on poster 014. It refers to bacterial degradation experiments in the incubator and includes the second RNA triplet: AGA.
7. Bacteria-Plastic Matching: In the incubator, Petri dishes show different bacteria acting on various plastics. Only one Petri dish contains biodegraded plastic. Matching this Petri dish with labeled one containing similar plastic on a nearby table yields a four-digit code: 0637.
8. Base Extraction Puzzle: The code unlocks a second large case containing beakers filled with various granular materials. Within the beakers, participants find capsules labeled with the four RNA bases (A, U, C, and G). Based on the previous clues, the participants must consider the differing grain sizes of the materials to deduce the final RNA triplet: UGC.
9. Code Assembly: Entering the complete sequence UCU AGA UGC (a segment of the mRNA of *Ideonella sakaiensis*) into the computer concludes the game and triggers a final video that summarizes the narrative and congratulates participants for successfully completing the mission.

4. Impact Assessment

During the three days of activity, a total of 450 individuals participated in the escape room experience. Following the activity, participants were invited to complete an optional anonymous questionnaire aimed at evaluating their engagement and perception of the experience. The questionnaire was filled out once per group, rather than individually, to capture a collective perspective on the activity. A total of 30 questionnaires were collected, corresponding to 162 participants. These results are indicative and should be interpreted with caution, due to self-selection bias and the group-based response format. These methodological choices were

primarily influenced by the context of the event — a large public fair characterized by high visitor turnover and limited time for extended interaction. In addition to the questionnaire data, qualitative evaluation was conducted through direct observation of participants' behavior during the escape room and informal interactions with them before and after the experience. In fact, at least one researcher with expertise in the field was always available to engage with participants in discussions about the scientific topics covered, both prior to and following the activity.

Participant groups ranged in size from 3 to 12 individuals (mean: 5.4), with a quite balanced gender distribution (approximately 45% women). The age of participants spanned from 5 to 63 years, with a predominance of students (middle school, high school, and university level) and families with children. All these groups successfully completed the activity within the allotted time, which was deemed sufficient (average rating: 4.9/5 on a Likert scale). Puzzle difficulty was rated as adequate (3.1/5), while the narrative scenario was considered realistic and effective (4.1/5). Overall enjoyment was rated very highly (4.7/5), and the perceived educational value of the experience was also strong (4.3/5). Informal interactions supported these findings, revealing widespread appreciation for the activity, increased interest and curiosity regarding the scientific content, and a noticeable improvement in participants' ability to articulate key concepts — evidenced by comparative discussions held with researchers before and after the experience.

5. Conclusions

This case study illustrates the effectiveness of educational escape rooms as a tool for informal science education and public engagement. *The Great Garbage Patch: The Bionauts' Challenge* successfully merged scientific content with a compelling narrative structure, offering participants an active and immersive learning experience centred on marine plastic pollution and emerging biotechnological solutions. The observed learning outcomes, along with high engagement and positive feedback, suggest that game-based formats can foster cognitive and emotional connections to complex environmental issues. Despite the limitations inherent in the evaluation methods — particularly the voluntary and group-based nature of feedback collection — the experience yielded valuable insights into audience reception and educational impact. The active presence of field experts and the integration of real scientific instruments further enriched the activity, enabling participants to relate abstract concepts to tangible experiences. Overall, this initiative supports the growing body of evidence advocating for the integration of gamified learning approaches into science communication strategies aimed at diverse, non-specialist audiences. Future iterations may benefit from enhanced evaluation frameworks and expanded dissemination to broader educational contexts.

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Game Design and Teaching for Understanding

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Abstract: This paper will look at how game design can be related to Learning Outcomes (LO) based on Blooms Taxonomy, and to the Teaching for Understanding (TfU) framework. I argue that traditional assessments often offer learners a closed pathway to solutions by delimiting the problem by title and required sources whereas requiring learners to design a game on a topic requires a research process which explores a wider range of possibilities. Game design as an assessment requires students to cross the bridge from narrative descriptions of problems to expressing them in the procedural rhetoric of game mechanics. Whereas narrative explanations always include an element of ambiguity, game mechanics require explicit rules. Based on actual cases in teaching, I will lay out how the different elements of a game design assessment fits with both learning outcomes and Teaching for Understanding. As Teaching for Understanding is focussed on process initiated by generative questions rather than outcomes, it is a better framework for developing the skills required to explore contemporary complex and 'wicked' systematic and systemic problems.

Keywords: Pedagogy, Game design, Assessment, Learning outcomes

1. Essay v Game

I began experimenting with game design based assessments around 2006 due to the limits of essay-based assessments in a humanities field. It was clear that many students were meeting the learning outcomes by producing papers which did indeed embody the tropes of the field but their work did not evidence of a mind at work indicating understanding of the problems being explored. This is more problematic when Large Language Models can generate text which models very closely the sort of writing which academics regard highly.

In essay-based assessments the title often closes off the question by setting limits and pre-determining the main axis of the argument. This may be further circumscribed by providing a set reading list and having delivered lectures on the topic. Many students come to university from secondary systems which reward answers based on 5 to 7 paragraph essays in which each paragraph consists of three facts and a date, and it is all too easy for them to slide through university and produce adequate answers by replicating this model.

Playing, or designing a game, demands a more open approach which weighs a wider range of possibilities and force learners to make decisions about possible alternative outcomes and their likelihood.

“This is to engage in counterfactual history – to ask not just what happened, not just why and how it happened, but also what else did not happen, and might have done, and what might have been the consequences of these alternative narrative causalities? To re-quote Patrick Rael “Counterfactual history is real history ... to engage in counterfactual history is actually to engage historical thinking, historical methods and skills ... Counterfactual history is serious history ...” (Suckling, 2024)

Even the simplistic designs of wargames (and games in general) prior to about 1976 offered a deeper challenge to learners than simply reproducing disciplinary tropes in an essay. Thus, in a game like Napoleon at Waterloo which offered learners complete control of all the elements of the action and the ability to finely calculate the likely outcomes of any combat in advance still required them to do more thinking than summarising the content of the accepted narratives.

But that is to disregard key concerns in the minds of the leaders in both cases. On the morning of Waterloo, and for most of the day, Napoleon had no idea where Grouchy was, if he would arrive and or if he would prevent the Prussians from appearing. At Gettysburg on the first day, Lee had no idea where most of his army was, and through the whole battle had no idea where Stuart’s cavalry was or if they might appear.

In conventional assessments, The Imperial Guard, Picketts Division, Hamlet and Romeo march resolutely towards their inevitable doom. In Game Based, and Game design based assessments, Learners must begin not at the end of the journey, but at the beginning, ripe with possibilities for alternative pathways. If we are to understand and learn from the humanities, we need to consider how the actors in our stories saw their situation and what alternatives they considered possible, and why they chose as they did

Additionally, game design-based assessments require learners to decompose problem into their components, identify relationships between parts of the problem, and quantify those relationships so that they can be expressed as game mechanics. These are important skills required for analysing real world problems. These

skills are particularly important for building any digital tool where the ability to convert narrative description to digital processes is an essential, and rarely taught skill.

We now know that our world is not a simple clockwork thing, where certain clear actions will produce predictable outcomes. From Bacon and Descartes until WWII, objective science based on clockwork models working within disciplinary boundaries led to huge advances in human knowledge. Since WWII we have come to confront a range of problems which do not admit of solutions by simply building a better clock. The most important real-world problems which we now face are complex rather than complicated.

Complicated problems are mainly confined to a single disciplinary field, may involve many moving parts but can be resolved with a simple, mechanical, and predictable methods. They can be reduced to pieces of knowledge which, when fitted together in the correct way, lead to a solution. Complex problems go beyond the clockwork model of complicated problems and involve systems which are often do not have clear boundaries and are sensitive to small variations in initial conditions. Complex problems manifest emergent behaviours and may exhibit sudden state changes. The relations between elements of complex problems are often non-linear.

Complex systems theories were first applied to understanding problems in ecology and climate (Meadows and Club of Rome, 1972) but are now seen as vital in understanding a range of problems.

2. Narrative Ambiguity, Procedural Rhetoric and Explicit Rules

Notwithstanding the difficulty involved in modelling complex problems in a game design assessment, it is possible to leading students through the process of deconstructing the narrative of a complex problem and exploring how one can grasp how some of the elements interact with each other. Over time, I have iterated towards a course sequence for my game design courses which helps to move from ambiguous narrative to explicit rules.

- Choose Topic
- Identify a lead character
- Identify 3-5 important actors
- Identify important processes linking characters and their journey through the game world
- For each of these, state a key step or event in 1 sentence. (Matrix Games)
- For this step, identify 3 things which contribute to a positive outcome
- For this step, identify 3 things which contribute to a negative outcome

Students are allowed to suggest their own topics for their game designs, but a list of possibilities is provided. Students are required to produce concepts for digital or analogue games for two different problems in semester long courses. Students, supported by readings on worldbuilding in games, describe the setting or world in which their topic is located. Students are then asked to identify a key character, a 'hero' and 3-5 important actors present in this game world. Identifying the processes at play in the problem setting is supported by readings on the 'Heroes Journey' and Vladimir Propps formalist theories of folklore, although these do not always fit well with this step of the process as we move from a narrative focus to a process one. By now the students are developing a systems model of the actors in the system and the interactions between them. Students are presented with an abstract model of a systems diagram and asked to name the objects and flows in it. (see Figure 1)

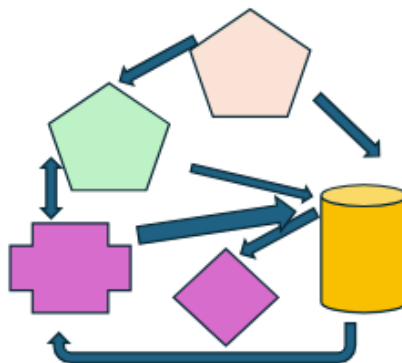


Figure 1: Simple systems model showing problems elements and flows between them

At this point in the semester, we begin to move towards explicitly describing processes or events in the game world. Students are asked to express action in the world in the form of matrix game statements. Matrix games develop from Delphi Method Simulations by requiring participants to state what will happen in a specific format: "My Character will sneak into the Temple of Elemental Evil. They will succeed because they will do it at night, because it is dark and some of the guards have poor vision. They may fail because there are traps, and some of the guards are dark elves with night vision."

The next step is to begin putting numbers on these interactions. This is a significant step, it can be considered a threshold concept in game design-based assessments. (Meyer, Land and Baillie, 2010) Probabilities on 3 normal 6-sided dice (which generate a normal distribution curve) are explained, as is the way in what character attributes in tabletop roleplaying games relate to real world abilities using GURPS (Generic Universal Role Play System) as an example. To explain this, I describe my own attributes and skills in terms of the GURPS system values – I have below average dexterity and skill, but above average intelligence. My research skill is excellent, but my academic writing skill would not be as high. Sherman Kent's work on language of estimative probability is also introduced to inform this step. Kent surveyed NATO officers to determine what they meant by the language they used to express the likelihood of future events, and from this produced a set of recommended terms for use in intelligence estimates (see Table 1) . This method is used in reverse to convert results from clinic drug trials into plain language on leaflets provided to uses of pharmaceuticals (Kent, 2025).

Table 1: Language of estimative probability

Kent's "words of estimative probability"		
Certain	100%	Give or take 0%
The general area of possibility		
Almost certain	93%	Give or take about 6%
Probable	75%	Give or take about 12%
Chances about even	50%	Give or take about 10%
Probably not	30%	Give or take about 10%
Almost certainly not	7%	Give or take about 5%
Impossible	0	Give or take 0%

By this point, students will have made significant progress from an initial narrative description of the problem on which their game design assessment is based to at least a partial quantitative model of the situation. Students are not expected to produce a comprehensive stock and flow diagram for a system they are exploring since they are required to produce outline concepts for two games on different topics during the semester.

I will now look at how this fits with assessments under LO and TfU in specific cases.

3. Learning Outcomes

While having Learning Outcomes is better than not having any form of common vocabulary to describe courses, they suffer from severe limits. LO based on Blooms taxonomy were originally defined in 1956 and therefore are firmly located in a period dominated by behaviourist concepts of education. Even though Blooms Cognitive Taxonomy was improved by the revision of Anderson and Kraithwohl in 2001 (Anderson and Krathwohl, 2001), the framework predates and does not reflect the emergence of constructivism or cognitive theories of pedagogy

It is possible to frame LO to reflect constructivist pedagogies, but this is not a comfortable fit. In particular, LO do not address the process of building understanding over the sequence of a course. LO approaches do not naturally accommodate what we now know about the internal process of cognition and how learners

incorporate new knowledge into their internal 'map's of knowledge. While constructivist theories of learning are by no means complete, they have moved on significantly from when LO were conceived. Criticism of LO is thin recently, because such critiques have been swamped by the bureaucratic stranglehold LO enjoy, but well-founded critiques do exist. For example, as early as 1971, Sockett and Pring both argue that Blooms taxonomy was not strictly speaking a taxonomy at all and imposed an impossibly precise veneer over complex concepts. Even at the lowest level, of remembering, in the case of a traffic accident, our memory of the 'facts' are affected and filtered by a reasoning process based on our prior ideas of how such an event unfolds. (Pring, 1971). Pring argues that

"To say that one knows that something is the case, namely, that Henry VIII had six wives or that gases expand when heated, means that one understands not only the concepts employed but also under what sort of conditions these statements might be considered true or false. That is, knowledge entails both comprehension and application – it is not possible to aim at knowledge and then at the understanding of this knowledge and then at applying it. To know that something is the case entails understanding what it means to say that something is the case and this in turn entails being able to apply this knowledge to particular situations."(Pring, 1971)

Pring in his conclusion argues that Bloom failed to investigate what it means to know something, making his classification inadequate for its purpose. Since behaviourism dominated theories about learning when the taxonomy was developed, it is hardly surprising that it did not take account of how we learn. Working within the system of Learning Outcomes based on a conceptually limited base is therefore difficult.

4. Teaching for Understanding

Teaching for Understanding (TfU) traces its intellectual lineage back to the progressive educational ideas of John Dewey who emphasized learning through experience and reflection rather than rote memorization. Dewey's philosophy laid the groundwork for pedagogies focused on active, student-centred learning (Dewey, 1938). It is also informed by constructivist theories of learning. Influenced by Jean Piaget and Lev Vygotsky, TfU emphasizes that learners construct knowledge actively through interaction with their environment and social contexts (Piaget and Cook, 1952,) (Vygotsky, 1978).

The TfU framework was developed in the late 1980s and 1990s by researchers at the Harvard Graduate School of Education. It responded to concerns that students were learning facts but failing to apply knowledge in meaningful ways. Howard Gardner, known for the theory of multiple intelligences; contributed ideas on personalized and meaningful learning while David Perkins advocated for understanding as the ability to think and act flexibly with what one knows. This leads to the idea central to TfU of 'performances of understanding' which lead to achieving understanding goals (Perkins, 1992) (Gardner, 1995).

The core elements of the TfU Framework are

Generative questions: Open-ended, thought-provoking inquiries that spark curiosity and guide learners toward exploring central ideas and developing deeper understanding.

Understanding Goals: Clear expression of what students should understand.

Performances of Understanding: Activities that require students to apply knowledge in new and increasingly challenging situations.

Implicit in the framework are the ideas of ongoing Assessment through performances of understanding and the provision of continuous feedback to guide and deepen student understanding. Also important is a learning environment which encourages curiosity, collaboration, and risk-taking in learning (Blythe, 1997).

TfU emerged as reaction to outcomes-based approaches and "teaching to the test", which is a natural consequence of the superficial use of LO. TfU provided a pedagogical response that aligned with constructivist theories(Wiske, 1997).

A key feature of the TfU framework is the planning grid which shows clearly the relationship between generative questions, throughlines, performances of understanding and understanding goals. In this version (Table 2) extra rows are included to allow for planning specific activities across a 12 week semester.

Table 2: Teaching for Understanding Organiser

	Generative Question		
Student entry point - prior knowledge? Relevant skills?	Throughline	Throughline	Throughline
Performance of Understanding 1 'Messing around'			
Performance of Understanding 2 Guided Inquiry			
Performance of Understanding 3 Mastery			
	Understanding Goal	Understanding Goal	Understanding Goal

5. Case: Wargame Design

The oldest case was in a second year undergraduate survey course on “War, State and Society, 1405-1920”. In this course a conventional mid term essay was replaced by a group task in which students designed a one page wargame on a battle from the ‘Age of Battles’.

The learning outcomes for the module were

1. Demonstrate an accurate knowledge of the major developments in military history since 1450 by deploying this information in examination answers and coursework.
2. Demonstrate a knowledge of the central historiographical debates and methodologies of military history and how they to the relevant historical issues, concepts, dates, figures, and evidence by deploying these concepts and methods in examination answers and coursework.
3. Demonstrate an ability to engage in online, reflective discussion of issues relating to the course
4. Locate, analyse and synthesise a body of primary and secondary source material appropriate to the field.
5. Acquire the necessary skills and abilities associated with studying the context and conduct of warfare.
6. Acquire and apply a range of skills associated with research, writing, analysis, argument, evaluation and historiography to participate in individual and group work associated with active analytic military history.
7. Acquire and demonstrate the necessary skills associated with writing clear and comprehensive examination answers.

There is no reference to game design in those, given that no one else was using game design as assessment, no 6 was inserted in which ‘active analytic military history’ clearly refers to wargame design in language which wargame designers would recognise but which would not attract the notice of curriculum rules committees.

Students were introduced to simple or entry level hex and counter wargames, specifically Napoleon at Waterloo (SPI, date). The mid-term was only 20% of the total course mark. Setting it as a group exercise reduced the risk an individual failing to grasp some element of what was required. Discussion threads for each group were created in the LMS, and their activity in those discussions was monitored. Technical feedback was

provided and, where needed, groups which were falling behind were engaged with. To provide clarity on expectations, the comparison with a conventional essay was laid out for the students. All of these were done to reduce the risk involved in introducing a novel assessment.

The initial version of this table (Table 3) only included indications of later grades whereas in this updated version specific sentences from the grade descriptors from the universities general rubric for all subjects are added for clarity.

Table 3: Elements of essay, wargame design exercise and grading guidance

Bloom's Taxonomy (revised)	Essay	Wargame Design	Grade
CREATING	Historical debates, Hist Understanding,	Design notes which reflect on the game	A. A highly developed capacity for original, creative and logical thinking
EVALUATING		Games rules in total, Special rules, victory conditions	B+/A well-developed capacity to analyse issues, organise material, present arguments clearly and cogently
Analysis	Linkages, relationships	Game rules – cases (move, fire etc)	C average critical awareness and analytical qualities
Application		choose scales and design counters, map	C some effort to engage, but only a basic understanding of the topic portrayed
Comprehension	Significant facts?	tables of organisation	D descriptive rather than argumentative or analytical answer presented
Knowledge	Facts	Order of Battle, Map	D basic grasp of subject matter but limited focus on question asked

The assignment proved to be uncontroversial and quite successful. From 2006 until 2012 student groups produced games which were usually comprehensive and accurate, within the limits of historical sources, for their cases. Many groups identified critical elements of the battles such as terrain features or leadership failures. Most groups were able to justify their choice of special rules or victory conditions. Games were playable and balanced (again, within historical constraints). Occasionally, attempts to devise innovative mechanics to resolve combat were not a success but this was often due to limited numeracy among humanities students and in any event, credit was given for making a genuine attempt to explore the representation of kinetic effects in the design. While the assignment had a substantial visual element, no marks were given for graphic quality since this was outside the capability of the students.

For the purposes of an example for this paper, I retrofitted that older assignment with the elements of the TfU framework – a generative question, throughlines, understanding goals and performances of understanding (Table 4). The main feature here is that the three performances of understanding align with the process suggested to the students for the original assessment, and groups which followed those steps were generally more successful than those which lacked a structured process. The third throughline and understanding goal on the value of games was not an explicit element of the original assessment but it certainly came up in discussions during the course and I would now include it explicitly. The three understanding goals could be presented as learning outcomes in a module description

Table 4: Wargame design exercise outline in Teaching for Understanding organiser

	Generative Question: How can designing a wargame help us understand the impact of, technology on the development of operational art in historical battles from 1450 to 1815?		
Student entry point - prior knowledge? Relevant skills?	Throughline: How did military strategies and technologies shape the outcomes of early modern battles?	Throughline: In what ways did geography and logistics influence historical warfare?	Throughline: How can games be used as tools to represent and explore complex historical events?
Performance of Understanding 1 'Messing around'	Students study a specific battle to identify troop types, units and terrain.		

Performance of Understanding 2 Guided Inquiry	Students explore their chosen battle to know about army organisation, how combat plays out and how terrain and leadership affect the battle		
Performance of Understanding 3 Mastery	Students create integrated rules and mechanics for a simple wargame that reflects the historical dynamics of their chosen battle, justifying their design choices with historical evidence.		
	Students will understand the tactical principles and key technologies that defined warfare in a chosen battle from 1450–1815.	Students will understand how terrain, supply lines, and troop movements impacted operational decisions.	Students will understand how historical simulations and games can model—but also simplify—real historical complexities.

6. Case: General Game Design Assessments

Over the past decade in the Dept of Digital Humanities we have explored several areas of game related research and teaching, including narrative driven games and the possible applicability of ‘auteur’ theory to the role of lead game designers. Since our teaching is strongly research led (and our research is often informed by our teaching), we have offered a range of game design based courses. The structure of our current offering follows the game design sequence outlined above (see section 1.3, key steps of which are included in this TfU chart)

Table 5: General game design assessment presented in Teaching for Understanding organiser

	Generative Question: How can game design be used to deepen understanding, inspire engagement, and provoke meaningful learning on TOPIC X		
Student entry point - prior knowledge? Relevant skills?	Throughline: Design shapes experience – Understanding how mechanics, narrative, and user interaction influence how players learn and what they take away on TOPIC X.	Throughline: Games are powerful learning environments – Exploring how games can simulate systems, encourage exploration, and support knowledge construction on TOPIC X.	Throughline: Games reflect and challenge values – Examining how games carry assumptions, represent (or misrepresent) perspectives, and offer space for critical reflection on TOPIC X.
Performance of Understanding 1 'Messing around'	Students select a topic and identify key elements of that topics - actors/characters, world/setting (Choose Topic, Identify a lead character , Identify 3-5 important actors, Identify important processes linking characters and their journey through the gameworld.)		
Performance of Understanding 2 Guided Inquiry	Students map the relationships between game elements and quantify those relations (For each of these, state a key step or event in 1 sentence, identify 3 things which contribute to a positive outcome, identify 3 things which contribute to a negative outcome.)		
Performance of Understanding 3 Mastery	Students have a near playable (B/C) or finished (A+) game on their topic and can reflect on how it explores the problem under study. Students can reflect on their learning from the process.		
	Understanding Goal: (Design shapes experience) Students will apply principles of game design to create learning experiences that align game mechanics learning on the chosen topic	Understanding Goal: ((Games are powerful learning environments) Students will understand how different types of games can facilitate various kinds of learning—cognitive, emotional, social—and evaluate their educational potential.	Understanding Goal: (Games reflect and challenge values) Students will analyse how games represent ideas, cultures, and systems, and design games that either reinforce or critically question existing narratives.

In this general framework(Table 5), activities related to each throughline and understanding goal will not always be evenly distributed across the duration of the module. Work related to throughlines 1 and 2 will

mainly arise in the first two thirds of the course. Work related to the third throughline-understanding goal pair (Students will analyse how games represent ideas, cultures, and systems, and design games that either reinforce or critically question existing narratives.) will mainly appear in the final part of the course. Throughout weekly feedback is provided in the discussion forums and by video. For Group work, students are introduced to current guidelines on crediting contributions and expected to meet these. This progression not only fits with the Community of Inquiry model but also with the Structure of Observed Learning Outcomes model (SOLO) offered by Bigg and Collis in 1982 (Biggs and Collis, 1982). SOLO represents a significant conceptual advance on Blooms taxonomy, showing how learners make richer and deeper connections at higher levels in a way which Bloom, even in its revised form, does not.

While the conventional TfU structure only identifies three assessed performances of understanding, I break the work into weekly sections with student answers posted in course discussion forums. This allows monitoring, especially in the early stages of student progress as the early stages tend to be fragmentary and exploratory. The later parts tend to range more widely, integrating ideas and advancing towards a critical resolution of the topic. Each weeks work, as well as the overall course arc, tends to follow the Community of Inquiry model (Trigger-Exploration-Integration-Resolution) which is similar to the Interaction Activity Model. (Garrison et al, 1999; Gunawardena et al 1997) Early weeks of the course include lectures on elements of contemporary games across genres – board, collectible card, deckbuilding, tabletop rpg – since students lack broad knowledge of the range of game type and possible mechanics.

When students have chosen topics for their game designs (and students, especially undergraduates, often have difficulty in choosing topics.) they can then be prompted to suggest their specific generative question and throughlines to help frame their specific game topic. Thus games on climate resilience for example may engage with issues like local and global action, or the just transition in their generative questions or throughlines.

7. Conclusions

Assessment across the Humanities and social sciences is still dominated by essay answers or similar. Academic planning is dominated by the learning outcomes rooted in Blooms taxonomy. The bureaucratic stranglehold enjoyed by learning outcomes based approaches, manifested in Europe by being explicitly mandated in the European Higher Education area because of the Bologna process, marginalises models which better reflect of growing understanding of cognitive process and the constructivist paradigms like Community of Inquiry, Interaction Activity Model, Structured of Observed Learning Outcomes and above all Teaching for Understanding. Advocates of game based and game design based assessments often face issues in linking their teaching to assessment guidelines. Here I have looked in detail at how this was resolved in my teaching. In practice, mapping game design assessments to LO was mainly done to comply with institutional rules but these assessments were framed in the TfU framework. Linking the sequence of activities in game and game design based learning to contemporary pedagogical theories facilitates explaining these to external examiners, as well as to students in ways which foster their metacognitive development

Ethics Declaration: No ethical approval was required for this paper

AI Declaration: LLMS were used for initial generation of some elements in Tables 4 and 5; necessary edits were applied to make these fit the models in these tables

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Bringing Healthcare-Level Hand Hygiene Skills to Children Through Iterative App Design

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Abstract: Handwashing is an effective and low-cost practice that offers protection against a host of infectious diseases, both respiratory and gastrointestinal—but only when it is done at the appropriate time, with proper technique, and consistently when indicated. Public health efforts that emphasized access to clean water, soap, and towels, were combined with public messaging through flyers, posters, and videos with prompts to wash hands. Yet despite these efforts to raise awareness, the public health achievement gap has remained intractably wide. One problem is technique: teachers and parents are not commonly taught proper handwashing skills, which translates into imperfect technique being transferred to children in their care. Another is healthy habit formation: despite years of pandemic, heightened awareness, and sincere efforts by adults and children alike, durable handwashing practices have not taken hold. To address this unmet public health need, we developed an interactive digital trainer for touchscreen devices commonly found in schools and at home. Teacher co-developers, domain experts, students, and parents participated throughout the project, through rapid and frequent cycles of design, build, test, and refine. The trainer 1) conveys proper technique with accurate hand anatomy for high-fidelity learning; 2) provides critical visual feedback of germs remaining, so that players learn to use the appropriate scrub motion to address specific areas on each hand; 3) simulates infection transmission schoolwide, for experiential learning on when handwashing is indicated; 4) fosters habit formation, over several sessions, for lifelong gains in hand hygiene. This approach to game design, development, and evaluation was critical to the success of this project and is broadly applicable to many other learning domains.

Keywords: Game design for education, Serious games for skill development, Mobile and tablet games, Interactive simulations, Games for public health

1. Introduction

While healthcare has been highly effective in diagnosing and treating disease, the final and missing link has been improving healthy behaviour in individuals. Clean water and sanitary sewer systems have greatly reduced the transmission of many common diseases, but the "last kilometre" of public health is individual behaviour. Where vaccines and masks have proved controversial, handwashing has been spared the intense political debates that have surrounded other public health measures. Handwashing remains cheap, and if performed correctly, very effective in reducing the transmission of a host of diseases, including the common cold, influenza, and polio.

Notably lacking in the worldwide public campaign to wash hands, and the expensive installation of handwashing stations and signage, was *effective training in technique*. To address this unmet need, we developed an interactive hand hygiene learning game (the *Bubble Beats Trainer* 2025), for children and adults, to teach how to wash, when to wash, and foster consistent practice. We set a very high benchmark for success, with the following design features:

- the training must be engaging
- the training must have high fidelity to real-world practice
- the training must be to a high standard

Interactive digital media training in *effective technique* has not been commercially available. For students, only low-fidelity simulation training has been assessed (Lee 2015, 2022). Fidelity to real-world behaviour is crucial to effective training and may explain the less-than-stellar improvements yielded from these approaches. Two studies *simplified the training* to an abbreviated hand washing procedure (Younie 2020, Lee 2022). One study used *video* examples of handwashing, was therefore not interactive (Lee 2022). Computer vision systems to identify handwashing motion are engaging, but low-fidelity, and often error prone (Kang 2019).

2. Design Choices and Trade-Offs

2.1 High Engagement: Capture Players' Attention, and Reward Their Participation

Creating an entertaining and accurate learning game about hand hygiene is not trivial. An important learning goal is systematic and thorough handwashing. Inducing the player to perform handwashing again and again is about as engaging as practicing musical scales on a violin. But practicing musical scales opens the door to a world of expressive music, but practicing handwashing simply leads to more handwashing. For good game design, many of the features we would expect to be present are lacking, as shown below in Table 1.

Table 1: Engaging games have features that real-world handwashing lacks

	Engaging Games	Real-world Handwashing
Activity	Varied	Repetitive
Visual Feedback	Often Immediate	Almost None
Learning Curve	Rising	Plateau
Strategy/Tactics	Frequently Vital	Absent

Table 1 illustrates how effective handwashing may be an important skill, but the training to wash hands at the sink does not immediately translate into an engaging game. Nevertheless, a good learning game design should resist the temptation to make a more engaging game in ways that harm the learning. One game (Sponge 2016) turned the handwashing activity into a chase across the hands: players moved a scrubbing cursor to capture a moving bug. Although pursuit is naturally engaging, the portrayal of accurate scrubbing suffers.

Adding visual feedback is another challenge, because in real life, germs are invisible without magnification and/or special dyes and illumination. Making them visible, or compressing the time between pathogen exposure to development of symptoms (SureWash 2024), risks sending the wrong message to the player. In real life, contaminated hands do not show creatures the size of small insects. In real life, it takes hours or days to incubate an infection. A player's own day-to-day experiences will contradict this message. Conversely, the message may prove to be *too effective*, encouraging unwanted phobias.

Finally, when presenting scenarios to a player, to learn when handwashing is indicated, the answer should not always be the same: *wash your hands*. To hold a player's interest, the game should provide *variety* in the activity, an increasing learning curve of *challenge* commensurate with the player's improving skill and involve some *planning* or *goal setting* through strategy or tactics for long-lasting engagement.

2.2 How to Wash: Efficient Visuomotor Transfer of Handwashing Technique



Figure 2: Hand anatomy is not a priority in these screenshots of popular handwashing demonstrations: (1) Sesame Street: Washy Wash Song, (2) Baby Shark Wash Your Hands, (3) Wash Hands reminder tracker, (4) Ellie's Hand Wash Adventure. A handwashing learning game that does not portray hands accurately, but instead shows static, flat artwork, is a missed opportunity to demonstrate proper technique

To foster good handwashing technique, the learning game should above all depict hand anatomy *accurately*. One severe shortcoming of existing learning games has been the use of cartoon-style hands. These simplified, two-dimensional representations fail to model the scrubbing motions needed for effective handwashing. In other contexts (Sharmin 2023), learners have struggled with the cognitive load to visualize 3D structures when presented only 2D representations. Accurate spatial representation (Hegarty 2011) can reduce this cognitive load (Ishikawa 2021).

For all players, including children, we chose the hand hygiene standard for healthcare workers (World Health Organization, 2009). Mere depiction of accurate anatomy is not sufficient, however. The player must participate in the manipulation of these 3D rendered hands.

For training in handwashing, augmented or virtual reality would be ideal. But the practical problems of implementing this technology are significant. One app (SureWash 2020) uses computer vision with augmented reality to train and assess whether learners are performing handwash scrub moves correctly. However, consumer-grade computer vision is still evolving. Rear facing cameras on smartphones and tablets are almost always superior to those facing forward and embedded in the display. On higher-end phones, rear-facing cameras may also be accompanied with depth-sensing scanners. Unfortunately, apps are limited to using the front-facing cameras when the user needs to interact with the screen at the same time the camera is in use. As a result, smartphones and tablets have difficulty resolving the positions of two hands with intertwined fingers. Finally, the number of virtual reality and augmented reality systems remains vanishingly small, compared to devices with touchscreens—especially in schools.

For these reasons, we chose to develop 3D animations of hands that would work on 2D devices with touchscreens, without special use of cameras.

2.3 Practical Endpoint: target Behaviour Change in the Real World

Designing a highly engaging game is by itself a challenge. More difficult is designing a learning game that holds the player's attention and delivers learning games. Still more difficult is a game for health: one that improves real-life behaviour that results in healthy outcomes (Verschueren 2019, Thompson 2010). Just how these behaviours can be changed through game play is a matter of debate (Baranowski 2016), with several similar, overlapping, and difficult-to-reconcile theories of behaviour (Noar 2005, Sheeran 2017). Many of these health behaviour models describe a *mediator* (MacKinnon 2011, Schwarzer 2008), or intermediate factor that influences health status. For example, a prevention program may target changing social norms (the mediator) to reduce tobacco use (MacKinnon 2002).

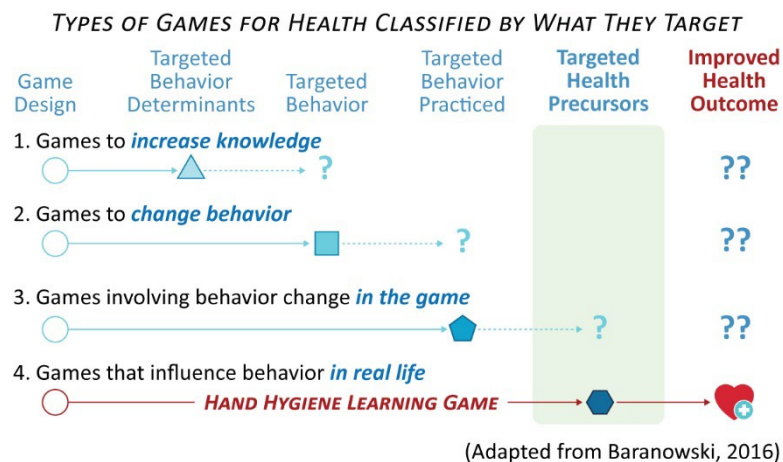


Figure 2: Games for health can be classified by how closely associated they are with the desired health outcome. The closer the game is to the health outcome, the stronger the association. For our hand hygiene learning game, the targeted health precursor will be effective handwashing, demonstrated by players, at the sink

Baranowski (2016) and others (Thompson 2007) have used the mediator of *self-efficacy* (Bandura 1998) to build games that manage childhood obesity and type-II diabetes in vulnerable populations, by encouraging players to regulate calorie intake. Others have built games that intervene in the days before a surgical procedure, or the onset of chemotherapy, to reduce anxiety and other *targeted health precursors* to improve medical outcomes: these acute interventions have resulted in more positive attitudes toward therapy and have even reduced hospital stays.

Baranowski classifies Games for Health into 4 types (Figure 2), with increasing penetration into the chain of events that influence health status. Type 1 games merely increase knowledge and have the weakest association with desired health status. Type 2 games attempt to change behaviour outside of the game. Type 3 games attempt to change this behaviour both inside and outside the game. Type 4 games intervene most closely to the

desired health outcome, have the strongest association, and the highest likelihood of successful behaviour change.

For the hand hygiene learning game, effective health behaviour change would use the endpoints of improved handwashing technique with an external, quantitative assay. It is superior to a Type 1 game, because it does more than increase the student's knowledge about handwashing. Because accurate handwashing is practiced and assessed both in the game as well as in real life, the learning game fulfils the criteria for a Type 2 and Type 3 game. Finally, because the learning game addresses a targeted health precursor to transmissible disease (hand hygiene) it has the potential to be a Type 4 game, the most powerful association with improved health status.

2.4 Interactive and Responsive: Provide Critical Visual Feedback to the Player

The challenge of teaching effective handwashing is the lack of critical visual feedback. Neither a parent nor a child can tell, merely by looking, whether the hands have been cleaned. Without visible evidence of what was cleaned and what was missed, a student may never practice handwashing correctly, even if highly motivated to do so.

There is, however, a helpful workaround when demonstrating handwashing in person: hand lotion with invisible dye that glows brightly under ultraviolet light (Glo Germ). Once applied, the dye cannot be seen on the hands. It is removed by thorough scrubbing with soap and water. After washing, inspection of the hands under ultraviolet (UV) illumination reveals bright fluorescent areas that were missed.

Therefore, we planned to emulate this experience in the learning game: players would wash the virtual hands, but would receive no visual feedback on their progress. Only after deciding that washing was finished, could they inspect their hands, using a virtual UV light that would highlight areas that were not completely washed.

2.5 When to Wash: Players Should Discover for Themselves When Handwashing is Indicated

The simplest, and most obvious way to teach players when to wash their hands is through flashcards. As Baranowski argued, however (see Figure 2), mere knowledge may not translate into real-life action. Instead, the learning game may do better to follow advice for effective writing: *show, don't tell*. This approach is the basis for *experiential learning*.

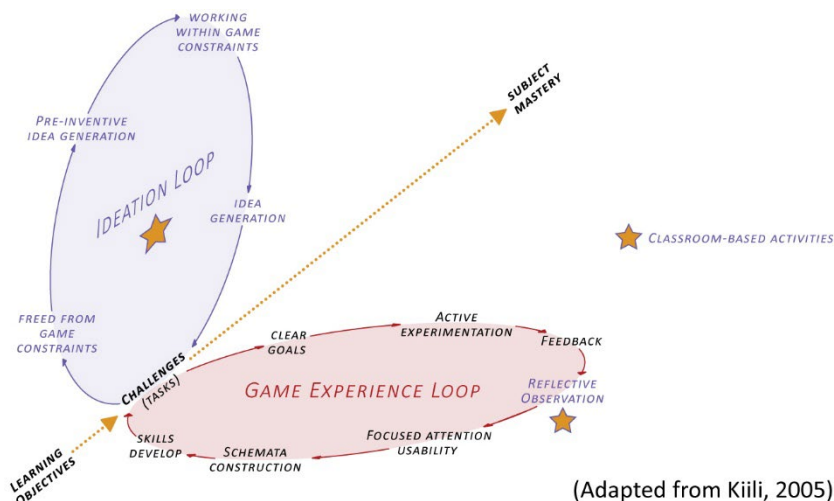


Figure 3: An experiential learning model for learning games adapted from Kiili (2005). Learning involves contributions from both direct gameplay (the game experience loop), as well as contemplation when not actively playing (the ideation loop). Good learning games embrace both—by supporting ideation, learning and memory consolidation outside the game. The game confronts players with challenges or tasks, which are overcome where these two loops meet. Progress towards subject mastery occurs when these loops function in concert

The experiential gaming model is composed of two activity loops: ideation and game experience. The ideation loop begins with free-form imagination (free of constraints otherwise imposed by the game onto the world), followed by idea generation that works within the constraints of the learning game. This cycle is the process by which players invent new models of how the game world might work; Kiili notes that this ideation cycle is best when performed in groups, such as in a classroom.

Next, players test these ideas in the game: good games have a clear goal, invite experimentation, and provide immediate feedback to the player. Reflective observation allows players to share their experiences, describing what they thought was at stake, their strategies, and the results of their choices (indeed, some of the greatest value derived from games is sharing the experiences with others). Consolidating the reflective observation may then lead to the formation of new and better solutions (schemata) which in turn may develop the player's skills to the point of steering the game to the desired outcome and subject mastery.

A learning game (or almost any computer game) can be thought of as a series of challenges served up to the player. For a learning game, these challenges stem from the learning objectives. When this system of ideation and experience loops are optimized, players are pushed into a zone of proximal development, at the edge of their competency, fully engaged, combined with immense drive to master the challenge. Harnessing this powerful engagement, and directing to mastering the targeted learning objectives, is the holy grail of game-based learning.

In the case of hand hygiene training, players should encounter scenarios where handwashing should occur. When they fail to act, they should witness pathogen transmission unfold, in a manner that mirrors actual disease. If the design is flexible, new scenarios can be added to the training, for comprehensive training on when to wash. The win state for this learning mode should be identification of these scenarios, with prompt action to wash hands.

2.6 Consistent Practice: Healthy Habit Formation for Lifelong Benefits Through Improved Hand Hygiene

Healthy habit formation for hand hygiene has been studied in healthcare workers (Al-Tawfiq 2013, Eiamsitrakoon 2013, Srigley 2015), using the theory of planned behaviour (Ajzen 1991) and the transtheoretical model of change (Prochaska 1997). We used this framework in designing our learning game, shown below in Figure 4.

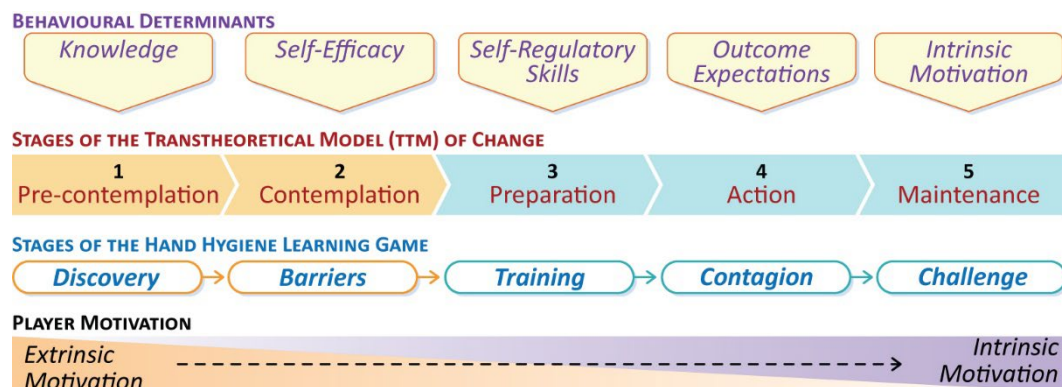


Figure 4: The hand hygiene learning game uses the Transtheoretical Model (TTM) of change (Prochaska, 1997) to migrate players, in stages, from pre-contemplation to maintenance of effective hand hygiene. Behavioural determinants (in yellow, top row) contribute to each stage of the TTM model. Like other models (Baranowski), TTM weighs pros and cons of choosing a healthy behaviour and uses self-efficacy to empower the individual to perform it. We used these insights to design stages of the hand hygiene learning game (text bubbles, third row). Finally, on the bottom row, player motivation will shift from extrinsic rewards in the game to intrinsic motivation as the player progresses through higher stages. This conceptual framework follows TTM theory—as well as good game design—to keep players engaged beyond initial superficial entertainment, to more durable and valuable achievements earned in the game

3. Playtesting Results

3.1 High Engagement

Early versions of the learning game used rhythm matching as a game mechanic: when players scrubbed in time with the music, they received higher scores, and cleaned more quickly. We discovered through gameplay that

some players would happily scrub at the fastest rate they could, oblivious to the rhythm. Another significant minority of players exhibited no talent for rhythm, and became frustrated playing this version of the game.

During 3 large rounds of playtesting, involving 20 to 50 children, participants used the hand hygiene learning game on Chromebooks with touchscreens for at least 25 minutes. At the end of each level played, data were logged including level achieved, playing duration, and the number and kind of scrub steps used to complete the level. If players consulted virtual UV inspection, and then returned to a scrub step, that step was counted a second time. Players completed about 3 levels during a playtest session. Participants received a post-intervention questionnaire to evaluate the game. Qualitative responses helped guide the next iteration, by identifying features that were popular, game mechanics that were engaging, and new wash steps that players had learned from the game. Quantitative results from three rounds of playtesting are shown below in Figure 5.

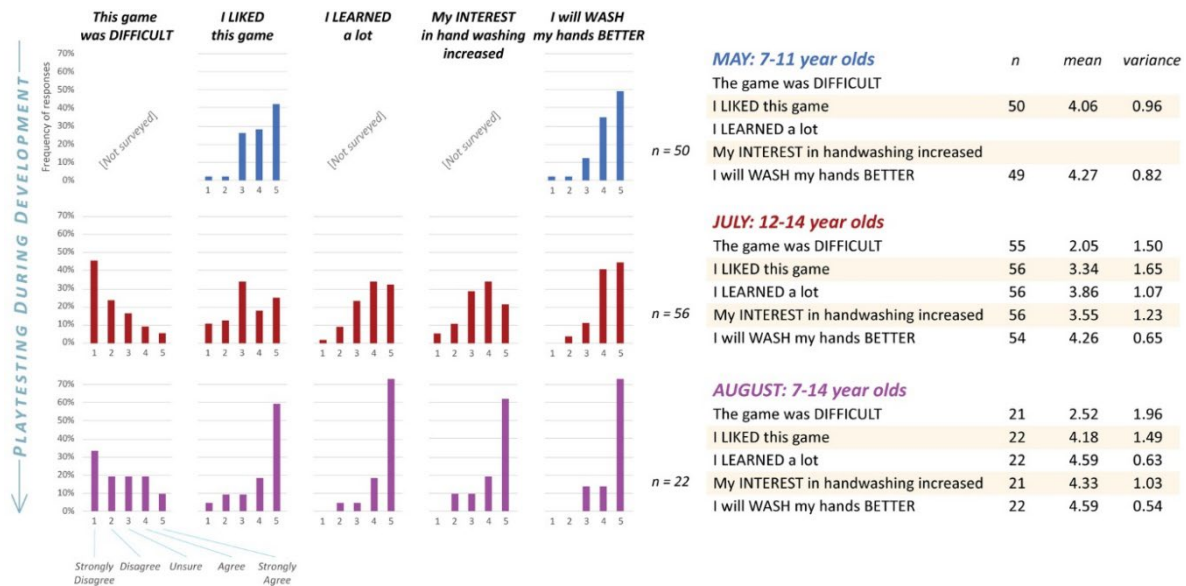


Figure 5: Playtesting results from rounds in May, July, and August show progression to higher survey scores across four measures (liking the game, learning, increased interest in handwashing, and intention to wash hands better). The reported level of difficulty was appropriate: showing nearly even distribution of difficulty

3.2 How to Wash: Accurate Depiction of Anatomy for Efficient Visuomotor Transfer of Handwashing Technique

The World Health Organization (2009) describes 6 specific scrub motions, 3 of which have separate steps for left and right hands. For our training animations, we included wrists, and specified separate left and right steps for fingernails, after discovering reference videos that demonstrated these additional steps (JHU 2019).

A digital single-lens reflex camera recorded reference videos at 4K resolution from a fixed position from the player's point of view when washing hands at the sink. Existing animation models were rigged and animated using Blender, and morphed to create anatomically accurate hands of a child. The completed animation files were imported to the Unity game engine.



Figure 6: The line-art drawing of right thumb scrub is taken from the WHO guidelines on handwashing. In the hand hygiene learning game, this scrub step has been transformed into a high-fidelity animation based on reference videos. Player participation in moving these virtual hands through the proper scrubbing motion increases engagement, learning, and retention

Choosing a touchscreen interface allowed for a broader user base beyond virtual reality systems, but created a new problem: how could the player use a 2D surface to control hands in 3D? Bringing left and right hands together for washing involves translation along the XYZ axes, but also rotation, extension of some fingers while curling of others. For complete handwashing, there are 7 different scrub steps, 5 of them with left and right variants—for 12 steps in all.

We ran a real risk of creating a player control that was *too complex*. Fighting games solve this problem by employing only a few button inputs on game console controllers, but relying on timing and combinations of buttons to create a variety of moves. However, these games require fine motor skills and quick reflexes that are beyond the youngest children in our target audience, and would likely frustrate older adults as well.

On the other hand, if we made the controls *too simple*, we risked losing any training value. If players simply pushed a button to scrub the right thumb, we would rob them of any participation in posing and scrubbing the hands, and likely weaken the connection between action *in the game* with that *at the sink*.

After several rounds of playtesting, we moved away from a cluttered user interface that had 7 buttons (plus a left/right setting), to a simpler, 3 x 3 grid, shown below in Figure 7.

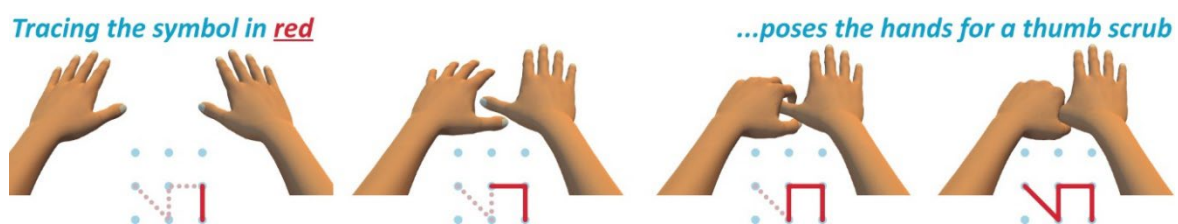


Figure 7: Players pose the hands by drawing a shape that connects dots on a 3 x 3 grid. Each shape is unique, and where possible, suggests the pose itself. In this example, the right thumb scrub shape resembles a hand with a thumb sticking out

This user interface is familiar to Android smartphone users, who use a similar method for unlocking their phones. The interface is compact, giving room to display the hands. An optional hint book helps beginners learn these symbols. When we take the hint book away later in the game, this same interface can be used *for testing*: experienced players can use this interface to demonstrate total recall of every WHO scrub step without prompts.

3.3 Practical Endpoint: Target Behaviour Change in the Real World

Video of handwashing at the sink was recorded before- and after-training for players and scored against a checklist of WHO scrub steps. The results reported elsewhere (Vukanovic-Criley 2025) showed the number of scrub steps performed increased dramatically, from a mean of 5.50 steps to 9.57 steps (t-test, two tails, $p = 0.00094$).

The videos themselves were a powerful testimony of the effectiveness of this training. Before software training, children who plainly wanted to wash hands well were unable to perform WHO scrub steps they had never learned. These steps, like the thumb scrub shown above in Figures 6 and 7, are distinct, and obvious when done properly. After software training, the players performed these new scrub steps unambiguously.

3.4 Interactive and Responsive: Virtual UV Inspection for Critical Visual Feedback on Handwashing

A second learning game feature we discovered through playtesting. Using fluorescent dye and UV illumination is a practical approach to assessing proficiency at the sink (Deochand 2019, Lee 2014). Glo Germ is a non-toxic hand lotion containing a suspension of fluorescent particles that glow brightly under ultraviolet light, but are otherwise invisible in natural light. Participants apply the lotion and rub their hands until the dye was invisible. Using a UV light box, their hands are photographed with Glo Germ applied, both before washing and after, to highlight areas that were missed by incomplete washing.

To help illustrate how Glo Germ is used, we created a virtual ultraviolet mode in the learning game. Players could wash their virtual hands, then turn on UV illumination to check for any areas of the hands they missed. From the first time we introduced virtual UV inspection to play testers, it proved extremely popular. Players were teaching us how to make the game more engaging. Therefore, we made UV inspection more integral to the gameplay loop. We also made UV more valuable by limiting a player's ability to use it.



Figure 8: UV inspection in the game compared to real life. The first two panels show hands illuminated in natural light, and the same hands under ultraviolet (UV) illumination. UV light reveals fluorescent Glo Germ dye that has not been washed from the fingers and thumbs. Virtual UV inspection: The next two panels show animated hands under natural and UV illumination, depicting white spots where handwashing is incomplete

Gameplay data recorded time on task, time on each step, and order of steps selected. Rounds of playtesting showed the following trends: increased playing time, with more scrub steps performed. The increased playing time indicates higher player engagement. The increase in scrub steps per game indicates that players are *increasing* their use of the *virtual UV inspect mode* to check their progress, and then returning to address uncleaned areas, until the job is finished. Maximum scrub steps decreased in August as students became more proficient in use of virtual UV inspection, which revealed when scrubbing was sufficient.

Table 2: Gameplay data from 3 rounds of playtesting

Month	mean playing time (minutes)	mean scrub steps	min scrub steps	max scrub steps
May	7.5	35.8	8	104
July	11.3	48.3	31	127
August	12.8	52.4	34	72

3.5 When to Wash: Immersive Experiential Learning on Disease Transmission

Players learned to wash their hands by witnessing the consequences of *not* washing in the school simulator shown below in Figure 9. The simulator, called Contagion mode, gives players a bird's eye view of classrooms, hallways, bathrooms, cafeterias, and playgrounds. Every time a student in the simulator sneezes, a cone of contamination sprays in the direction he or she was facing. In this simulation, students in this zone of contamination should wash their hands, as well as the student who sneezed. Players can prompt a student in the simulation to visit the sink, to wash his or her hands. This simple game loop delivers powerful learning: other events like a visit to the lunchtime cafeteria, or using the restroom, are layered into the game as the simulation progresses. If a student in the simulation skips handwashing, there is a strong likelihood they will become infected. As the days progress through the simulation, unwashed students can spread germs, develop illness, and become absent from school. If too many students are absent, the school shuts down.

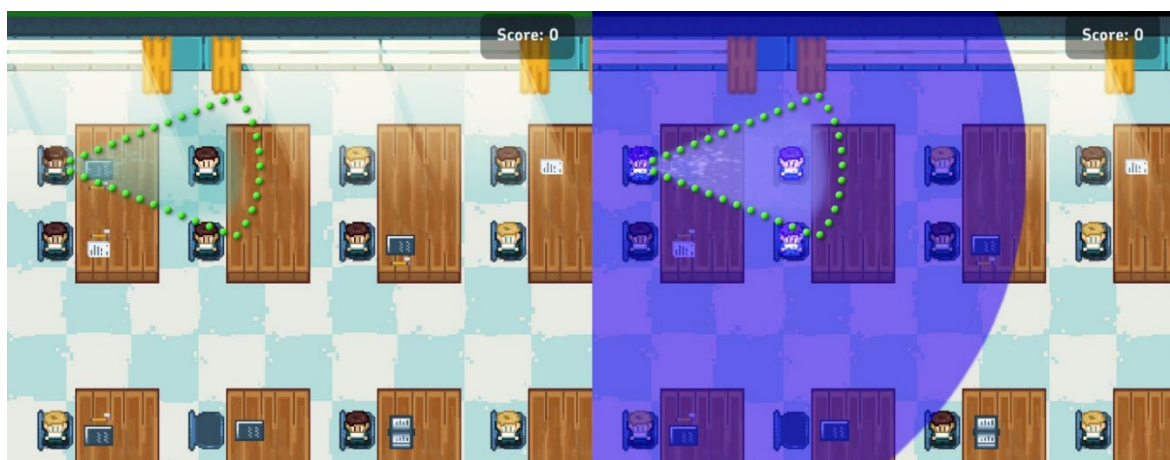


Figure 9: The panel on the left shows a detail from Contagion mode, the simulated classroom in natural light. A child has just sneezed, creating a cone of contamination highlighted with the dotted lines.

The panel on the right shows the same scene with ultraviolet (UV) inspection turned on. In both views, a student has been contaminated

During playtesting, players intuitively clicked on students and discovered that this would prompt them to wash their hands. Without telling them anything about how to play, they quickly discovered the two means of transmission in the first round of the game: respiratory and fecal-oral transmission. Since this initial playtesting, we have added several other viruses and bacteria to the game, each with different profiles of transmission, probability of contracting illness, and speed of development.

3.6 Consistent Practice: Replay Value for Repeated Exposure to Hand Hygiene Training

We developed an achievement system in the learning game that provides the player with short-term, medium-term, and long-term goals. This system invites exploration of the separate modes of the game from training to contagion simulation. It rewards repeated play over several days. And it reveals important facts about hand hygiene, specific pathogens responsible for disease spread, and careers in infectious disease and public health that help prevent outbreaks. Evaluation of the trainer and the achievement system for long-term learning gains is underway.

4. Discussion

Infectious diseases will always be with us. Wherever humans and animals congregate, there is ample opportunity to transmit and amplify viruses, bacteria, and other pathogens. This problem has vexed leaders in cities and commanders of armies since ancient times.

The era of modern public health began in the 19th Century, improving urban life immensely. Pioneers include the Hungarian obstetrician Ignaz Semmelweis, who practically eliminated deaths from post-partum infection in the largest hospital in Vienna by means of careful handwashing—decades before the bacteria responsible for these deadly infections were discovered. In Germany, France, and England, Robert Koch, Louis Pasteur, and John Snow helped usher in the germ theory of disease, microbiology, and the science of epidemiology. These scientific advances have saved more lives than any medicine, surgical procedure, or medical device. To this day, our communities have benefited from systems that deliver clean drinking water, sanitary sewer systems, and countless other public health measures that have been as successful as they are *invisible* (Paiva, 2016, Pedraza 2017).

Yet public health has become a victim of its own success: because it is ubiquitous and invisible, it has also become *mundane*—and, tragically, *misunderstood*—by the very people it hopes to serve. The most recent pandemic exposed and accelerated the erosion of trust between the public and public health officials. Some of this erosion can be attributed to increasing distrust in all institutions, public and private. But this larger social trend does not excuse how poorly prepared our leaders and institutions were, how incoherent the messaging was, and how much public goodwill, which was in abundance early on, was squandered.

Handwashing is both cheap and effective protection against a host of transmissible diseases. Through proper training, healthcare-level proficiency in hand hygiene is possible for both children and adults. The missing component has been scalable, standardized training, to a high level, that not only transfers effective technique, but also fosters healthy habit formation. The design of the interactive trainer, reported here, has features that can be applied to other learning domains: high-fidelity simulation not only reduces the cognitive load, but also allows training to a very high standard. Close connection of the learning game to the desired behaviour, and evaluation of that behaviour in real life, has the greatest chance of improving health outcomes. Experiential learning invites players to discover for themselves when handwashing is indicated, and the consequences of skipping it. Finally, awareness of how behaviours form, and how they can be reinforced through repeated gameplay, can deliver lifelong benefits to health.

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Future Teachers' Perceptions of Different Educational Escape Room Designs

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Abstract: Educational escape rooms have gained popularity as an innovative method for enhancing student engagement and problem-solving skills. However, little research has been conducted on how future teachers perceive different escape room designs and their potential application in school settings. This study investigates the perspectives of pre-service teachers specializing in mathematics, physics, and computer science on various educational escape room formats. The research compares four distinct escape room designs: (1) digital escape rooms created in Google Forms, (2) digital escape rooms designed using the Room Escape Maker tool, (3) fully immersive physical escape rooms designed as actual room, and (4) box-based escape rooms, which involve a physical chest containing objects and puzzles. Data were collected through multiple methods, including direct observation of students interacting with these escape room formats, interviews exploring their experiences and engagement, and an open-ended questionnaire assessing their perceptions of design effectiveness, feasibility for classroom integration, and overall educational value. The results show that while students personally preferred the immersive experience of physical escape rooms, they found digital formats to be more practical and feasible for classroom use due to lower logistical demands. However, box-based escape rooms emerged as a promising middle ground—offering hands-on engagement while being more manageable in school settings. Many students suggested combining digital and physical formats in their future teaching. The insights also inform the development of a teacher training workshop within the EcoMystery Erasmus+ project.

Keywords: Educational escape rooms, Game-Based learning, Pre-Service teacher education, Innovative teaching methods

1. Introduction

Educational escape rooms (EERs) are an innovative form of group-based game-based learning that provide dynamic, motivating environments that encourage student engagement, problem-solving, collaboration, and critical thinking (Nicholson, 2015). Derived from popular recreational escape rooms, EERs have been used in a variety of educational contexts, including STEM disciplines, where their potential to promote active learning is increasingly recognised (Taraldsen et al., 2022).

EERs are theoretically grounded in social constructivism (Vygotsky, 1978). They emphasize the construction of knowledge through real-time collaboration and interactive activities. Students engage in authentic, often complex puzzles that require teamwork and communication (Fotaris & Mastoras, 2022). This approach is also consistent with situated learning theory (Lave & Wenger, 1991), which suggests that learning is most effective in a context that reflects real-world situations and is rich in social interactions.

Several frameworks have been proposed to guide the design of educational escape rooms. One is the escapED framework (Clarke et al., 2017), which emphasises a human-centered, narrative-driven approach that supports interdisciplinary learning. This framework encourages the integration of project-based learning principles and promotes cognitive and behavioural engagement through immersive storytelling and teamwork. It places particular emphasis on the value of physical and social interaction.

Room2Educ8 (Fotaris & Mastoras, 2022) provides a design-thinking oriented framework structured around nine iterative stages: empathise, define, contextualise, design, brief, debrief, prototype, document and evaluate. This framework focuses on the ways in which EERs can foster emotional engagement, intrinsic motivation and flow state. It is particularly relevant for helping educators, including those with no previous game design experience, to create escape rooms that are pedagogically sound and adaptable to any learning environment.

Systematic reviews (e.g. Veldkamp et al., 2020) confirm that EERs can enhance motivation, knowledge retention and the development of cognitive skills when designed with careful attention to game mechanics and educational goals. Key features that contribute to the pedagogical effectiveness of EERs include narrative context, interactive problem-solving, immediate feedback and puzzle complexity. These features not only support mastery of content, but also promote ownership and autonomy in learning, particularly through collaborative engagement.

In teacher education, and particularly in the context of pre-service teachers of mathematics, physics and informatics, EERs are increasingly being explored both as teaching tools and as objects of reflection during training. Research suggests that pre-service teachers find it valuable to engage with different EER formats, such as digital story-based games and digital interactive adventure games (Čujdíková & Vankúš, 2023). In this paper we follow up with the study on how pre-service teachers perceive and evaluate four different escape room designs, contributing to a better understanding of which formats they perceive as most effective, feasible and engaging for future classroom use. Specifically, we included four different escape room formats in our study: (1) digital escape rooms created in Google Forms, (2) digital escape rooms designed using the Room Escape Maker tool, (3) fully immersive physical escape rooms, and (4) box-based escape rooms, which involve a physical box containing objects and puzzles. Therefore, our research focus is which design of the offered types of educational escape rooms do preservice mathematics teachers consider the most suitable for use in their future teaching practice.

2. Methodology

In our research, we adopted a qualitative approach (Creswell, 2012). Specifically, we chose a case study design. Our aim was to better understand how students evaluate different types of escape rooms that they had the opportunity to experience themselves. These included two types of digital escape rooms and two types of physical escape rooms, as described in more detail in chapter 3.

We posed three research questions:

RQ1: How do students perceive their experience with the selected digital escape rooms?

RQ2: How do students perceive their experience in the physical escape rooms?

RQ3: How do students perceive the usefulness of physical and digital escape rooms in the classroom?

The participants in the research were first-year bachelor's students enrolled in a mathematics education program in combination with another subject. These pre-service teachers are being prepared to teach pupils in grades 5 to 13 (ages 10–19). As part of the first year of their studies, students have the opportunity to enroll in the elective course *Game-based Teaching of Mathematics*. The aim of the course is to familiarize students with innovative learning technologies, to show them examples of their use in mathematics education and also to gain experience in creating their own learning activities in the form of digital escape games. The research was conducted within the framework of this course. A total of 14 students were involved.

We used multiple data collection methods. For digital games, students first played a sample story-based escape room. Afterwards, they worked in groups to design their own escape rooms of this type using Google Forms. Upon completion, they played the escape rooms created by other groups. The same procedure was followed for interactive adventure escape rooms created using the Room Escape Maker tool (<https://roomescapemaker.com/>).

Subsequently, in groups of 3–4 students, they played a physical escape room in the form of a real room, as well as a box-based physical escape room (Janiga, & Haverlíková, 2024).

Throughout all these activities, we observed the students and conducted interviews with them. In addition, they completed three questionnaires. One focused on their perception of the physical escape room in the form of a real room. The second gathered feedback on both digital and physical escape rooms, as well as their ideas about the potential use of these types of escape rooms in teaching. The third aimed to capture their preferences regarding the type of escape room they liked the most, and which they considered most suitable for inclusion in classroom instruction.

All collected data were analyzed through content analysis (Schreier et al., 2019), using the MaxQDA tool. In our analysis, we aimed to identify categories of ideas related to our research questions. We first coded the entire dataset using emergent codes, which we then grouped into broader categories.

3. Description of Used Escape Rooms

The aim of this chapter is to present and categorize the escape rooms used in the course. We present specific examples of escape rooms developed by pre-service teachers during this course.

The digital escape rooms in this paper can be classified into two main categories: story-based (developed in Google Forms) and interactive adventure (developed in Room Escape Maker) (Čujdíková, & Vankúš, 2024).

In the story-based category, pre-service teachers created a total of eight digital escape rooms using Google Forms, all of which integrated mathematical tasks. Two of these escape rooms focused on the theme of climate change, while the remaining six explored a variety of other thematic contexts. A specific example of a story-based escape room is “Príbeh kolobehu vody v prírode” (“The Story of the Water Cycle in Nature”; Figure 1), in which participants are tasked with saving a river and its associated reservoir tank. As they progress through the escape room, students engage with content related to the natural water cycle and its environmental significance. Simultaneously, they solve mathematical problems embedded within the narrative, such as calculating the rate of reservoir evaporation and predicting the timeline for potential drying out of the river.

Príbeh o kolobehu vody

Jedného dňa sa však rieka začala obávať, že niečo nie je v poriadku. Počas dlhého obdobia sucha sa hladina vody v nádrži veľmi znížila a oblasť, ktoré by mohli priniesť dážď, bolo málo. „Ako môžeme spočítať, koľko vody nám ešte ostáva?“ pýtala sa rieka.



Ak jazero obsahuje približne 15000 m³ vody a každé ráno sa vyparí 3% jeho objemu, koľko vody ostane v nádrži po 10 dňoch?
Výsledok uveď v celých číslach.

Vaša odpoveď

Figure 1: Story-based escape room “The Story of the Water Cycle in Nature” (source:

https://docs.google.com/forms/d/e/1FAIpQLSeua0egf6Oq-7UMTlvoNRK1TtLWF55ZE6vfNxZNkHEU1r39_A/viewform)

As illustrated in the Figure 1, each section of the escape room presents a narrative segment (story part), an illustrative image, and a related mathematical puzzle, with a designated space for the pupil to input their answer. Depending on the needs of the story, it is possible to include multiple follow-up questions within a single segment. Once a pupil is satisfied with their response, they submit it, which leads to one of two outcomes: if the answer is correct, the system advances them to the next puzzle (i.e., the next page); if the answer is incorrect, it is highlighted in red, and a message appears indicating the response was not correct. Pupils are allowed an unlimited number of attempts to revise and resubmit their answers. However, some difficulties may occur due to formatting requirements in Google Forms. For instance, an answer may be marked incorrect simply because it does not match the expected input format. In cases where no specific format is provided in the task instructions, pupils may need to experiment with different variations until the response is accepted.

Upon successfully completing all the puzzles, pupils are informed through the concluding message that they have succeeded in saving the river, thereby achieving the story’s resolution and providing a sense of accomplishment tied to both the mathematical problem-solving and the environmental theme.

In the interactive adventure category, pre-service teachers created the same number of escape rooms as in the story-based category, using Room Escape Maker. In this case, however, their primary focus was on designing mathematically oriented puzzles embedded within a simulated virtual environment. In addition to the mathematical content, attention was given to sustaining player curiosity through interactive exploration and visual engagement.

These category of escape rooms are designed to replicate the experience of a physical escape room in an online format. At the start of the game, players find themselves in a virtual room where all visible objects are presented in front of them, and they can navigate by shifting the view to the left or right. The environment

typically includes a variety of interactive elements such as doors, furniture, and usable tools that can be collected and stored for later use (see Figure 2).

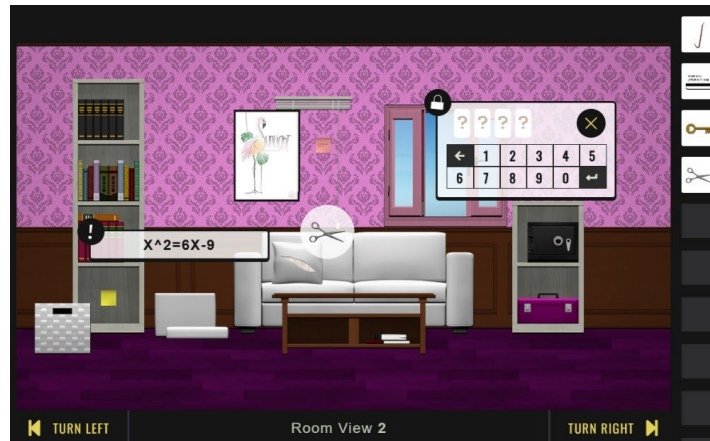


Figure 2: Digital escape room designed in Room Escape Maker (source: <https://roomescapemaker.com/u/kristi03/escape>)

In the specific example shown in Figure 2, the players have already discovered a pair of scissors, which they used to cut open a pillow. Inside the pillow, they found a card and placed it in the inventory panel located on the right-hand side of the screen. They then moved a white box, revealing a note with a mathematical clue. Although they opened a window in search of an additional hint, it yielded no useful information. Eventually, they interacted with the safe itself and discovered that a four-digit code was needed to unlock it. The inventory also shows that the players have previously explored other parts of the room. The ultimate objective is to find a specific key or a code that will allow them to unlock the exit door, which is in a different viewpoint of the virtual room.

We also provide basic information about the physical escape rooms that the pre-service mathematics teachers attended as part of their course experience. The first physical escape room designed as actual room is located at premises of Comenius University and includes two connected rooms. It is designed for teams of two to four players, requiring collaboration and communication to achieve the final goal: obtaining the “treasure”. The complex structure of the room (Nicholson, 2015) and progression of the puzzles are illustrated in Figure 3.

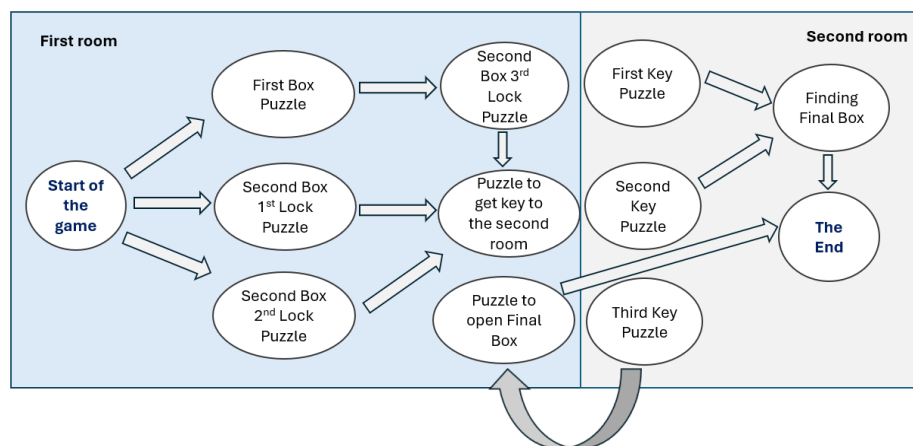


Figure 3: Structure of our physical escape room designed as actual rooms (source: authors' library)

As shown in Figure 3, participants must solve five puzzles in the first room to gain access to the second room. Once inside, they are faced with an additional set of three puzzles. Successfully completing these tasks unlocks the final puzzle, which must be solved to retrieve the key for Final Box where they can find the “treasure”, thereby marking the end of the game. In all of the puzzles, players are required not only to communicate effectively but also to apply logical reasoning and mathematical knowledge. The tasks are designed to reinforce mathematical thinking in a collaborative and engaging environment, providing pre-service teachers with a hands-on understanding of how mathematical problem-solving can be embedded in experiential learning contexts.

The second type of physical escape room that pre-service teachers encountered during the course was a box-based escape room “Chest of Lord Maxwell” (Janiga, & Haverlíková, 2024), where the primary objective was to retrieve specific information hidden inside a locked box as quickly as possible. In this particular scenario, the activity was framed by a fictional narrative: participants have a mysterious box from the late physicist James Clerk Maxwell, rumoured to contain clues leading to the discovery of a previously unknown Maxwell’s equation. The first challenge involved unlocking the main box itself (see Figure 4).



Figure 4: Physical escape room “Chest of Lord Maxwell” designed as box (source: authors’ library)

Once opened, participants found two smaller boxes inside, along with a series of clues and puzzles displayed on the inner lid. In total, the escape room included five interconnected puzzles. Each task was designed around physical principles, offering a creative and interactive opportunity to review key concepts from magnetism and electromagnetism.

4. Results

In this chapter, we present our findings. The results presented in section 4.1 address RQ1, the results in section 4.2 correspond to RQ2, and those in section 4.3 answer RQ3.

4.1 Evaluation of the Experience With Digital Escape Rooms

Although students found playing the digital escape rooms to be a less intense experience than the physical one, they still evaluated this activity positively. The main advantage of digital escape rooms, in comparison with physical ones, was seen in their independence from space, time, and group size. One student stated: *“What I liked was that we didn’t have to go anywhere, and we could all solve it at once – which is definitely more suitable for teaching. Students don’t have to go anywhere, and it’s for everyone, not just three people at a time.”* Other similar comments included: *“Can be used anywhere,” “Fast, accessible,”* or *“Convenient – you can sit on a chair.”*

Students also appreciated that, with digital escape rooms, they were not only able to play them, but also create them. In this context, they valued the opportunity to express their own creativity, and similarly to playing, they considered the digital format advantageous due to its flexibility: *“The ability to create from anywhere, at any time.”*

4.2 Evaluation of the experience With the Physical Escape Rooms

Students generally preferred the experience with the physical escape room over the digital ones. They perceived the experience of playing it as more “real.” They appreciated being physically present in the room and interacting directly with real objects. One student, for example, noted: *“That I could touch the objects and see it all live myself.”* Another commented: *“I really liked the physical escape room – it’s a different atmosphere when you’re ‘directly in the action’ and experiencing it in the room with other people.”* As this statement also suggests, another key aspect students appreciated was collaboration, and the shared nature of the game experience. Students positively highlighted the fact that some tasks had to be solved collectively: *“[What interested me was that this escape game was] also focused on cooperation between us (e.g., the snorkel).”*

Several students also liked the theme of the escape room, its design, and the individual puzzles. Most notably, they appreciated that all these elements were meaningfully connected within the room: *“I really liked the*

physical escape room we visited, it was well-designed, we had to think a lot and look for connections. I also liked that there were two rooms and the whole theme was based on the underwater world."

The puzzles themselves were considered thoughtful and creative. Students appreciated their variety and the fact that they were not too easy, but instead presented a challenge. This is reflected in comments such as: *"I liked that it was a bit more difficult,"* or *"We had to think a lot and find connections."* In connection with the puzzles, students also specifically highlighted: *"I liked the way perspective was involved."*

4.3 Perceptions of the use of Digital and Physical Escape Rooms in Teaching

While students personally preferred the physical escape room, most would choose the digital version for use in the classroom. They viewed it as more suitable primarily because it is less demanding in terms of implementation, especially with larger student groups.

One student stated: *"For teaching, the digital one – it would be more efficient and take less time."* Another expressed a similar opinion: *"The digital one, due to space and time constraints."*

However, many students also emphasized that they would prefer the physical escape room if its implementation were easier, and that they considered the digital version more appropriate only because it is more practical. In this respect, they made comments such as: *"In an ideal world, the physical one. But it's unrealistic for every student in a class of 30 to try it out within a reasonable timeframe,"* or *"Ideally the physical one, but digital rooms are much more practical and can be shown to more students in a shorter time."*

Given these preferences, it may be worth considering the development and use of box-based escape rooms. This alternative was also suggested by one of the students: *"The physical one, for example, an escape game in a box – the idea of L. Janiga. Since I study mathematics and physics, I would clearly use physical ones more."* Regarding the box escape room, some students highlighted its practicality for use with larger numbers of students and also the advantage of a physical experience compared to digital versions: *"For the pupils in the classroom I would probably like the physical box the most - by having more of them [boxes] we could solve the problems all at once and by not having it on the internet the pupils get more into it".* Some students also advocated the use of both digital and non-digital versions: *"Digital in Google Forms or physical box. The physical box is very good for teaching science and for pupils to actually work with those things and tools and Google Forms I think is useful for teaching maths - because maths is mainly made up of tasks. Both approaches are very good and have their good points, so I think we can use them together."*

The following Table 1 summarizes the key themes of our finding and participant feedback.

Table 1: Summary of key themes and participant feedback

Themes	Key Findings	Illustrative Quotes
Experience with digital escape rooms	Students appreciated the flexibility, accessibility, and opportunity to create their own games. They valued that the format was not limited by their location or time.	<i>"We didn't have to go anywhere, and we could all solve it at once."; "Can be used anywhere."; "The ability to create from anywhere, at any time."</i>
Experience with physical escape rooms	Students preferred physical rooms due to the immersive experience, teamwork, and hands-on interaction with real objects.	<i>"That I could touch the objects and see it all live myself."; "It's a different atmosphere when you're directly in the action."; "We had to think a lot and find connections."</i>
Usefulness of escape rooms in teaching	Digital escape rooms were considered more practical for classroom use, especially with large groups. Box-based rooms were seen as a good compromise.	<i>"For teaching, the digital one – it would be more efficient and take less time."; "Ideally the physical one, but digital rooms are much more practical."; "The physical box is very good for teaching science."</i>

5. Conclusion

In our paper, we investigated the preferences of pre-service mathematics teachers regarding the design of educational escape rooms. As part of a university course in *Game-based Teaching of Mathematics*, students engaged with different types of escape rooms. These were digital educational escape rooms in the form of story-based escape rooms created in Google Forms, and interactive adventure escape rooms designed using the Room Escape Maker tool. Students also completed two types of physical educational escape rooms, namely fully immersive physical escape rooms designed as actual rooms, and box-based escape rooms, which involve a physical chest containing objects and puzzles.

During all these activities we observed and interviewed the students. In addition, they completed several questionnaires. Students were active while working so the escape rooms exposed them to collective teamwork, foster engagement and persistence in completing tasks, strengthen social relationships, activate team spirit, and facilitate the benefits of deep learning through group discussion, which is consistent with previous researchers' experiences in this area (Fotaris, & Mastoras, 2019). The positive response to immersive and embodied activities aligns with situated learning theory (Lave & Wenger, 1991), which emphasizes that learning is most effective when it occurs in meaningful contexts that reflect real-world experiences.

As for the results we found out, that students preferred physical escape rooms themselves, but they found digital more suitable for classroom integration. Students' preference for physical escape rooms, despite recognizing the practicality of digital formats, underscores the importance of physical and social interaction in learning — a key principle of social constructivist theory (Vygotsky, 1978). The collaborative, hands-on nature of physical escape rooms appeared to support deeper engagement and mutual problem-solving, allowing knowledge construction to emerge through interaction with peers and with tangible materials in real time.

However, after the students experienced the box-based escape rooms, they realized that this form is appealing to them and at the same time it is also suitable to use in a classroom setting. Based on this, several of them concluded that they would use digital learning escape rooms in combination with box-based physical escape rooms in their future teaching practice. These results are consistent with previous studies that have noted the practicality of using box-base physical escape rooms in education (Duggins, 2019). The results will also inform the development of a teacher training workshop focused on the use and creation of box-based escape rooms with a theme of climate crisis issues. These trainings will be part of the ERASMUS+ project The EcoMystery Project: Interactive Escape Rooms for Climate Crisis Awareness and Civic Engagement in School Education, which focuses on designing educational escape rooms with themes related to climate change.

While the study provides valuable insights into pre-service teachers' perceptions of educational escape rooms, the findings should be interpreted in light of the small sample size of just 14 participants. As a qualitative case study, its primary aim was to explore experiences in depth rather than produce generalisable results. However, future research could build on these findings by conducting larger-scale studies to validate and extend the observed trends. Furthermore, longitudinal research could examine how attitudes towards educational escape rooms evolve as pre-service teachers transition into their careers and apply these tools in real classroom contexts.

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Framing the Development of a Gamified App for m-Health and Well-Being

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Abstract: This paper outlines the rationale behind the development of a gamified mobile-application for the promotion of mental health and wellbeing of health professionals. The application aims to provide constantly available support for healthy lifestyles and to promote behavioural change. Indeed, while the health literacy of professionals may be high, their implementation of healthy behaviours is hindered by several factors (work schedules, workload, etc.) and requires changes that are difficult to put into practice for people who have to reconcile complex life and work demands. For these reasons, boosting awareness and motivation is necessary to initiate and maintain health-promoting behaviours. Design of the gamification for the application was based on the literature regarding both gamification for mental health and behavioural change to identify the most appropriate game elements to implement. In particular, the design was built on existing intersections of gamification principles and digital health-behaviour-change science. Motivational aspects were factored in, since the aim was to promote the internalisation and integration of the regulation of health behaviours. Such a complex and intertwined system of references was geared to ensure the robustness of the result and give the application the capacity to support long-term changes. The application was designed with a customised approach based on an initial assessment that the user undergoes at his/her first access, so as to provide an initial scaffolding that dwindles after conclusion of a predefined set of activities. This supports familiarisation with the app and the acquisition of increasing autonomy by the user. In this way, goals are initially set by the application and then autonomously. Progress displays and feedback prompt self-monitoring of behavioural outcomes, to increase the user's sense of competence. A narrative metaphor was implemented to guide the user to progress in the app activities: in the guided paths the user follows the growth of a tree, from a seed in a greenhouse to flowering outdoors, in the open air the tree blossoms and bears fruit. The rewarding mechanics were aligned with the narrative so as to make them meaningful and informative.

Keywords: Gamification, m-Health applications, Behaviour change, Healthcare professionals, Self-determination theory, and gamified health interventions

1. Introduction

Health professionals make up a population in need of meaningful interventions in mental health and well-being. In recent years, and especially after the pandemic, they have had to work in conditions that are harder than ever: a lack of personnel, the traumatic situations they constantly face, their workload and the frequent aggressions they suffer are all aggravating the mental and physical burden they bear (Søvdal et al., 2021). Despite their knowledge of the importance of healthy lifestyles, they often have difficulty in putting what they know into practice since they struggle to reconcile life and work demands (Holtzclaw Arlinghaus, and Johnston, 2020).

The WE CARE project (Erasmus plus) aimed at supporting health care professionals in adopting a healthier lifestyle, and to this end identified a mobile application as the optimal solution to create a kind of “companion” continuously available and flexible enough to adapt to the needs of these people. Indeed, the increasing availability of smart technology devices (smartphones, smartwatches, etc.) has facilitated seamless healthcare interventions; a broad range of applications to monitor and manage one's own health and well-being have been developed (Martínez-Pérez et al., 2013; Middelweerd et al., 2014). Web-based applications are widely recognised as a cost-effective means to deliver proven and effective interventions (that were traditionally face-to-face) and to improve mental health and well-being outcomes. That said, dropout and nonadherence are,

unfortunately, often high and vary widely (they range between 35% and 99%) (Brown et al., 2016). Approaches that seem to be able to help improve adherence to interventions foresee the development of applications such as games or the integration of gamification into them (Wattanasoontorn et al., 2013; Kharrazi et al., 2012). Nevertheless, developing an attractive game is a cost- and time-intensive process that cannot easily be afforded. Gamification is a way to overcome the above-mentioned problems, since game elements able to trigger user motivation can be applied to different kinds of applications that can be used in everyday life. For this reason, we decided to implement gamification in the WE CARE application.

According to Cheng (2020) gamification has been increasingly used in digital health services, especially in the field of physical health, while it seems less adopted for mental health and well-being. A review of stress management apps in the Google Play Store (Hoffman, Christmann and Bleser, 2017) found low levels of gamification, with only 32% of the sampled apps employing gamification. Some literature reviews in the field have explored the effectiveness of gamification in e-health services; the results of the studies are often inconsistent (Aschentrup et al., 2024; Johnson et al., 2016) or do not show any effect (Six et al., 2021). This may be due to different reasons, including a missing analysis of the game elements at play.

Several studies and reviews of e-health applications have sought to identify the most prevalent game design elements used in this context. However, the majority of these papers do not differentiate between distinct domains—such as physical health, chronic illness management, mental health and general well-being—nor do they consistently distinguish between mobile and desktop platforms. An additional limitation concerns the use of the term *gamification*, which is, at times, extended to include fully developed games; consequently, some reviews incorporate actual games within their scope. Moreover, the absence of a universally accepted definition and categorisation of game design elements has led individual studies to adopt, and in some cases formulate, divergent terminologies, classifications or taxonomies. These inconsistencies substantially constrain the comparability of the findings, although they do allow for the emergence of some general insights. It is also worth noting that, as highlighted by several researchers, many of the applications analysed appear to have been developed without reference to established theoretical frameworks related to motivation or behavioural-change strategies. The predominant approach in many of the gamified health and well-being apps reviewed tends to emphasise positive reinforcement mechanisms, primarily through the use of rewards (Hoffman et al., 2017; Johnson et al., 2016). In line with the above-mentioned results, Sardi, Idri and Fernández-Alemán (2017) report that most of the e-health applications and serious games analysed have been shown to support short-term engagement through extrinsic rewards. For this reason, the authors advocate theory-based e-health solutions that exploit the central experience and psychological effects of game mechanics.

The work reported in this paper aimed to overcome these limitations, by framing the development of an e-health application, dedicated to health professionals, in solid theoretical foundations. In the following sections we firstly discuss the theoretical foundations to which we referred to select the game elements to integrate. Then, we present the design of the WE CARE application and its development, highlighting the link between the decisions taken in terms of game elements to integrate and the theoretical references.

2. Theoretical Foundations: Motivation and Behavioural Change

As said in the introduction, the idea of gamifying an application rose from the consideration that, although web-based interventions for m-health and well-being are recognised as powerful tools, users' adherence to the proposed applications is often low. The rationale behind gamification is to exploit the universally recognised motivational power of games in real world situations; in this sense we wanted to boost health professionals' motivation to make them adhere to the proposed health-oriented activities. Moreover, we also aimed to increase their awareness of the importance of assuming specific mindsets and behaviours to increase their physical and mental well-being. To achieve these objectives, we had to identify theoretical frameworks to guide us in identifying the game elements to be implemented in the application. In the following subsections, we present them to pave the way for the description of the design process.

2.1 Motivation

The motivational theory we referred to is the most used in the field of gamification studies, the Self Determination Theory (SDT; Deci and Ryan, 1985). Ryan and Deci (2000) highlight that motivation is not a unitary phenomenon but differs not just in the amount in which it is present (being more or less motivated) but also in the *orientation* of motivation (the type of motivation). For example, a person may want to do something because they think that it is interesting or to have something in return (an acknowledgement or a reward). The authors distinguish between '*intrinsic motivation, which refers to doing something because it is inherently interesting or*

enjoyable, and extrinsic motivation, which refers to doing something because it leads to a separable outcome' (Ryan and Deci, 2000a, p. 54).

Extrinsic motivation is often viewed as potentially being able to undermine intrinsic motivation; however, Ryan and Deci (2000a) argue that it is not inherently an impoverished form. It becomes relevant in activities that lack inherent enjoyment, driving individuals to value and self-regulate such behaviours. This issue is dealt with in SDT in terms of fostering the internalisation and integration of values and behavioural regulations (Deci and Ryan, 1985). Within SDT, Organismic Integration Theory (OIT) differentiates types of extrinsic motivation along a continuum of autonomy, from external to integrated regulation (Ryan and Deci, 2000a). These forms are dynamic; for instance, an individual may initially engage in an activity due to external regulation (e.g. receiving a reward), if the reward is not perceived as overly controlling, the individual may come to appreciate the activity's inherent interest, thereby facilitating a shift toward integrated regulation. Conversely, the imposition of external control may diminish the perceived personal value of an activity, potentially leading to a regression toward a less autonomous form of motivation. As a consequence, Deci, Koestner and Ryan (2001) conclude that it is essential to foster an understanding of the importance of what is being done and, therefore, the internalisation of its regulation so that people are motivated to perform a specific action or behave in a certain way. This conclusion offered theoretical support to our goal of raising awareness in health professionals through gamification.

Another mini theory within SDT is the Basic Psychological Needs Theory (BPNT). Ryan and Deci (2000b) identify three specific psychological aspects (needs) that facilitate internalisation of regulation:

- Relatedness: sense of belongingness and connectedness to the persons or to a group
- Competence: sense of accomplishment or mastery
- Autonomy: sense of control

Based on this theory Przybylski, Rigby, and Ryan, 2010 proposed a model, the 'player experience of need satisfaction' (PENS) model, suggesting that both the attractiveness and well-being effect of video games are based on their potential to satisfy basic psychological needs for competence, autonomy and relatedness. These theoretical principles provided us with lenses to 'read' and analyse the effects of different mechanics on motivation that will be discussed in the section dedicated to design of the WE CARE application.

2.2 Gamification for Behavioural Change

The use of gamification to support behavioural change has been addressed by several researchers (Bassanelli et al., 2020). To design the gamification of the WE CARE application we referred mainly to the work of two different authors. The first was Nicholson, who approached the issue in the light of SDT. In his chapter 'A Recipe for Meaningful Gamification' (2015) the author highlighted the general tendency to rely on a reward-based gamification to drive subjects to engage in real world settings and perform specific actions that are, indeed, rewarded. Nicholson emphasises the limits of this kind of gamification that clearly supports extrinsic motivation and that may be suitable for a short-term change or to get a user initially engaged. The problem resides in the fact that, usually, when a reward is no longer given the desired behaviour may stop contextually. To overcome these limits, Nicholson studied how to make gamification 'meaningful' (2012). The term "meaningful" was taken from Mezirow (1991) and his model of *transformative learning*, that links a change in beliefs and behaviours with a connection of an experience to previously held beliefs. From this perspective, what is meaningful is not universally fixed but varies from person to person.

Considering these premises, to design a meaningful gamification system it is necessary to include a variety of experiences and ways of engaging to reach the goal that different participants will find meaningful. In 2015, Nicholson operationalised the conclusions reached in 2012 and identified six elements from the game design field for meaningful gamification: [1] 'Play' – allow users to explore and fail within boundaries, [2] 'Exposition' – create stories for participants integrated in real world-settings and allow them to create their own, [3] 'Choice' – empower users by giving them control over their experiences, [4] Information – use game-like design elements to help users understand real-world issues, [5] Engagement – foster collaboration and shared learning among participants, [6] 'Reflection' – encourage users to connect new experiences with their personal interests and past knowledge for deeper learning. Despite these premises, Nicholson (2015) is not completely negative about reward-base gamification: it can be used both to reach a short-term change but also for a long-term change; in the latter case the design of the gamification should be very attentive, and rewards must be used parsimoniously.

Given the specific focus of the WE CARE application, we also relied on the findings of Cugelman (2013) who deepens the existence of links between gamification principles and digital health behaviour-change science. The author started from the consideration that from the point of view of evidence-based behavioural medicine, gamification could be considered useful only if it is possible to identify links with principles and strategies that are proven to influence health outcomes. The author compared 7 persuasive strategies of gamification identified from the literature ([1] Goal setting, [2] Capacity to overcome challenges, [3] Provide feedback on performance, [4] Reinforcement, [5] Compare progress, [6] Social connectivity, [7] Fun and playfulness) to behavioural-change techniques that have been proven to work in digital health behaviour-change interventions (Cugelman, Thelwall and Dawes, 2011). As for the capacity to overcome challenges, for example, Cugelman found a match with two behavioural-change techniques: ‘time management’ and ‘action planning’; another interesting match was found between two gamification strategies (Feedback on performance and progress comparison) and three behavioural-change techniques: ‘prompt self-monitoring of behavioural outcome’, ‘prompt self-monitoring of behaviour’ and ‘provide normative information about others’ behaviour’. The only gamification strategy for which the author did not find any correspondence was ‘Fun and playfulness’. The parallelism identified is not considered conclusive by the author to endorse the effectiveness of gamification in digitally mediated interventions, but it undoubtedly offers an overview of what gamification elements need to be implemented to align with behavioural-change strategies.

3. Gamification Design and Implementation in the WE CARE Application

3.1 Gamification Design

The gamification of the WE CARE application was designed in such a way that it will be consistent with the findings of SDT for motivation (Deci and Ryan, 1985) and Cugelman’s studies (2011, 2013). Moreover, Nicholson’s (2015) indications about meaningful gamification were brought into the equation. The game elements to be integrated in the application were selected referring to a taxonomy proposed by Hervas et al. (2017). Starting from a review of the literature, the authors developed a classification of the most common gamification mechanics and put them in relation with psychological fundamentals on behavioural change. The taxonomy includes 7 categories of gamification mechanics with subcategories:

1. Goals (e.g. achievement, challenges, levels)
2. Status (e.g. ranking, leaderboard, social sharing)
3. Randomness (e.g. luck, surprise)
4. Appointment (e.g. countdown, schedule)
5. Scoring (e.g. points, bonus)
6. Immersion (e.g. role, narrative)

To the game elements listed in this taxonomy we added elements from other taxonomies, in particular:

- Feedback and progress from the categories proposed by Hamari, Koivisto and Sarsa (2014)
- Personalisation and customisation (Cheng, 2019)

We mapped these elements against the three basic psychological needs (Deci and Ryan, 2000b) and behavioural-change techniques (Abraham and Michie; 2008, Cugelman et al., 2011) and selected a subset of the elements. As shown in Table 1, to address the need for competence, various elements were identified including levels, points, badges, challenges, feedback and a display of progress. Autonomy was to be supported by enabling customisation of the user experience and allowing individuals to set their own challenges and corresponding goals. As for need for relatedness we decided to use narrative; although desirable, social sharing mechanisms were not considered due to privacy constraints. Among the behavioural-change techniques, we addressed self-monitoring, but we also wanted to support goal setting and action planning through challenges, and to provide users with graded tasks through levels. Rewards for successful behaviour were included.

Table 1: Game elements in relation to the BPNT and behavioural-change techniques

Game element	BPNT	Behavioural change
Personalisation and customisation	Autonomy	
Levels	Competence	Setting graded tasks
Points/badges	Competence	Provide rewards contingent on successful behaviour

Game element	BPNT	Behavioural change
Challenges (Goals)	Competence/Autonomy if self-set	Goal setting Action planning
Narrative	Relatedness	
Feedback	Competence	Prompt self-monitoring of behavioural outcome
Progress display	Competence	Prompt self-monitoring of behavioural outcome

As for Nicholson's six elements (2015), we included 'Choice' since we decided to implement levels and also the opportunity to skip them and freely explore the contents, and 'Exposition' and 'Information' by integrating a narrative.

3.2 Implementation of Gamification

The description of the process of development of the application as a whole is beyond the scope of this paper, but some key points are reported here to explain the integration of gamification elements.

Several theoretical references in the field of psychology guided the development of the application, among which the transtheoretical model (TTM) and its stages of change (Prochaska and DiClemente, 1983). To identify the contents to address in the application, users' requirements were collected through a preliminary questionnaire developed on purpose, that was administered to a sample 161 health professionals from different countries. The questionnaire, divided in seven parts, had the aim of profiling the target group (parts 1-5) and investigating the interest in an app supporting mental health and well-being (parts 6-7). In particular, part 6 investigated needs of the target group for the app and part 7 the intention of use.

To tackle the topics that emerged from part 6, physical and mental exercises - derived from existing approaches such as mindfulness, self-compassion, etc. - and information, were included in the app.

Personalisation and customisation were the general principles guiding the development of the application. Cheng et al (2019) assimilate them with the term tailoring (commonly used in health behaviour-change literature), and state that this offers users increased levels of autonomy, which, according to the OIT, would contribute to increased likelihood of internalised motivation.

To personalise the experience with the application, we set an initial assessment through a questionnaire, which orients the first approach. The questionnaire includes two parts. Part A covers stress and well-being and includes a couple of questions on current stress level and the WHO-5 well-being index (WHO, 1998), part B includes questions on familiarity with m-health applications and intention to adopt healthy behaviours. The preliminary research led us to the creation of a matrix that took into account TTM stages (Prochaska and DiClemente, 1983) and stress levels: the matrix included 4 conditions, and the exercises presented within the app were allocated to the different conditions. Thus, the questionnaire results are used to place the user in one of the four conditions and to recommend a set of exercises/pieces of information that would fit best to their needs; indeed, the user is advised to follow a 14- or 7-day path - including two exercises per day - or has the option to freely use the application. This structure can be equated to **levels**, each offering varying degrees of scaffolding to accommodate users with differing levels of motivation and stress. Individuals who are less motivated and experience higher stress are provided with more extensive and prolonged guidance, whereas those who are more motivated/less stressed receive comparatively less support. Upon completion of the guided pathways, users attain the autonomy to explore all the exercises and information (open mode). Alternatively, users may opt out of the recommended pathways and directly access the open mode. As for **goals**, in the two paths these are set by the application (e.g. the user needs to complete a couple of pre-defined activities per day) while the user becomes free to self-set them in open mode. In this sense the availability of daily (optional) assessments allows one to compare the activities selected by the user with the actual needs and set personal challenges.

A **narrative** related to the theme of life and growth was implemented to enrich the experience and to increase user awareness of the effects of changes in their life habits. In the two guided paths the user is presented with the growth of a seed that becomes a tree, inside a greenhouse. This narrative is intended to communicate that that part of the pathway is somehow "protected" with a high level of support. Each day carries a motivational quote (see Figure 1 - left side). In open mode, the tree is planted in the ground and continues to grow, flourish and bear fruit (Figure 1 – right side).

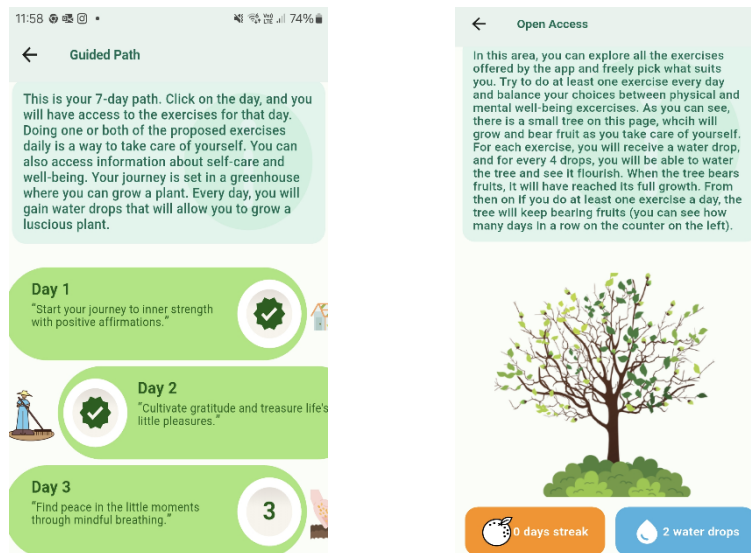


Figure 1: Guided path (left) and Open mode (right)

Achievements during and at the end of the levels are recognised with **points** and **badges**. To avoid the risk highlighted by Nicholson (2015) we integrated them with the narrative so as to strengthen their informative function: for exercise completion users receive water drops that can be used to water the plant and make it grow. In open mode, the tree is watered by the same mechanism, and when fruit appears on the tree there is a counter on the mid-left part of the screen showing consecutive days of use (see Figure 1). In the badge area the user can see his/her achievements related to pre-defined challenges (e.g. the completion of the recommended guided path). **Feedback** is implicitly given through the metaphor of the tree, the growth of which shows adherence to the path and continuity of use in open mode. Progress is displayed through progress bars in the badge area, in relation to the achievement of predefined challenges; in addition, progress is represented through the metaphor of the tree growing in different areas of the application.

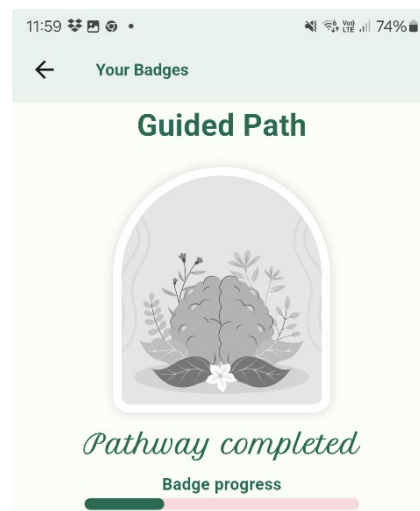


Figure 2: Badge area

4. Conclusions

The WE CARE application was built resting on solid theoretical foundations. Having looked at gamification as a strategy to increase users' engagement and motivation, it was clear that the discourse on motivation could not be overlooked. Moreover, we followed the indications provided by Hoffmann and colleagues (2017), who emphasise that for behaviour-change programmes, including those delivered through applications, to be effective and lead to lasting results, they must be grounded in evidence-based principles from behaviour-change theories. For these reasons we took both the theoretical fields as references to identify the game elements to implement in the application.

In the process of designing and developing the application we stuck to the guidelines of Cheng (2020). The suitability of gamification for our target audience was investigated preliminarily with the users by collecting users' requirements. Gamification was implemented at a systemic level in the application, namely game elements interact with the other components of the technology to create a coherent system. Finally, the entire process (the design, development and evaluation) was documented comprehensively. Unfortunately, our conclusions are limited by the absence of meaningful feedback from consistent and diverse user groups. Despite the limits, our experience prompted us to identify additional recommendations for those wishing to design gamification of m-health applications, which, while not groundbreaking, seem important considering the limitations highlighted in the literature:

- Identify the game elements to be integrated in the application from existing taxonomies, which will help to consider a wide range of elements that can be included.
- Ground the gamification of the app on solid theoretical foundations, identify and implement game elements coherent with the reference theories.
- Consider providing a narrative context, which is recognised as increasing user engagement and experience and which can be used to increase awareness and reflection.

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AI-Powered Game-Based Learning for Project Management Education

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Abstract: Bridging the gap between theory and practice remains a core challenge in project management education, as students often struggle to transfer classroom knowledge into complex, uncertain, and ethically charged environments. As serious games increasingly integrate artificial intelligence (AI), new opportunities arise for scalable, adaptive, and ethically informed learning. This paper introduces and evaluates an AI-enhanced Game-Based Learning (AI-GBL) framework that positions AI as a pedagogical co-orchestrator—modulating narrative and challenge—rather than a content add-on. It embeds serious game mechanics through two interactive modalities: AI-driven stakeholder interviews and collaborative crisis scenarios requiring students to make decisions, weigh trade-offs, and reflect on consequences. Structured debriefs and ethically ambiguous dilemmas reinforced reflection, judgment, and leadership identity. Within this framework, the lecturer served as a game master, shaping the environment, guiding discussion, and ensuring ethical engagement, while AI dynamically adapted gameplay. Grounded in Kolb's experiential learning cycle and scaffolded by the 5E model, the design also drew on Self-Determination Theory and Flow to support autonomy, competence, and engagement. A mixed-methods, quasi-experimental pretest–posttest design was applied in live classrooms. Undergraduates ($n = 113$) were grouped by tutorial exposure (experimental: ≥ 3 , $n = 66$; control: ≤ 2 , $n = 47$), while a postgraduate cohort ($n = 47$) contributed qualitative reflections. Students in the AI-GBL group achieved significantly higher posttest scores (means: 66.64 vs. 48.00). ANCOVA controlling for pretest confirmed a large effect (partial $\eta^2 = .799$), though this should be interpreted cautiously due to the non-randomised design. Qualitative reflections revealed growth in ethical reasoning, collaborative identity, and adaptive decision-making, alongside signs of over-reliance on AI—highlighting the need for scaffolding in ethical AI literacy. Findings suggest that AI-GBL can enhance domain-specific performance and the metacognitive and affective dimensions of adaptive expertise—ethical sensitivity, reflective judgment, and leadership identity. Three design principles emerge: (1) AI should function as a co-orchestrator, modulating challenge and feedback in real time; (2) open-ended, ethically complex scenarios deepen reflection beyond procedural accuracy; and (3) critical scaffolding is essential to prevent passive reliance on AI-generated outputs. This study builds on prior conceptual work published in *Project Leadership and Society* by providing empirical evidence of AI-GBL's effectiveness, advancing design principles for AI-integrated serious games, and identifying directions for future research, including longitudinal tracking, replication, and cross-domain application.

Keywords: Generative AI, Game-Based learning, Experiential learning, Project management education, Serious games

1. Introduction

Bridging the gap between theoretical instruction and practical application remains a central challenge in project management education (Darrell et al., 2010; Egginton, 2012; Nicholson, 2015). While students often demonstrate proficiency with established tools and methodologies, many struggle to transfer this knowledge into real-world contexts marked by ambiguity, stakeholder complexity, and emergent crises. This persistent theory–practice divide reflects a broader misalignment between academic models and the adaptive, human-centred problem-solving required in contemporary project environments (Darrell et al., 2010; Huemann & Turner, 2024). This gap is further exacerbated by the "accidental project manager" phenomenon—individuals promoted into leadership roles based on technical or managerial expertise, rather than formal training in project management (Pelgrim et al., 2022; Ward et al., 2018). As demand for project-based competencies grows, conventional educational approaches are increasingly insufficient for preparing professionals to navigate modern projects' volatile, uncertain, and ethically complex terrain.

Traditional project management education prioritises routine expertise—using known methods to address well-defined problems efficiently. While this expertise is necessary, it is insufficient for tackling today's complex project landscapes. In contrast, adaptive expertise involves the ability to transfer knowledge flexibly, innovate under pressure, and make sound judgments in uncertain or novel situations (Pelgrim et al., 2022; Ward et al., 2018). As Huemann and Turner (2024) put it, "Complex projects are mysteries which require innovation. Conventional project management is not good at innovation." This observation highlights the core educational imperative: to equip learners not just to solve familiar problems, but to lead through ambiguity, engage in ethical reasoning, and adapt their decision-making to dynamic contexts.

This paper introduces an AI-enhanced Game-Based Learning (AI-GBL) framework that integrates generative AI simulations with experiential learning principles to address the limitations of static case studies and linear instruction. The AI-GBL model presents emotionally resonant, high-stakes scenarios that provide a safe

environment for learners to practise decision-making, navigate ethical dilemmas, and cultivate adaptive, reflexive leadership skills. Unlike simulations, which typically model fixed processes with predetermined outcomes, the AI-GBL design incorporated game mechanics—role-play, uncertainty, trade-offs, and narrative consequence—that required active decision-making and reflection. This distinction situates the intervention within serious games rather than passive simulation.

This study builds on prior conceptual work published in *Project Leadership and Society* (Daniels et al., 2025), which outlined six pedagogical themes—relevance, agility, identity, ethics, motivation, and adaptability—and proposed AI as a pedagogical co-orchestrator for leadership education. The present paper extends that work by subjecting the model to empirical testing in live classroom contexts, reporting quantitative outcomes alongside qualitative reflections.

2. Theoretical Framework

The design of the AI-GBL intervention is grounded in Kolb's Experiential Learning Theory, which conceptualises learning as a cyclical process in which knowledge is created through the transformation of experience (Kolb & Kolb, 2005, 2008, 2022). Kolb's experiential learning cycle—concrete experience, reflective observation, abstract conceptualisation, and active experimentation—fosters the metacognitive and strategic capacities central to adaptive leadership.

AI_GBL operationalises this model by immersing learners in complex, simulated challenges, reinforcing learning through iterative action and reflection. To operationalise this cycle within a digital environment, the intervention adopted the 5E Instructional Model: Engage, Explore, Explain, Elaborate, and Evaluate (Daniels et al., 2025; Owens & Sadler, 2024). This constructivist framework scaffolded learner interaction with AI simulations by structuring engagement through the 5E model. Simulated crises-initiated inquiry (Engage), followed by stakeholder exploration (Explore) and guided debriefings that connected gameplay to theoretical concepts (Explain). This sequence rendered experiential learning systematic and pedagogically purposeful, deepening conceptual understanding and applied competence.

Sustaining motivation in complex learning environments remains a challenge in higher education. This intervention addressed it by integrating Self-Determination Theory (SDT) and Flow Theory (Beard, 2015; Csikszentmihalyi & Csikszentmihalyi, 1990; Nash, 2025; Ryan & Deci, 2000). SDT posits that intrinsic motivation arises when learners experience autonomy, competence, and relatedness, while Flow Theory describes deep task immersion achieved through an optimal balance of challenge and skill. The AI-GBL design reinforced both: adaptive task difficulty supported competence, branching narratives fostered autonomy, and collaborative crises promoted relatedness. Together, these elements sustained self-directed engagement in emotionally and cognitively demanding scenarios.

In this intervention, AI functioned as a pedagogical co-orchestrator—actively shaping the learning environment alongside the instructor (Kamalov et al., 2023). Reflecting a shift from AI as a content provider to an instructional partner, this model aligns with emerging research that emphasises augmentation over replacement of human expertise. Building on the concept of classroom orchestration (Dillenbourg et al., 2011), the AI dynamically moderated narrative flow, introduced adaptive challenges, and sustained decision complexity in real time. The system created unpredictable, high-fidelity learning conditions by generating context-sensitive disruptions—such as ethical dilemmas or stakeholder shifts. These just-in-time interventions enabled scalable, responsive engagement, supporting critical thinking and the development of adaptive judgment in complex project scenarios.

The AI-GBL was structured as a serious game, employing game mechanics to foster project leadership through immersive, high-stakes simulations that replicate professional challenges without real-world risk (Daniels et al., 2025; Michael & Chen, 2005). Gameplay was governed by explicit rules and resource constraints, requiring learners to manage time, budget, team capacity, and risk buffers. Decisions were locked before outcomes were revealed, compelling learners to commit and reflect on consequences. Each cycle followed a four-phase loop—planning, action, feedback, and reflection—through which learners analysed scenarios, enacted decisions, received AI-generated outcomes, and iteratively refined strategies across progressively complex rounds. This design promoted iterative learning, critical reflection, and adaptive decision-making.

The intervention employed two modalities to cultivate leadership and adaptive expertise: virtual stakeholder interviews and collaborative crisis management. In the former, learners engaged with AI-generated stakeholders to practise questioning, negotiation, and synthesis, strengthening communication and analysis skills. In the latter, teams responded to time-sensitive crises such as budget cuts or personnel losses, requiring rapid analysis,

coordinated decisions, and emotional resilience. Together, these modalities fostered strategic leadership and collaborative problem-solving under conditions of uncertainty.

A defining feature of the AI-GBL model is its integration of ethical ambiguity with structured feedback, designed to provoke reflection and sustain productive struggle. Feedback was delivered to preserve cognitive tension, encouraging persistence rather than premature closure, consistent with research highlighting its impact on performance and retention (DeFalco et al., 2018; Emerson et al., 2020; Goldberg, 2015). Using multimodal learning analytics, the AI adapted feedback to learners' cognitive, emotional, and behavioural states—for example, adjusting difficulty or offering scaffolds when frustration was detected. In this way, the AI functioned as a responsive learning partner, regulating cognitive load, supporting emotional resilience, and clarifying complex decision-making processes in real time.

Explicit win and fail conditions were embedded into the game structure to distinguish the intervention from an open-ended simulation. A win state is achieved when learners meet key project goals—such as completing deliverables on time and within budget—while maintaining positive stakeholder relationships and upholding ethical standards. Conversely, a failure state is triggered if a team accumulates too many strategic missteps, such as exceeding strike limits or depleting their risk buffer entirely. These outcomes create tangible consequences for decisions, reinforcing motivation and sustaining meaningful engagement throughout the learning experience.

The game content embeds ethical ambiguity and promotes productive failure—where learners grapple with complex problems before receiving direct instruction, leading to deeper conceptual understanding (Daniels et al., 2025). Scenarios are deliberately open-ended, requiring students to balance competing values and justify their decisions. For example, in "The Fast-Track Offer," a subcontractor proposes bypassing mandatory safety inspections to accelerate delivery, forcing a choice between meeting a tight deadline and safeguarding public welfare. In "No Right Answer," students face irreconcilable demands from multiple stakeholders, ensuring that any decision will inevitably disadvantage at least one party. Such morally and strategically complex challenges foster *phronēsis* (practical wisdom) and adaptive judgment. The mechanics and their pedagogical alignment are summarised in Table 1.

Table 1: Mapping of Serious Game Mechanics to Pedagogical Themes

Pedagogical Theme	Serious Game Mechanic	Learning Outcome
Relevance	Realistic, industry-aligned scenarios with complex stakeholder dynamics.	Bridges the theory-practice gap by applying concepts in authentic contexts.
Agility	AI-generated disruptions (e.g., budget cuts, regulatory changes).	Develops adaptive responsiveness and strategic decision-making under volatility.
Identity	Narrative-rich dilemmas require reflection on personal values.	Fosters the construction of a reflexive and ethically grounded leadership identity.
Ethics	Scenarios with conflicting moral values and biased AI advice.	Cultivates ethical AI literacy and the capacity for values-based judgment.
Motivation	Adaptive challenges, clear goals, and an immediate feedback loop.	Sustains intrinsic engagement by satisfying needs for competence and autonomy.
Adaptability	Open-ended problems with no single correct solution ("productive failure").	Encourages iterative learning and the development of adaptive expertise.

3. Methodology

This study employed a mixed-methods, quasi-experimental pretest–posttest design to evaluate the effectiveness of an AI-enhanced Game-Based Learning (AI-GBL) framework. Quasi-experimental approaches are suitable in authentic classroom contexts where random assignment is not feasible due to existing timetables and groupings (Creswell & Creswell, 2017). Baseline comparisons were conducted to reduce the risk of selection bias, and no significant differences between groups were confirmed. An Analysis of Covariance (ANCOVA) was then used with posttest performance as the dependent variable, group membership as the fixed factor, and pretest scores as the covariate. This analytic strategy adjusted for prior knowledge, yielding a more accurate intervention effect estimate.

The study sample comprised 113 undergraduates enrolled in project management modules at an Irish university. Group membership was determined by level of exposure to AI-GBL tutorials: students who attended three or

more sessions formed the experimental group (n = 66). In comparison, those attending two or fewer sessions formed the control group (n = 47) and received conventional case-based instruction. A separate postgraduate cohort (n = 47) was not part of the quasi-experiment but contributed qualitative data through reflective journals and project plans.

Although individual QCA (Quality Credit Average) scores were unavailable for the study participants, institutional records show that the average QCA for project management students has remained stable at approximately 3.00 (B2 classification) over the past three academic years. This benchmark corresponds to an upper second-class honours level and reflects the typical academic profile of students in the programme. Given the consistent entry requirements, module structure, and assessment practices, it is reasonable to assume academic comparability across the sampled groups. While this assumption does not eliminate the possibility of selection bias, it helps contextualise group equivalence and supports the plausibility of the observed intervention effects.

The intervention positioned AI as a pedagogical co-orchestrator rather than a content add-on, embedding serious game mechanics rather than passive simulation. Two interactive modalities were central. In the virtual stakeholder interviews, students engaged with AI-driven characters representing clients, sponsors, or team members, requiring negotiation, probing, and interpretation of incomplete or conflicting information. In the collaborative crisis management exercises, teams responded to AI-generated project disruptions such as budget reversals, shifting deadlines, or stakeholder disputes, which introduced volatility and demanded collective decision-making under pressure. Each activity was followed by a structured debrief in which the lecturer acted as a game master—shaping the flow of play, motivating learners, and framing ethically ambiguous dilemmas as opportunities for reflection. This pedagogical presence ensured that AI-driven dynamics remained embedded within a purposeful game-based learning environment. Scenarios were deliberately framed without a single "right answer," encouraging learners to confront trade-offs and strengthen reflective judgment, leadership identity, and ethical sensitivity.

To clarify the logic of the intervention, Table 2 Summarises how each activity mapped to targeted competencies and pedagogical features.

Table 2: Mapping of AI-GBL Modalities to Targeted Competencies

AI-GBL Modality	Description	Targeted Competencies	Pedagogical Features
Virtual Stakeholder Interviews	AI-driven role-play requiring negotiation and sense-making with incomplete information.	Communication, negotiation, critical thinking, uncertainty management	Adaptive AI dialogue, emotionally resonant interaction
Collaborative Crisis Management	Teams respond to AI-generated project disruptions.	Teamwork, strategic decision-making, adaptability, and leadership under stress	Collective problem-solving, dynamic escalation
Structured Debriefs	Facilitated reflection on decisions, trade-offs, and implications.	Reflective judgment, ethical reasoning, and leadership identity	Guided discussion, values clarification
Ethically Ambiguous Scenarios	Challenges framed without a single "right answer."	Ethical sensitivity, metacognitive awareness, adaptive expertise	Moral tension, exploration of consequences

Several pedagogical frameworks informed the design. Kolb's experiential learning cycle guided the structuring of activities into phases of experience, reflection, conceptualisation, and experimentation. Classroom delivery followed the 5E model (Engage, Explore, Explain, Elaborate, Evaluate), ensuring progressive consolidation of learning. Self-Determination Theory underpinned the motivational design, sustaining autonomy through choice, competence through graduated challenge, and relatedness through collaboration. Finally, flow theory informed the adaptive use of AI to balance challenge with skill, maintaining immersion and engagement.

Quantitative data were collected through scenario-based pretests and posttests administered to the undergraduate cohort. ANCOVA was applied to assess posttest outcomes while controlling for pretest scores. Qualitative data were drawn from postgraduate reflective journals and project plans. Thematic analysis identified patterns of adaptive thinking, ethical reasoning, and engagement with AI-generated content, with coding iteratively cross-checked to ensure reliability. These insights were used to contextualise and triangulate the quantitative results. The scenario-based pretest and posttest instruments were developed in alignment with module learning outcomes and the targeted competencies outlined in Table 2. While not standardised assessments, they were reviewed by teaching faculty for content validity and piloted in previous iterations of the module to ensure alignment with intended learning goals.

4. Results

Unadjusted posttest means indicated markedly higher performance among the experimental group ($M = 66.64$, $SD = 5.47$, $n = 66$) than the control group ($M = 48.00$, $SD = 2.89$, $n = 47$). Pretest means were broadly comparable (Control: $M = 19.04$, $SD = 7.49$; Experimental: $M = 21.36$, $SD = 7.26$). Gain scores likewise favoured the experimental group ($M = 45.27$, $SD = 8.47$) over the control group ($M = 28.96$, $SD = 7.82$).

Descriptive statistics were calculated for tutorial attendance to ensure transparency in intervention exposure. Control group students (≤ 2 tutorials, $n = 47$) attended on average 0.81 tutorials ($SD = 0.85$, range = 0–2). Experimental group students (≥ 3 tutorials, $n = 66$) attended on average 4.48 tutorials ($SD = 1.52$, range = 3–8). These figures confirm a clear differentiation in exposure to the AI-GBL intervention (Table 3).

Table 3: Tutorial Attendance by Group

Group	N	Min	Max	Mean	SD
Control	47	0	2	0.81	0.85
Experimental	66	3	8	4.48	1.52

After adjusting for pretest performance, a one-way ANCOVA showed a very large group effect on posttest scores, $F(1, 110) = 437.78$, $p < .001$, partial $\eta^2 = .799$. This means that group membership (AI-GBL vs. control) explained almost 80% of the difference in learning outcomes, independent of students' starting ability. The pretest covariate was insignificant, $F(1, 110) = 1.46$, $p = .230$, indicating that baseline knowledge did not drive the observed gains. The model explained 80.6% of the variance in posttest outcomes ($R^2 = .806$). Table 4 Presents the statistical components underlying these results. The Sum of Squares (SS) values show how much variation each factor explains, while df (degrees of freedom) and MS (mean square) standardise this variation for comparison. The resulting F and p values test whether each effect is significant, and partial η^2 estimates effect size. The group factor had a very large effect ($\eta^2 = .799$), while the pretest covariate contributed little ($\eta^2 = .013$).

Table 4: ANCOVA Results for Undergraduate Posttest Scores (Covariate: Pretest Score)

Source	SS	df	MS	F	p	Partial η^2
Pretest Score (Covariate)	101.9	1	101.9	1.46	.230	.013
Group (Exp vs Ctrl)	30,530.6	1	30,530.6	437.78	<.001	.799
Error	7,673.0	110	69.8	—	—	—

The ANCOVA controlled for students' initial knowledge (pretest scores) to isolate the effect of the intervention. The F and p values test whether between-group differences are statistically significant, while partial η^2 estimates the proportion of variance in posttest performance explained by group membership. In this study, pretest scores did not significantly predict posttest outcomes ($p = .230$). However, group membership (AI-GBL vs. control) had a very large effect (partial $\eta^2 = .799$), suggesting that approximately 80% of the variance in posttest performance—after adjusting for baseline knowledge—can be attributed to the intervention. While this represents a substantial effect within the institutional context, it should be interpreted cautiously given the quasi-experimental design and non-random group allocation.

Thematic analysis of postgraduate reflective journals and project plans revealed a broad spectrum of engagement with the AI-GBL environment. Most students demonstrated growth in ethical reasoning and strategic awareness. Approximately 22% of students demonstrated high levels of ethical engagement, employing frameworks such as virtue ethics and showing nuanced consideration of stakeholder trade-offs. These students frequently used collective language—e.g., "our decision" and "our ethical position"—indicating a shift toward collaborative identity and values-based leadership.

By contrast, approximately 24% of students relied heavily on AI-generated suggestions with limited critical evaluation, often accepting outputs at face value without reflecting on ethical or contextual implications. This tendency was more pronounced in the absence of tutor guidance, suggesting that high autonomy in AI-rich environments may lead to superficial engagement unless explicit scaffolding is provided.

Taken together, the quantitative and qualitative results present a consistent pattern. While AI-GBL enhanced applied performance and fostered ethical reflection for many learners, it also revealed a potential risk of over-reliance on AI tools when lacking pedagogical support. For example, the qualitative theme of "leading through uncertainty" identified in postgraduate reflections aligns directly with the intended outcomes of the crisis

management scenarios and reinforces the posttest improvements observed in strategic reasoning and adaptive thinking.

5. Discussion

The findings demonstrate that the AI-GBL framework significantly enhanced applied learning while reaffirming the vital role of the lecturer as game master. Far from a passive simulation, the intervention established a structured game-based environment aligned with recognised definitions of serious games (Gee, 2003; Kiili, 2005; Prensky, 2001). Game-based learning incorporates challenge, feedback, decision-making, and reflection. AI components provided adaptive challenges and narrative variation, while the lecturer coordinated motivation, guided debriefs, and transformed ethically ambiguous scenarios into opportunities for judgment and leadership development. Rather than replacing the teacher, AI amplified their role within a carefully designed game-based structure.

Quantitative results showed that students exposed to AI-GBL achieved significantly higher post-test scores than the control group, with ANCOVA indicating that group membership explained nearly 80% of the performance variance. These outcomes demonstrate the effectiveness of key mechanics: decision-making under uncertainty, dynamic AI-generated consequences, and reflective debriefs. Unlike static case studies, this approach created interactive, playable problems where learners could test strategies, adapt, and experience productive failure in a safe environment.

Qualitative reflections further highlighted the framework's affective and metacognitive impact. Many postgraduates demonstrated growth in ethical reasoning, collaborative identity, and adaptive decision-making—often neglected in traditional instruction. High performers used collective language ("our decision") and critically engaged with AI outputs, signalling identity-based leadership and critical AI literacy. In contrast, some students deferred uncritically to AI, reflecting a known risk in game-based contexts: without scaffolding, players may prioritise superficial success over deeper engagement (Kiili, 2005). Crucially, the lecturer ensured the activities retained their integrity as serious games—anchored in rules, uncertainty, and consequence—while framing them as spaces for ethical reasoning and leadership. Learning gains, therefore, resulted from AI's adaptive capabilities and the educator's active pedagogical presence.

Finally, this study extends the conceptual model introduced in Project Leadership and Society (Daniels et al., 2025). Whereas the earlier paper proposed six pedagogical themes—relevance, agility, identity, ethics, motivation, and adaptability—these findings demonstrate their real-world enactment. AI-generated crises supported relevance and agility; open-ended dilemmas cultivated identity and ethics; dynamic challenge sustained motivation; and reasoning through uncertainty fostered adaptability—core affordances of serious games (Gee, 2003; Prensky, 2001).

5.1 Limitations and Implications

The study's quasi-experimental design introduced the possibility of self-selection bias, as group allocation was based on tutorial attendance. While pretest scores were statistically equivalent and ANCOVA adjusted for baseline variance, the absence of random assignment limits causal inference. The large observed effect size (partial $\eta^2 = .799$) should also be interpreted with caution, as it may reflect novelty effects or contextual factors specific to the institutional setting. Although full academic records were not available for all participants, historical programme data indicate a consistent average QCA of approximately 3.00 (B2 classification) over the past three academic years. This benchmark supports the assumption that participants were broadly representative of the wider cohort, helping to contextualise the observed learning gains. Nevertheless, future studies should adopt more robust designs to address residual bias—such as randomised controlled trials (RCTs), propensity score matching (PSM), or hierarchical linear modelling (HLM) to account for nested data structures across classes or institutions. As the lead researcher also acted as the facilitator and game master during the intervention, some degree of instructor bias cannot be entirely ruled out. However, all learning outcomes were assessed through independently scored pre/post instruments, and future studies should consider using external facilitators or blinded raters to minimise this risk further.

The single-university setting and focus on project management also constrain generalisability. Future work should examine the AI-GBL framework in other disciplines, educational levels, and cultural contexts. Additionally, reflective accounts from postgraduate participants highlighted the potential risk of over-reliance on AI outputs, underscoring the importance of scaffolding to promote ethical AI literacy. Despite these limitations, the findings demonstrate that AI can operate as a pedagogical co-orchestrator when meaningfully embedded in serious games. For educators, the implication is clear: AI-GBL should not be seen merely as a

simulation or efficiency tool, but as a deliberate, systems-oriented design that invites learners to engage with complexity, navigate ambiguity, and develop leadership and ethical reasoning in uncertain environments.

6. Conclusion and Future Directions

Bridging the gap between theoretical instruction and practical application remains a persistent challenge in project management education. This study shows that an AI-enhanced game-based learning (AI-GBL) framework can meaningfully address this divide by embedding complexity, ethical tension, and identity formation into the learning process. Moving beyond static case studies and procedural training, the framework enabled learners to practise decision-making under uncertainty, reflect on consequences, and develop adaptive, ethically informed leadership.

The findings confirm three key contributions. First, the AI-GBL model produced substantial learning gains in applied decision-making and critical thinking among undergraduates. Second, it showed that AI can act as a pedagogical co-orchestrator, dynamically adjusting challenge and narrative to sustain engagement. Third, it highlighted that autonomy in AI-rich environments demands explicit scaffolding: without ethical and reflective framing, learners may fall into uncritical reliance on algorithmic tools.

At the same time, the lecturer remains indispensable. Acting as a game master, the teacher motivated learners, shaped the flow of activities, and ensured ethically ambiguous scenarios became opportunities for reflection rather than confusion. The intervention's success depended not only on AI's affordances but equally on the educator's pedagogical presence.

Beyond empirical findings, this study contributes to the evolution of serious games. Traditional designs often emphasise rules, scoring, or optimisation, while AI-GBL prioritises narrative consequence, ethical ambiguity, and adaptive feedback. This reorientation aligns game-based learning more closely with professional leadership's complex, value-driven nature. Future research should pursue randomised controlled trials, longitudinal designs, and cross-domain applications in engineering, healthcare, and business education. Ethical AI literacy also deserves greater emphasis, ensuring graduates emerge technically proficient and critically engaged with the tools shaping their practice.

This study builds on the conceptual model previously outlined in *Project Leadership and Society* by offering empirical validation. It demonstrates how AI-GBL can bridge the persistent theory–practice gap while amplifying—rather than replacing—the educator's role. In this way, AI-GBL provides both a blueprint for reimagining teaching practice in the age of AI and a pathway toward cultivating more reflective, resilient professionals equipped for the complexities of contemporary project environments.

Ethical Clearance Statement: This study involved standard classroom teaching and publicly available teaching materials as part of a routine educational programme and thus did not require formal ethical clearance according to University of Limerick policy. Nevertheless, all data were anonymised, and informed consent was obtained for student contributions.

AI declaration: No AI was used in this paper.

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Trust, Pedagogy and Play

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Abstract: This paper reports selected findings from a set of classroom studies across several elementary school grades that involved a program of “just playing”, where videogame play was the focus of positive pedagogical attention. The focus here is on observations and analysis of gameplay in two middle school Canadian classrooms. The paper argues that, and illustrates how, playing video games engaged participating students, and their teachers, in overlooked, but educationally impactful, pedagogical practices--- specifically those engendering social relationships of mutual trust. Trust forms an overlooked bridge connecting play and pedagogy. Indispensable to both, trust is a central, indeed a necessary, condition of learning and play: you have to trust to play; you have to trust to learn. Building on observations and analyses of a 10-week videogame study with 2 middle school classes, this paper highlights the important role trust plays in learning generally, and in learning from video games in particular.

Keywords: Game-Based learning, Trust, Play, Pedagogy, Nintendo Switch, Learning

1. Studying “Trust” in a Play-Based Learning Program

The study here reported was one of a series aimed at understanding whether and how collaborative digital game play could help elementary students develop their language and communication skills. Two previous iterations had been in early elementary (K, 1, 2); this time two senior elementary (grade 7) teachers in a small suburban community school in British Columbia had expressed interest in trying out a game-based learning program. To better align our game-based learning study with the grade 7 curriculum guidelines, we added to our language and literacy-focused study design, a set of digital design activities linked to their gameplay. For 9 weeks, 15 minutes a day, these grade 7 classes played two games on the Nintendo switch: *Warioware: Get it Together*, a fast past pure fun party game, and *Super Mario Maker 2*, a game for learning game design. Students played in teams (set by their teachers), and their progression in both games was tracked at the beginning, middle and end of the study.

The first game was used as an easy and fun way to give everyone functional familiarity with the game controllers, basic game conventions, and, through extension activities, to draw students’ attention to fundamental game elements as models for their own game designs, including character, setting, game instructions, goals and tracking, level design, narrative, mechanics and some coding basics. The second game, which included comprehensive tutorials and an extended introductory example game (in “story mode”), had students designing and creating and testing and modifying their own games (in “maker mode”). Teachers were invited to devise extension activities of their own, encouraged to play alongside their students and urged to learn both games. To minimize disrupting the “usual” classroom environment, we documented the study remotely, using audiovisual recordings of daily play sessions and post-play debriefs, short *in situ* videos taken by teachers ‘on the fly’, student sketchbooks, player progression data stored on the game devices, and recordings of the games that students produced by the end of the program. This “hands off” approach, initiated during COVID when in- class research became impossible, while it enhanced ecological validity by minimizing researcher influence/interference, did place greater demands upon collaborating teachers. They were asked to distribute, collect and charge the class set of switches, oversee the use of the pair of GoPro cameras we installed in each classroom, and to use a (provided) iPad to record interactions, student gameplay or any other notable situations they found of interest. At the end of each week, we asked teachers to complete a quick, 5 question online “check in” form, sharing any photos they felt important from that week, as well as having a short (30 minute) zoom chat with the researchers. At the end of the study each teacher was interviewed individually.

Data sources for two grade seven classes included 265 pages of student notebooks, 375 supplementary photos and videos taken by the researchers, and 98 photos and 58 supplementary videos by teacher-participants on a (provided) i-Pad. One class teacher contributed six short, (optional) paired interviews. Another shared a PowerPoint presentation on videogames used instructionally to support students’ game-based learning. For the two classes combined, we compiled 33.8 hours of recorded and accessible footage, made up of 21 hours of playing time, 5 hours of debrief, and 7.8 hours of instructional time.

Analysis involved viewing and transcribing audiovisual recordings of play, debrief and extension activities: then re-viewing for both unusual events, and recurrent patterns, looking at types of interaction, types of discourse, disruptions, quiet periods, high attention, distraction, incidence and patterns of student mobility), drafting and sharing reflections in the form of “researcher notes”, discussing experiences and interpretations at weekly meetings, posting all research documents and data online (which only the researchers and teachers could access), and examining students sketchbooks with special interest in the alignment (or not) between the game they designed “on paper” and the one they actually developed in *Mario Maker 2*.

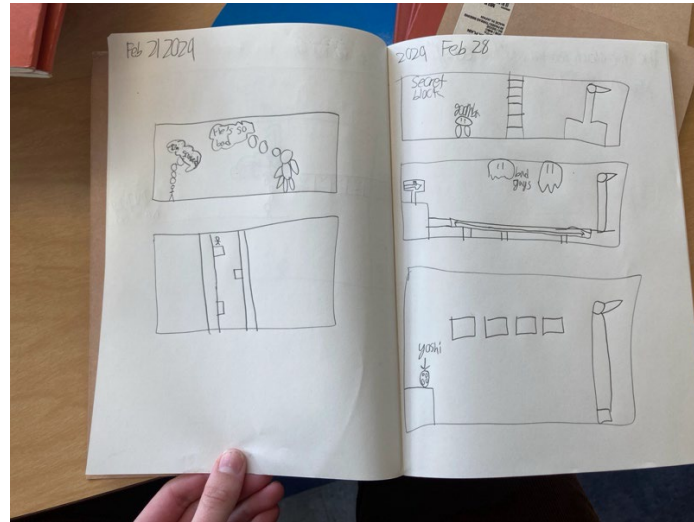


Figure 1: Game Design Concepts

As we sifted through, discussed, re-thought and re-examined our data, we tried to put together an explanatory framework that might account for the kinds of play-based experiences and activities we observed, to help us understand what was going on when things came together, and what was going on they came apart.

Having carried out the first part of this same study twice before (with early years students) the most surprising finding was that these more advanced students progressed more slowly thorough the game, with most students producing less well-developed sketches and drawings, and the class appeared less interested in discussing their gameplay in debrief sessions than their much younger counterparts. As surprising was discovering that these seventh-grade teachers appeared less interested in, and could find less time for, ‘digging in’ to games as a medium for learning, and their extension activities often did not support gameplay, or invite the use of media beyond text, or encourage and scaffold high-level or complex kinds of thinking about playing and designing games. With very few exceptions, these students’ sketchbook productions were underdeveloped, evidencing little creativity or risk-taking and even less playfulness or humour. This was not what we had expected, and we wrestled with how to make sense of what we were seeing, which looked less like engagement in play, and more like detached compliance with the program activities. While these students appeared happy enough when engaged in playing the games, they didn’t display much interest or effort in debriefs, game challenges, or extension activities. This kind of detached, under-involved relationship with classroom learning activities is by no means unusual in classrooms---which is what made it so strange! Because multiple iterations of this kind of game-based learning program have led us to expect marked *improvements* in student attention, engagement and productivity, evidenced by more detailed and developed drawings, a burst of growth in vocabulary, new relationships among students previously not “friends”, increased class solidarity demonstrated through patience, support and kindness, longer and more detailed stories, greater physical proximity and mobility within the classroom space, and different uses of space, like huddling on cushions on the floor instead of sitting in chairs at desks. It was almost as if classes of grade seven students didn’t “buy in” to what we were inviting them to do, didn’t believe it was a worthwhile investment of their interest and energies. It’s telling that, at the end of the study, asked by their teacher if they thought games should be used in school, unlike in previous studies like this one, (Author, 2023), the majority in that class disapproved. Where did thing go awry this time?

Classroom artefacts and progression data provided evidence that these students were not greatly impacted, inspired, engaged or challenged, even as classroom video recordings provided plenty of examples of high enjoyment during play, expanded “friendship groups”, and classes that did not require much, if any, teacher management during daily play periods. Videogame play, in this study, made for good entertainment and good

social relations---but perhaps not so much for good learning. Reviewing video data, transcribing, analyzing and looking for patterns that might help explain students' compliant but educationally inconsequential engagement with game focused learning activities, we asked why 'just playing' games in class looked and felt so much like "regular school", with a bit of an entertainment break every day. . How could something so different from regular school come to look and feel so much like it? Conversely, how is it that the strong catalytic effects of gameplay on student effort, attention and productivity that we had observed and documented in previous studies were far less in evidence in this one? The question came over time to turn on the matter of trust: did students trust that it would be worthwhile for them to put serious effort into the program activities? The analysis began to focus on the many ways trust appeared an overlooked but critical element in pedagogy in general, and game-based pedagogy in particular, and in so doing, changed from research reporting to theory-building as it became clear how trust was in play at many levels: the game, the technology, the teacher/s, classmates—and even the researchers (of which more later.)

Participants, teachers and students, had to trust in the game itself—that it would be suitable for these students, that it would or could support some worthwhile kinds of learning, that the game would engage participants and that it would work well, not be buggy or boring or glitchy. Students had to trust their teachers: that this would be a worthwhile use of their class time, that they would enjoy the study because it was based in play, that they would be learning in a different way, and learning different kinds of things than in their usual classroom activities. And students had to trust their co-playing partners, and their co-participating classmates, that they could relax and enjoy playing without being "messed with"—humiliated, shamed, threatened, ridiculed, exposed—or cheated.

2. "Trust me, I'm Your Teacher"

Students shuffle into their classrooms on the first day of school justifiably hesitant and watchful. Most often, they do not know who their teacher is beyond a name, sometimes teacher 'reputations' are garnered from siblings or previous students. We don't hear much about 'trust' in education, but it's a hugely important, indeed a necessary condition of play, and critical to students' ability to learn from someone else, to take risks, to try (and fail), to ask difficult questions, to go along with their directions even when—especially when—you either don't agree with those directions, or don't even understand the purpose or expected outcome of what you are being directed to do, read, say, act out, imagine, paint, sing...To get on well at school, it helps to trust your teacher.

A quite specific kind of trust is at stake here: just as doctor trust is believing your doctor has the knowledge, ability and intention to heal you, and above all not to harm you; contractor-trust is the belief that your contractor has the know-how and experience to carry out your building needs, and not sink you in a shoddy money-pit. Teacher trust is believing your teacher has the knowledge, ability and intention to educate you, and above all, not to miseducate, deceive, distract, or—since attendance at school is compelled by law—to bore you to death. It is trust that the time you are compelled to be sequestered away under someone else's authority and control is time spent on learning, and not time wasted. Since time turns out to be the most precious of all commodities (and "lack of time" invariably appears the primary impediment for teachers in implementing digital literacies and technologies), wasting time is surely among our cardinal sins. Videogame play, along with 'play' writ large, has been viewed by many teachers as a 'waste of time', and versions of "Stop playing around!" have been ubiquitous in teacher reprimands. In this study, however, videogame play was the focus of strongly positive teacher-attention and support. Identifying and describing the range of pedagogical practices we observed led us to explore trust as a key "para-pedagogical" condition integral to game-based learning.

3. Trust and Learning; "Epistemic Trust"

Trust has not had much attention in educational theory and research—and it will not be a familiar topic to games and learning scholars either. Chew (2023) observed "there is remarkably little research on the role of trust in educational settings." ¹ He further reports that his own research showed that "students are more willing to work hard and take on more challenging work when trust in the teacher is high" (Chew et al., 2020). Trust so

¹ Chew, a psychologist, defines teacher trust as involving 3 components: (1) Competence: The teacher has both the disciplinary knowledge and teaching skill to teach a successful class; (2) Integrity: The teacher is truthful and conscientious, and treats students respectfully, and (3) Beneficence: The teacher will work to promote and enhance the learning and development of students in the class

seen is a “paracognitive condition,” not itself knowledge/understanding, but working right alongside it, in a supportive but essential role. It’s essential because learning is a risky business.

Learning is an epistemic undertaking, concerned first and foremost with developing knowledge and understanding, and cultivating and sustaining students’ epistemic trust—their ability to believe what is being communicated to them—must therefore be a primary pedagogical concern. When what is being communicated to you is NOT what you already believe, learning poses epistemic *risk*. And that’s because when we learn something new, we are in effect also learning that we are, or anyway we have been, thus far, wrong about that thing (Beckett, K. 1983). Learning contradicts (contra=against; dict[um]=authoritative assertion) what we (thought we) knew, and requires us to change, modify, correct or further develop what we (thought we) knew. Learning must, of necessity, destabilize us, whether only slightly, or profoundly: significant learning means epistemic vertigo, and takes some getting used to. Thus, unavoidably, teaching risks a kind of violence, and learning risks becoming a kind of oppression. That’s not thought about as much as it should be.

Because learning is a profoundly unsettling thing, it requires well-supported engagement and attention, what educational philosopher R.S. Peters memorably described as “willingness and wittingness”. *Ethical* educational work, however compromised that may be by schooling being compulsory, must still involve students’ wanting to learn something, and students having their ‘wits about them’, that is, being attentive and engaged in learning, and be able to trust enough to take the dizzying risks that learning entails.

It doesn’t help matters that the classroom is an enclosed social space that is regulated by external rules levelling all individuals into ‘students’ and authorizing adults as primary (Teacher/s) and secondary (Assistants) leaders. Any utterance (or action) by a student is thrust immediately into a hierarchically structured and regulated discursive order, whether individuals so enmeshed like it or not.

However, this pre-figuring discourse requires a kind of language many students withdraw from, or outright refuse to enter. For example, normatively re-mediated by and for that social space, any utterance can be read as either ‘consent’ (or ‘dissent’) to its identity-forming structuration. Speaking out in class has always had complex constraints as well as affordances, making student participation a fraught and perilous journey. Freire many years ago spoke of a “culture of silence” among the people he was writing about at that time; the classroom can be no less such a culture. Silence speaks volumes, as Freire there observed. So, it’s valuable to recognize that there is always risk and danger for students who speak (or otherwise participate) in class, because within the regulative surveillance culture of the classroom, every discernible communication can, legitimately, be taken up as a “symptom” of who a student is or where they are going or what they think. Those institutionally imposed relations of power and control just have to be worked within and around by teachers as they build the social order of their own classrooms. This can be a slow and difficult process, and sometimes an uneasy collaborative performance will satisfy basic requirements until the year is over. To counterbalance the disempowering and silencing epistemic and cultural architecture of schooling, we can identify some ways of building the supportive classroom social relations that are foundational for epistemic trust, because there has to be some safety net, incentive, or support, something that makes learning both less risky, and worth the risk.

Teachers’ epistemic trust in technologies—like videogames—that change educational media ecologies, by destabilizing traditional text-based literacies and replacing familiar media with new media and digital tools, present quite dizzying ‘epistemic risk’ to teachers. In terms of curricular content, people who would never think of assigning to their class a book they hadn’t read, that they didn’t get enough time for, or found too difficult, or just didn’t find they were interested in, or they just weren’t that great at at reading...And yet its understandable that, even while encouraging students to engage with a videogame-based study, it is only exceptionally that a teacher has seen sufficient value in knowing the ‘text’ her students have been assigned to learn with and from. It might be that the principal message conveyed to students is that this exposure to games is a ‘special event’ that’s more for fun, as a break in the day, than a springboard for significant learning. And in terms of pedagogical process, trusting the game technology means letting the tool co-control the interaction, and needs no further regulation by a third party. When a good teacher is one who has classroom control, this can be experienced as an *existential* epistemic risk, because if that is true, why a teacher? For these and more reasons it is probably important to consider the epistemic risk for teachers of a technology—in this case a videogame—and especially a technology that takes control of student attention and brings with it a whole new medium.

4. Trust and Play: “Ludic Trust”

Like learning, play has to be both “witting” and “willing”. You can no more be compelled to play than you can be forced to be free—even though, in professional athletics or compulsory school sports, you can be required, even compelled, to perform the role of a player, but paradigmatically, play is voluntary.

And, like learning, play depends upon trust. Try playing with a person you don’t trust. All the ways trust is essential for play come easily to mind. Some of these are the necessary belief that person will ‘play fair’, not only not rule-break or cheat in game terms but potentially cause direct harm by making play serious—physically dangerous, for example. Traditionally theorized as a “magic circle”, play so seen inhabits an imaginary protected zone in which fantasy, physical challenges, role-play and story weave together a world apart from everyday life. But suspending the norms and certainties of the everyday world brings risks of every kind, which is why inhabiting that vertiginous domain requires players to trust one another—that this is really “play”, and it’s by the “rules”, whether adopted or contrived in the moment. Play in this sense is un-strategic---that is to say, it is ‘not-for-profit’, so to speak, not intentionally deployed to achieve some desired end in the ‘real world’, the world that is **not** play. Of course play is full of strategizing which is also a major part of its challenges, excitements and rewards. But play’s strategies are “within the game”, and part of ‘fair play’ is the operating assumption that players purposes are intrinsic to the game and to playing it. In that paradigmatic sense of play, “ludic trust” is a necessary condition of play, just as than “epistemic trust” is for learning.

What makes trust of particular interest to games-focused researchers is that while not everything that requires trust is play, everything that is play requires trust.

5. Trusting the Game: Is This Playable?

In terms of the *game* itself, when students were asked how they enjoyed the two games they were asked to play, their verbal responses, and our observations of their game play behaviour, made clear that while they regarded the initial game *Warioware: Get it Together* as too ‘young’ for them, they nevertheless enjoyed playing it, and, with the exception of a small group in one class that did not participate in the study, the class as a whole was keenly engaged in playing, and the game itself presented no technical problems at all. Students also told us they enjoyed the second game (*Mario Maker 2*), with several expressing a strong preference for the second, more challenging game, but several others largely withdrawing from its challenges. Both games were perceived as solid and well-functioning, not ‘buggy’, or laggy or disjointed—and, even if a bit too young in the first case, engaging and fun. It was clear students saw the first game as entertaining, and the second as more recognizably ‘educational’. No one challenged the adequacy of these two as “good games”, indicating they trusted the games, as games, to be both playable and worth playing.

6. Technological Trust: Machinery and Agency

Trusting the technology cannot be overlooked—and promises to be an increasingly important consideration with the sudden and transformative emergence of AI Chatbots as legitimate educational agents. It may be supposed that what is at stake in relation to technologies is not “trust” so much as “reliance” (See Hawley, 2017), a more pedestrian and, indeed, mechanical virtue: the thing will work. Distrust, argues Haley, embodies a moral criticism. As she goes on to explain, “We trust people as *speakers*, (as writers, as signers, etc.) and we trust people as *actors*” (Hawley, 2017, p.72.). As more than just hardware, though, as programmed hardware, non-humans can become, and have become, actors, as learning technologies, paradigmatically LMS systems and ‘tutors’ direct and regulate and control human action and interaction, both individual and social. It will be of great interest to discover over time their epistemic ‘resiliency’, that is, the extent to which, despite known and oft identified AI-generated errors in learning management system content and feedback, these technologies come, nevertheless, to be “trusted” by school boards, teachers, parents and students, to be regarded as “beyond criticism”, very much—even more than—in the way that school textbooks used to be. Looking at the materiality of gameplay, the *devices* students were given to play on were a classic and well-respected “brand” (Nintendo switch), and although the ones we used were not the latest version, there was never any tension observed around the devices being too hard or not working, or any kind of “blaming the tool”.

7. Trusting the Teacher: Are we Really Going to (*Learn Through*) Play?

Are we really going to be *allowed* to play (and will it really be fun or just ‘fun’?), and are we really going to learn something worthwhile, or is this videogame study, as Greta Thunberg most famously said, just more “blah, blah, blah”? (<https://www.theguardian.com/environment/2021/sep/28/blah-greta-thunberg-leaders-climate-crisis->

co2-emissions). Imagined or not, these, or questions like them, probably shape, for students, the seriousness with which they attend to and engage with class activities—and the teacher is in authority.

How do teachers convey to students what and how they can learn by playing? One way is by simply allowing students the time, space and conditions to play. For example, simply leaving students free to play, to move around the class, chat with their playing partners and classmates, and play uninterrupted for the designated period, giving just one time reminder in the last few minutes, enables them to focus entirely on their play, and in that temporarily suspended play space, interacting with ‘reality’ only as gameplay demands (which is of course what drives parents to distraction, but this is not the place to take that up). Impeding students’ focused engagement on play, or immersive ‘flow’ experience in play, were teacher- provided frequent “time checks” (sometimes with minute-by-minute countdowns). Interspersed interruptions about organizational matters throughout the assigned 15 minutes of daily play meant the only way students could concentrate on playing was by ignoring what the teacher was saying! Time was also the issue in a class where considerable time in one class was taken up every day in “set up”, that is, in distributing switches to, and collecting them from, their pre-assigned teams, a task carried out by the class’s “educational assistant”. In the other class, where students were directed to collect (and return) their switches by themselves, this less teacher-driven process left the class with several minutes more playtime every day than their counterparts.

What about *learning* through play? (Or is this not a learning activity?) Although the recreational and social aspects of gameplay are certainly important conditions for learning, there are other directly curricular objectives that gameplay can serve, objectives that students can share, if they are made sufficiently evident. Such evidence, in our study, consisted in teacher questions that probed into students’ initial responses, and that sometimes challenged those responses with counterexamples. Taking time for students to formulate, and then asking them to reformulate, responses to significant (and answerable!) questions demonstrated to students the importance placed by their teacher on their own developing understanding— ‘recall Chew’s beneficence’ condition for teacher trust: “The teacher will work to promote and enhance the learning and development of students”).(Chew, 2023) When a teacher assigned a task, however, and then within the lesson iteratively reduced its original demands (“Write a letter to the superintendent about whether you should have videogames in school”) to “use any form you like, word cloud, list, pros and cons”, to “just 3 bullet points”, behavioural compliance gets prioritized over cognitive engagement. Other instances that may have signaled a lack of ‘beneficent’ concern with students’ learning included questions being posed, then students asked their opinions in a show of hands that were, however, never actually counted, or being given just minutes to write answers in their ‘notebooks’ to a question on the board, then the teacher circulating giving students one example after another of what they “might say” or “might argue”. In these ways, the game-focused “extension activities” designed at the outset did not serve their intended purpose of challenging students to learn a new skill set (game design) and to take risks and create in non-textual forms (sketchbooks), becoming instead undemanding exercises in compliance.

When teachers gave control over to the technology and the students, there was more time for play. Whether that time was spent, however, in what has been elsewhere described as “serious play” (Beavis, et al., 2017) is likely to be influenced by what the teacher conveys about the importance or educational value of doing so. But when teachers chose not to play alongside their students, or, if they played, when they directed attention away from their students’ play experiences and towards their own, by disavowing competence or game experience, or asking for student (invariably boy) help, play, and the educational value of play, was undermined. Because why else would a teacher be unable to play a game that first-graders were successful at?

8. Trusting the Medium: Making Media Ecology Shifts Credible

The promise of educational value through play can be supported, or it can be undermined. Not only students, but teachers as well, can offer powerful resistance the introduction of a new technology, with its shifting of the familiar media ecology of the classroom. Change can be resisted by converting experiences of and in the new medium (here, videogames) into ‘regular’ classroom activity. For example, to deepen and enrich her students’ videogame experiences, one teacher created and delivered a multi-part series of ‘lessons’ on videogames, informing students about videogame history, famous game designers, types of games and game characters, and touching on issues (‘addiction’, violence, business), concluding with questions about whether videogames should be used in schools. The majority in this teacher’s class said no. (They may have thought that asking if the activity the class had been engaged in should have a place in the classroom expresses their teacher’s lack of confidence in its educational value).

In designing the study, “game designer’s sketchbook” was an integral element. The intent was to provide each student with their own individual (to keep after the study) ‘canvas’ to express their ideas in a different form than usual, a blank-page booklet whose structure suggests and invites development over time—continuity and iteration--rather than separate thoughts, information, or images.



Figure 2: Game Designers Sketchbook

We provided a series of activities that these sketchbooks could be useful for, as well as a few complementary resources about how people have used their sketchbooks to come up with game ideas and components. In both classes, teachers invited students to use “any form they like (picture, list, word web, sentences, etc.)” in their sketchbooks (see Figure 3). From the first day forward, however, teachers referred to these as “your game notebooks” and assigned questions to which written answers in the game notebooks were assigned. Beyond an initial naming of alternative ways/other media assigned “game notebook” tasks could take, we observed no further explicit attention to the specific and quite different media involved in game play and in learning from games: how to design and develop sound, images, characters, mechanics, coding, how to experiment and take playful risks in game design. Game-based activities had to be translated into the traditional “textual preferences” of school-based learning.

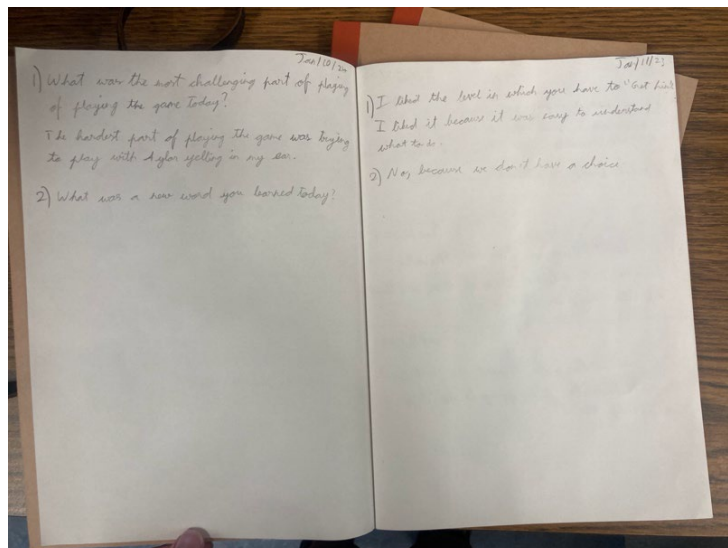


Figure 3: Written answers: From Sketchbook to Notebook

But the intent had been that a “game designer’s notebook” would extend a different kind of invitation for students to learn, in a different medium, on the presumption that building game-based pedagogies call upon a set of abilities qualitatively distinct from those enabled in educational theories and pedagogical practices that are rooted in language and text.

When teachers refer to the sketchbooks as notebooks, however, and ask students to use them to provide written answers to questions on the board, they ‘cancel out’ the kind of information and understanding students can derive from playing and thinking about and making games. Instructive here is McLuhan’s answer to what “media ecology” means: “It means,” he explained: “arranging various media to help each other so they won’t cancel each other out, to buttress one medium with another. You might say, for example, that radio is a bigger help to literacy than television, but television might be a very wonderful aid to teaching languages. And so you can do some things on some media that you cannot do on others. And, therefore, if you watch the whole field, you can prevent this waste that comes by one canceling the other out” (McLuhan, 2003b, p. 271). What this means for educational media ecology is that, whatever the educational value of videogame play, it would be impossible to benefit from it if its interactive multisensorial medium is cancelled, in McLuhan’s sense, out by traditional didactic and textual forms. Whatever the value of sketchbooks, their affordances are lost if students are told that “three sentences is your ticket to recess”.

9. Trusting the Researcher

Always, in the background and normally not spoken about, is the issue of trust in the research and in the researcher, for both teachers and students. Students had all been told about the study, of course, and asked to give their assent, in addition to their parent’s consent. Notwithstanding these standard processes, the extent to which students did so as “informed” and “consenting” participants is always in question when the context is the classroom, where the teacher holds both authority and power, and where both peer and parental pressure can exert a considerable influence on what students “freely” do. Because we used audiovisual documentation in place of in-person observations as our primary data source, students had little direct contact with the researchers beyond a visit by the research assistant to set up cameras or pick up sd (data) cards. It may well be because the subject of the study was videogames, rather than because of any trust in the worth of the study, that explained students’ willingness to comply with its various activities. Students made their awareness of the cameras in their classroom apparent in several ways: they looked up then actively moved out of the way, they directly addressed the camera/researcher, for example saying hello, or “acting up” for the camera, or reminding a swearing student of the presence of the camera. In those small ways we could see students deferring to the camera, and changing their behaviour in front of it, however we saw no evidence that the presence of the camera in any significant way skewed students’ usual patterns of daily classroom behaviour.

Teachers were also fully aware of the cameras since they were in charge of turning them on and off each day, and they were far more directly in contact with the research team, with weekly zoom meetings and online check-ins, as well as interviews at the start and on completion of the project, with intermittent emails concerning arrangements, tech needs, schedule changes and the like. However, no researcher was present during instructional time or daily, play sessions, nor was there any direct contact between school administrative staff and the research team. Nevertheless, as every teacher knows, it is a risky business inviting research into your classroom, and it takes a high degree of confidence, as well as some initial trust, because access to the “everyday classroom” means access to “the good, the bad and the ugly”— a potentially intimidating thing in itself. Remember that these teachers had not used videogames in their classrooms, were not familiar with the games we proposed to use, and were not themselves avid game players, so unlike studying subjects in which teachers had expertise, this study was looking at something they were decidedly not experienced or expert at. As with so many classroom studies, however, this one was introduced in the context of a personal acquaintance (between the graduate research assistant (GRA) and one of the two teachers in this study. As well, the GRA was herself a fully qualified teacher. So whereas it has been shown that institutional trust is the primary reason for agreeing to participate in a study—that is, the credibility of the institution is what gives prospective participants confidence that the research is worthwhile and will be conducted capably and ethically, (Guillemin, M. 2018) “interpersonal” trust likely played a role in building “researcher trust” in this study. Two other elements may have contributed to teachers’ trust in the researchers/research: first, it was made clear from the start that the purpose was to observe (using cameras and teachers’ own documentation an, videos and images), and to describe. There was no researcher intervention, and no ‘agenda’ about what teachers “ought” to be doing—we simply asked to observe and describe, analyze what we were seeing (always the tricky part!) and share that analysis with the teachers participating. We shared meeting notes (recorded) and researcher notes (intermittent preliminary analyses, discussed ideas about extension activities, questions to pursue, and so on) on email. As well, and this is both extremely important in principle, and also probably inconsequential in practice, our explicit aim was transparency. That meant making ALL data and ALL analyses available to the teachers, excepting only the occasional (unrecorded) conversation between the lead researcher and the Graduate RA. Recognizing how classroom research can impose requirements at odds with teachers’ instructional wants and needs (Quinsaas,

1997), and can too often result in critical and even undermining representations of teachers, their classrooms and their pedagogical activities, this study aimed to find a way to make critical observations and reflections possible, at the same time making a commitment that we would not include anything in our documentation and analysis that we were not willing to share with the participating teachers. Nevertheless, whether or not this move impacted teachers' trust of the research/researchers, it certainly helped to "keep US honest" to recognize that whatever we did would be available to teachers, even if they might not avail themselves of it. The greatest responsibility for researchers is to make good use of the time and space and generosity—and bravery!—of research participants, given all the kinds of risks that courageous generosity can incur, is to make good use of the study data, at the same time respecting the feelings of the teachers whose classes we observed, and who are doubtless as aware of "the bad and the ugly" as they are of the 'good'.

Transparency is a grand aspiration conveying mutuality of regard and respect for participants by the researcher/s. However, it's also common knowledge that participants, even when given hard copy of printed transcripts, and not just links to online data, typically do not much change, correct or modify the transcripts, and indeed may not actually read them closely, or at all. This study's aspirations to transparency worked mostly as a kind of ethical self-discipline, to keep us in check, conscious of how participants might feel or react to the ways we were—unavoidably selectively—taking up and interpreting the data captured. If we had hoped teacher participants might themselves view particularly unsettling events and provide insights or an alternative interpretation or some explanation that made sense of what we were perceiving—like the several times the educational assistant had up to a third of the class hovering around his desk playing a card game he routinely carried on with 4 students who did not consent to participating during gameplay sessions—we soon realized this was not going to happen. So, the onus has remained very much on us to navigate the tricky ground between an honest, fulsome and critical accounting of the observational data these teachers so generously provided, and taking care to respect their rights and dignity and self-esteem. And in the end, this obligation has been the reason the present paper gradually shifted from a close examination and dispassionate analytical report of research findings, to a philosophical exploration that ranged beyond this one study to reflect on the whole set of studies of which this was a part. This approach, we very much hope, has afforded a way of honoring participants' trust, while at the same time making illuminating use of the insights their participation enabled, that helped us recognize and describe the challenges classroom teachers find, and make, to successfully implementing videogames as a legitimate and impactful educational technology.

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Ethics declaration: This study was approved by the Research Ethics Boards at Simon Fraser University and the school district that participated in the study. All participants (teachers, students, students' parents) signed research consent/ assent forms.

AI declaration: There was no use of AI in this paper, nor in the research study.

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Understanding Systems Engineering Decision-Making Through Game-Based Simulation: Insights from Industry

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Abstract: Learning how Systems Engineers (SEs) make architectural design decisions in real-world settings is challenging due to the involvement of interdisciplinary stakeholders, shifting priorities, and multiple trade-offs often across extended project timelines. While interviews, observations, and participatory sessions provided valuable insights in our research, they fell short of capturing the nuanced decision-making patterns, challenges encountered, and strategies adopted by SEs. To address this gap, we developed “*Decision Pathways*” a board game designed to recreate realistic SE design conditions in a structured and observable environment. *Decision Pathways* is a team-based, one-hour game where participants take on the role of SEs tasked with designing a system architecture. Gameplay involves selecting a knowledge pathway, navigating stakeholder networks, identifying and purchasing knowledge cards within a limited budget, and adapting architectural designs in response to evolving constraints. All decisions are made under time pressure, and the game concludes with each team presenting a physical architecture canvas. The game is structured around the Octalysis framework to ensure player engagement through motivational drivers such as time scarcity, ownership, unpredictability, constraints, and collaborative challenge. Following iterative design refinement and a pilot with 10 cross-disciplinary PhD researchers, the game was implemented with 54 practicing Systems Engineers from high-tech industry. The sessions yielded rich data on decision-making patterns, organization-wide considerations, knowledge identification and use, and team dynamics including the challenges faced and strategies adopted. Participant feedback validated the game’s realism and identified its value beyond research as a training and reflection tool for both novice and experienced SEs. This paper details the conceptual foundations, design methodology, core mechanics, and empirical insights from “*Decision Pathways*.” The research demonstrates how simulation-based board games can effectively support engineering research, professional development, and reflective practice while offering novel perspectives on complex decision environments. The implementation and results gives ideas for broader applications in systems thinking education and engineering design training.

Keywords: Game-Based simulation, Systems engineering, Design decision-making, Octalysis framework, Serious games in engineering

1. Introduction

Architectural design decisions in Systems Engineering (SE) are made under high complexity, involving multiple stakeholders, conflicting priorities, and interdependent trade-offs (Madni and Sievers, 2018). These decisions shape how systems are structured, integrated, and realised (Becker and Walker, 2017). Yet, understanding how SEs make such decisions in practice is challenging. The processes unfold over time, are embedded in collaboration, and shaped by organizational dynamics not easily captured through traditional methods. This gap is also recognised in SE training, where simulation environments like the Experience Accelerator (SERC, 2024) aim to support decision-making under realistic constraints.

In our research, conventional methods like interviews, observations, and workshops provided valuable context but fell short of capturing the dynamic, real-time nature of decision-making. This led us to explore game-based approaches, which offer a structured yet flexible way to simulate complexity and provoke reflection. Serious games have shown promise in engineering education, supporting systems thinking, teamwork, and motivation (Urgo et al., 2021; Núñez-Pacheco et al., 2023; Zourmpakis et al., 2023). While most studies focus on academic settings, their insights offer parallels for professional practice.

Building on this foundation, we developed *Decision Pathways*, a board game that simulates early-stage architectural design in SE. Grounded in motivational principles from the Octalysis framework (Chou, 2016), the game functions as both a research tool and a reflective exercise, enabling deeper insight into how engineers navigate architectural decisions in complex environments.

2. Game Design and Development

Decision Pathways, a serious board game, was developed to investigate architectural decision-making in Systems Engineering (SE) as part of an ongoing research project within the Systems Engineering and Multidisciplinary Design (SEMD) group at the University of Twente.

The game was conducted in a workshop format, serving as the core activity followed by theme-based discussions aligned with our research aims. The primary purpose of the game was to simulate realistic SE decision-making in a controlled setting to support data collection. Earlier methods such as interviews and observations yielded fragmented insights, often influenced by the specific project phase participants were engaged in. The game addressed this limitation by creating a shared, complete design experience that set the stage for richer post-game discussions.

Grounded in insights from our industrial partner, the game simulates design pressures through a realistic scenario, knowledge acquisition pathways, architectural planning under budget constraints, evolving conditions, and uncertain information sources. It retains the complexity of SE work while enabling structured observation of decision-making, knowledge strategies, and team dynamics. By engaging participants in stakeholder complexity, incomplete knowledge, and trade-offs under constraints, the game creates conditions that surface authentic decision-making behaviours for analysis. The format is both cooperative and competitive: teams collaborate internally while aiming to produce the most effective architectural solution.

Participants design a system architecture in response to a scenario by acquiring stakeholder knowledge and managing constraints such as time, budget, and evolving conditions. There is no single correct solution; teams must make trade-offs, justify decisions, and relate their approach to real-world SE practices. The game promotes reasoning and negotiation, and encourages participants to reflect on their own decision-making practices. Gameplay follows structured phases: scenario briefing, rule explanation, knowledge exploration, decision rounds, introduction of constraints, architecture finalisation, presentations, and concluding reflection.

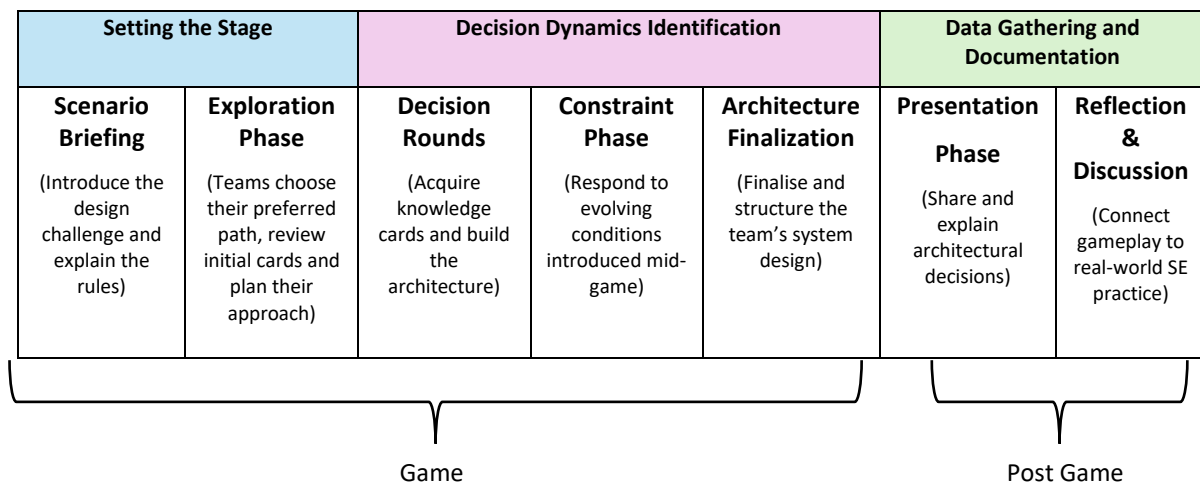


Figure 1: Decision Pathways Game Flow

The development process included two major stages: development and final design. The game evolved through multiple design cycles, informed by insights from the partner company to ensure realism and industrial relevance. Key elements refined included the scenario, card-based stakeholder knowledge, the distinction between people and process pathways, and the integration of time and budget constraints. The final design incorporated the Octalysis Framework's eight psychological drivers (Chou, 2016) to align gameplay with decision-making themes. While other models such as Kapp (2012) or Zichermann and Cunningham (2011) exist, Octalysis offered a practical structure and had been used by one author in a prior context (Pessoa, 2023).

The game was piloted with 10 PhD researchers at the University of Twente to test structure, clarity, and realism. Conducted as a 90-minute workshop, it included briefing, gameplay, and debriefing. Two teams of five used printed materials stakeholder maps, knowledge and constraint cards, budget tokens, and architecture canvases to complete the full cycle from selecting a knowledge path to presenting a final design.

Facilitators observed the session, made notes, and collected data through audio recordings and sticky notes. Participants engaged with trade-offs and stakeholder reasoning, showing clear understanding of the design challenge. Feedback led to refinements in instructions, visuals, canvas layout, and constraint timing, informing the version later implemented with 54 practicing systems engineers in industry.

3. Decision Pathways Board Game

As the game was designed to mirror real-world SE architectural decision-making, it includes components that reflect typical SE work conditions while embedding motivational design principles from the Octalysis framework. As shown in Figure 1 (game flow), players move through a sequence: understanding the scenario, choosing a knowledge path, acquiring knowledge cards, designing the architecture, and finally reflecting on their choices. Each element serves both a gameplay function and a motivational purpose, as outlined below:

- The game begins with an *imaginary company profile and design scenario* that provides players with clear context and purpose. This frames the challenge and supports the core drive of **epic meaning and calling**, as teams step into the role of Systems Engineers solving a realistic architecture problem.
- A key setup feature is the *Organisational Stakeholder Map*, which visually represents internal and external actors. Each stakeholder links to two colour-coded knowledge cards aligned with distinct pathways: the *people pathway* (orange), representing informal, experience-based knowledge (e.g., preferences or routines), and the *process pathway* (blue), representing formalised sources (e.g., documentation or logs). This dual-path design introduces **curiosity, unpredictability, and early trade-offs** in knowledge strategy.
- Teams are given a *fixed budget of 20 coins* to purchase stakeholder knowledge. This constraint, combined with a *60-minute time limit*, pressures teams to prioritise and manage uncertainty reinforcing **scarcity & impatience** and **loss & avoidance**. Not all knowledge cards are equally useful; some are detailed, others vague or misleading. This variability requires strategic adaptation, further engaging **unpredictability and curiosity**.
- Midway through the session, *constraint cards* are introduced. These simulate disruptions such as organisational shifts, compliance issues, or conflicting requirements. Teams must adapt their evolving architecture and rethink decisions on the fly, reinforcing **unpredictability**, and encouraging reflective, adaptive decision-making.
- As teams work toward a solution, they use the *architecture canvas* to visualise their final design. This shared space externalises reasoning and links stakeholder knowledge to design choices supporting **ownership & possession, creativity & feedback**, and a sense of accomplishment. Players often refer to the canvas as “our system,” highlighting engagement and collaboration.
- Additional materials like *stationery, tokens, and printed instructions* support gameplay and help externalise thinking. The structured flow and completion of the architecture contribute to a sense of progress, aligning with **development & accomplishment**. Team-based play naturally encourages role division (e.g., card reader, budget manager), activating **social influence and relatedness** through shared decision-making and negotiation.
- The game’s open-ended format, with no single correct solution, allows for creativity and diverse approaches. Final presentations provide space for **empowerment of creativity & feedback**, as participants explain their logic and reflect on decisions supporting both learning and professional insight.

The Octalysis framework helped ensure the game was structured and engaging while reflecting the realities of SE decision-making. Rather than applying it as an overlay, we used the core drives to shape key aspects of the game from the outset from time pressure and resource limits to team interaction and design ownership. This alignment of gameplay mechanics with motivational patterns made the experience meaningful in both learning and professional contexts.

The game is designed as a one-hour session for teams of 2–6 players. For a given design scenario, participants collaboratively build a physical system architecture using fragmented knowledge, while managing time, budget, and evolving constraints. Success depends on strategic choices: selecting knowledge paths, navigating stakeholder networks, acquiring and applying relevant cards, and adapting designs under pressure. Each team ends with a completed architecture canvas. While primarily intended for group play to encourage discussion and role division, the game can be played solo though this may reduce key dynamics such as negotiation and collaborative reasoning.

A typical session moves through a series of phases that reflect key parts of SE project work. It starts with a short briefing on the design scenario, followed by phases where teams explore knowledge paths, collect information, deal with constraints, and develop their architecture. The session ends with a presentation and reflection. Each phase has a set time and is simulating aspects of SE decision-making. The sections below explain each phase step by step, linked to the visuals in Figure 2 (numbers in the text * correspond to the numbers in the figure).

3.1.1 Briefing (0–5 mins)

The session begins with a short introduction where the facilitator presents the scenario. This is done using a brief presentation and a printed handout that participants can refer to. Participants are told they will act as Systems Engineers, working in teams to design a system architecture within the given time and budget.

The facilitator then explains the structure of the game, including its components (*1-5). One of the first choices teams must make is selecting a knowledge path (*2): either the people path (orange) or the process path (blue). The people path represents informal, experience-based knowledge such as stakeholder preferences, team culture, or hallway conversations. The process path focuses on formal sources like documentation, reports, emails, and system logs. This early decision shapes the team's starting point, as it determines which set of knowledge cards they receive. However, participants are informed that their paths remain flexible later in the game.

The briefing also covers how to read the stakeholder map (*1), use the knowledge cards (*3,4), manage the fixed budget of 20 coins per team (*5), and work with the architecture canvas (*7) to build and present their design. Basic rules are introduced, and each component is detailed. Participants are encouraged to ask questions to ensure the game mechanics are clear. Once the rules are understood, teams begin reading the scenario and discussing how they might approach the challenge. This leads into the exploration phase, where they receive their first set of knowledge cards (*4) and begin working through the scenario.

3.1.2 Exploration Phase (5–15 mins)

Teams receive a set of five pre-selected knowledge cards based on their initial choice of the people or process path, marking the start of the exploration phase. They begin by reviewing the content of the cards to identify useful information, spot connections to the design scenario, and determine which elements might guide their next steps.

During this phase, teams typically spread out the cards, divide reading tasks, and highlight key points or stakeholder references (*6). Some teams begin sketching rough ideas on paper or directly on the architecture canvas, while others focus on discussing what kind of architecture might be feasible given the information they currently have. Early roles such as timekeeper, card reader, or design lead often emerge organically as the group starts organising its thinking.

The exploration phase is intentionally open-ended, with no prescribed structure for how teams must proceed. This flexibility allows participants to define their own approach to navigating the design challenge from the outset. While their initial cards are drawn from one pathway, teams are free to switch between the people and process paths in later phases and can access any available knowledge card (*3) using their remaining budget.



Figure 2: Decision Pathways Board Game (Numbers in the figure correspond to the gameplay phases described in Section 3.)

3.1.3 Decision Rounds (15–60 mins)

In the main phase of the game, teams decide which additional knowledge to acquire and begin constructing their architecture using the stakeholder map, knowledge cards, budget coins, and architecture canvas. Stakeholders (*3) represent internal and external actors, each linked to two knowledge cards one from the people path (orange) and one from the process path (blue). Cards are uniquely numbered and assigned a budget cost (*5). Teams may select any card at any time, using their remaining coins to access knowledge aligned with their evolving strategy.

A key design element emerges here: people and process cards have different costs, which teams discover only after choosing a path. This prompts reassessment of budget use and strategy. Not all cards are equally valuable, some offer clear insights, while others are vague or less relevant. This variability introduces uncertainty and requires teams to judge whether a card is worth the cost. The resulting trade-offs stimulate strategic decision-making under pressure.

As teams gather more knowledge, they begin shaping their architecture. Some cluster cards by stakeholder (*6); others sketch layouts or trace reasoning paths. The game supports varied working styles. Teams build, test, and revise ideas, often adjusting direction as new insights emerge.

3.1.4 Constraint Phase (30–50 mins)

Midway through the session, teams face a new challenge through the introduction of constraint cards, which simulate real-world disruptions such as stakeholder changes, compliance issues, or resource limitations.

Three constraints are introduced during this phase, spaced approximately 5–7 minutes apart. The facilitator reads each constraint aloud, and all teams receive the same one simultaneously. Teams are given a short window to respond by revising their architecture, reconsidering prior decisions, or acquiring new knowledge. Some constraints require removing a card, shifting priorities, or integrating new requirements; others introduce ambiguity or conflicting information. This phase often sparks intense discussion as teams adapt their strategies to meet evolving challenges.

Introduced during the final 30 minutes of gameplay, constraints test teams' adaptability under pressure, mirroring the shifting conditions of SE work. Some teams use their remaining budget to acquire new cards, while others rework their designs using existing knowledge.

3.1.5 Architecture finalization (ongoing)

As teams gather knowledge and respond to constraints, they begin shaping their final architecture using the canvas (*7), which represents both the system design and the reasoning behind it. The canvas is open-ended: teams may draw component layouts, list design features, map stakeholder priorities, or trace knowledge connections. This flexibility mirrors how design logic unfolds in SE practice. Teams revisit earlier decisions, check alignment with scenario goals, and identify gaps or contradictions.

This phase often triggers creative reasoning. As teams integrate information and respond to constraints, discussions become more strategic. Final disagreements are resolved, and decisions are finalised. Some teams divide tasks for example, one member sketches others review cards while others collaborate on every part of the layout. By the end, each team produces a completed canvas that reflects their design logic, knowledge use, and responses to the challenges encountered during the game.

3.1.6 Presentation phase

At the end of the one-hour gameplay, each team presents their final architecture using the canvas they developed (*7). Presentations are informal but focused, typically lasting around five minutes per team. Teams explain their design choices, use of knowledge cards, and responses to constraints. While there is no single correct solution, facilitators may ask questions to probe reasoning or challenge trade-offs. The "winning" team is selected based on overall coherence, creativity, and alignment with scenario goals.

This phase allows teams to reflect on their design process, compare strategies, and discuss how knowledge was used or interpreted. Despite starting from the same scenario, teams often arrive at different solutions, showing SE diversity.

Facilitators also recorded observational notes throughout gameplay, capturing how teams interpreted the scenario, engaged with knowledge, responded to constraints, and collaborated. These notes supported post-game reflections and offer insight into participant strategies.

3.1.7 Reflection and discussion (post game)

After presenting their final architecture, teams move into a structured reflection phase, where participants reflect on the game with SE practices. Facilitators guide the discussion using predefined themes: organisational-wide knowledge thinking, knowledge identification and use, and stakeholder alignment, each rooted in prior research. Participants are encouraged to link game reflections with their own work experiences.

This phase supports research data. As participants reflect on their reasoning and collaboration strategies, researchers gain insight into SE behaviour under pressure backed by audio recordings for further analysis. Participants also use sticky notes (*8) to reflect on the challenges encountered.

Together, the game phases create a realistic simulation of SE decision-making. From scenario to reflection, each element aims to keep participants engaged while surfacing how they handle knowledge, constraints, and collaboration, supporting both learning and empirical observation.

4. Implementation and Insights from Industry Sessions

The Decision Pathways supported simulated reflection for participants and research data collection. From the participant perspective, the goal was to simulate realistic SE decision-making and promote systems thinking by engaging with stakeholder complexity, navigating incomplete knowledge, and making trade-offs under constraints. From the research perspective, the sessions aimed to verify the game's structure and realism and provided a controlled, observable environment to study how SEs engage with knowledge, constraints, and team decision dynamics.

The game was implemented with 54 practicing Systems Engineers from a high-tech industry between December 2024 and March 2025. Sessions were conducted in small groups, each facilitated and followed by a structured post-game discussion. Participants consistently noted the game's resemblance to real-world SE challenges, describing it as structured, realistic, and engaging with several calling it "fun but intense." Many valued the opportunity to reflect on their decision-making styles in a simulated yet familiar setting. Each session followed the gameplay flow described in Section 3 and Figure 1, progressing through seven phases: briefing, exploration, decision rounds, constraint phase, architecture finalisation, presentation, and reflection. This structure enabled consistent yet flexible engagement and supported observation of behaviours such as knowledge navigation, trade-off reasoning, and team dynamics elements often difficult to capture in long-term, distributed SE projects.

Data collection included facilitator observations, team architecture canvases, sticky notes, and audio recordings. Analysis followed a thematic approach based on four predefined themes developed during game design: organisation-wide knowledge thinking, knowledge identification, knowledge use, and stakeholder alignment. These themes also framed the guided post-session reflections. Audio data were reviewed to extract decision-making challenges and strategies, triangulated with in-game observations and artefacts. Emergent patterns such as negotiation strategies and trade-off reasoning were compared against the predefined themes. These analytical methods supported interpretation of observed behaviours and decision patterns during gameplay.

Several design patterns emerged across sessions. Some teams focused on internal stakeholders, others prioritised external perspectives. Interpretation of knowledge also varied: some trusted formal documentation, others relied on stakeholder input or informal cues. These choices often reflected team preferences or established decision habits. When constraints were introduced, some teams revised their architecture quickly, while others struggled to adapt without major rework. These differences revealed how rigid or flexible decision strategies played out in a simulated yet realistic design environment.

Facilitators documented how participants engaged with the game, interpreted components, collaborated, and responded to constraints. These observations confirmed that the mechanics functioned as intended and reflected typical SE decision behaviours. In post-game discussions, participants compared the experience to real projects, noting parallels such as knowledge gaps, stakeholder pressures, and conflicting needs. These insights affirmed that the game successfully surfaced relevant SE decision-making patterns.

The sessions revealed how teams manage fragmented knowledge, make trade-offs, and collaborate under pressure. Beyond outcomes, the game functioned as a reflective tool, prompting participants to consider how such decisions unfold in their actual work. This aligns with the game's original aim to serve both as a structured

simulation for research and a means to mirror SE complexity. Participants' spontaneous reflections, negotiation dynamics, and varied design approaches suggest that the game effectively surfaced common decision challenges and strategies. By making these patterns visible in a compressed, observable format, the game fulfilled its dual role of fostering reflection and generating insight into SE practice.

We conducted a thematic analysis of qualitative data from audio recordings, facilitator notes, and artefacts such as architecture canvases and sticky notes. The analysis was guided by four predefined themes organisation-wide knowledge thinking, knowledge identification, knowledge use, and stakeholder alignment established during game development. Transcripts of post-game discussions were coded using a hybrid approach: deductive coding identified data aligned with predefined themes, while inductive coding captured additional insights such as negotiation strategies and team adaptation behaviours. Coding was performed by two researchers, with regular discussions to ensure consistency. Triangulation across data sources supported the validity and helped surface recurring decision-making behaviours and team dynamics reflective of real-world SE practice.

5. Reflections on the Decision Pathways Game

The implementation of Decision Pathways offered valuable insight into how participants engaged with a simulated SE environment. Observations and reflections indicated that teams perceived the game as a realistic design challenge, prompting deep reasoning and collaboration. The balance between realism and playability was well received; participants found the scenario and stakeholder layout reflective of actual SE conditions, while the format maintained focus within time limits. Some teams welcomed greater complexity, while others appreciated the clarity, suggesting the design supported flexible engagement across experience levels.

Teams demonstrated structured reasoning throughout gameplay, discussing which knowledge to acquire, how to interpret it, and how to reflect it in their system design. The architecture canvas helped externalise logic and trade-offs. Rather than focusing on winning, many teams approached the game as a collaborative exercise, mirroring real-world working styles. Reflection began informally during gameplay and deepened in the post-game discussion. Participants drew clear parallels with project work, especially in handling incomplete knowledge, shifting requirements, and internal alignment. For many, the game mirrored their team dynamics and decision-making habits. They saw value in the game not only for research, but also as a tool for training, onboarding, and team learning. The tangible materials and structured format helped surface abstract thinking in a practical, engaging way.

Several Octalysis drives were actively experienced during gameplay. Scarcity and Impatience were triggered by the 60-minute time limit and fixed budget, which pressured teams to prioritise and make quick decisions under uncertainty. Ownership and Possession emerged in how teams referred to the architecture canvas as "our system" and defended their decisions during presentations, reflecting a sense of control and commitment. Social Influence and Relatedness surfaced through natural role division teams appointed timekeepers, budget managers, and design leads mirroring real-world SE collaboration. Empowerment of Creativity and Feedback was seen in how teams interpreted knowledge differently, adapted to evolving constraints, and creatively justified their designs. Unpredictability and Curiosity were sparked by the varied content of knowledge cards some clear, others vague or misleading which pushed teams to reassess decisions and adapt strategies throughout the game.

One participant noted:

"The design game workshop is an exercise in system-level design and would be a good conversation starter on SE ways of working. It triggers reflection on how to approach design questions. It has an attractive example case and is well-prepared with game cards and an overall storyline, including last-minute changes in boundary conditions. I really enjoyed playing it and would love to see it as part of regular training material." - Senior SE, high-tech industry, NL.

These experiences suggest that the Octalysis-based design supported both engagement and reflection, surfacing complex decision behaviours in collaborative settings. Participants viewed the game not just as an activity, but as a realistic simulation of SE practice. Its structured format supported decision-making under constraints, encouraged team dialogue, and revealed reasoning strategies. The game offered participants a chance to think, act, and reflect like Systems Engineers in a setting that was controlled and authentic. It shows promise not only as a research tool, but also for professional learning, training, and team development.

6. Conclusion and Future Potential

Decision Pathways was developed to address the research challenge of exploring SE decision-making without relying on extended industry access or fragmented observations. It also provided participants with a structured, collaborative space to engage with SE complexity. Though initially designed for research, the game quickly proved to be a valuable learning and reflection tool, prompting insights into design strategies, collaboration, and decision-making patterns. A key takeaway was the value of shared, hands-on experience in revealing hidden aspects of decision-making. The game's physical format encouraged participants to think aloud, explore trade-offs, and engage with abstract constraints in a tangible way, bridging research aims with practical SE challenges more effectively than interviews or post-hoc reflections. The Octalysis framework shaped both the game's design and player experience. Its motivational drivers, integrated from the outset, made gameplay purposeful and engaging, and offered a lens to understand not just what players did, but why certain mechanics resonated. Although created for research, participant feedback highlighted its broader value as a reflective and developmental tool. Many reported increased awareness of their reasoning, team dynamics, and working styles, noting its potential for onboarding, training, and team learning. Grounding the game in real-world SE conditions made it feel authentic. While these insights stem from a context, they suggest directions for adaptation and testing elsewhere. The open-ended gameplay supported flexible use beyond its original research intent. Looking ahead, the game can be adapted to other settings, such as academic programmes, digital formats, or industries with similar decision-making structures. While the current implementation involved a specific industrial context with a limited but diverse participant group, the core structure and thinking behind Decision Pathways show promise for broader application. Although recurring patterns were observed, generalisability remains a direction for future work. We view the game's transferability not as a fixed outcome, but as potential that requires contextual validation. Nonetheless, the game's value extends beyond observing decisions it also supports how decisions are made, shared, and reflected upon in practice.

Ethics Declaration: This study was conducted in accordance with institutional ethical standards for research involving human participants. Participants received an information sheet and provided written consent for the use of anonymised gameplay artefacts and audio reflections. Participation was voluntary, without incentives, and no personal or sensitive data were collected.

AI Declaration: After the development OpenAI was used to improve language clarity and format references. All content and analysis are the author's own.

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Designing Meaningful AI-Generated Dialogue: The Behaviour-Driven Conditional Prompting Framework for Serious Games

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Abstract: Many serious games use dialogue between players and non-player characters (NPCs) to enhance learning. However, designing appropriate dialogue is often time-consuming for game developers. Recent advancements in artificial intelligence, particularly Large Language Models (LLMs), have made open-ended dialogue with virtual characters feasible, though managing it in educational contexts remains a significant challenge. This study explores how game designers can guide open-ended dialogue powered by LLMs to create meaningful educational conversations. Expert interviews and a review of existing approaches to implementing open-ended conversation in games led to the formulation of design requirements for a new framework. Based on these insights, the Behaviour-Driven Conversational Prompting (BDCP) framework was developed. This framework offers practical guidance for designers to create scenarios where behavioural learning objectives are achieved through structured dialogue. It combines lock-and-key narrative design, dynamic character prompts that dictate LLM-generated responses, and behaviour analysis prompts that assess player interactions. To validate the framework, a functional prototype called 'Detective Duck' was created. This detective-style 'whodunit' game has players solve crimes through open-ended conversation with AI-driven characters. Players encounter challenges such as persuading hesitant witnesses, or verifying alibis. These challenges can only be solved by demonstrating reasoning and conversational strategies relevant for detectives such as lateral thinking and persuasion. Upon demonstrating these behaviours, character prompts can be dynamically adjusted, ensuring that - only then - players receive key clues needed to advance the narrative. The framework and prototype were evaluated against the established design requirements and through expert interviews. Results were largely positive, indicating that the BDCP framework supports meaningful, open-ended dialogue aligned with educational objectives. However, some inconsistencies in dialogue coherence and adherence to designer intent were noted. Future work will focus on refining narrative consistency and enhancing adherence to designer intent by fine-tuning the language model, integrating AI-driven player feedback, and incorporating other game mechanics into the framework. These improvements would further strengthen the BDCP framework as a tool for designing serious games centered around open-ended conversation.

Keywords: Dialogue generation, Serious games, Game design framework, Large language models, Behaviour-driven conditional prompting framework

1. Introduction

Dialogue has played an important role in many digital games, from the early days of text adventures, where the system provided the players with verbal descriptions of the game world while graphical capabilities were still limited, to games like *L.A. Noire* (2011), which incorporates spoken dialogue by actors who show facial expressions, and may be lying or telling the truth (Domsch, 2017). In interactive drama games such as *Faade* (Mateas & Stern, 2005), the dialogue plays an important role in advancing the game's narrative. In serious games, dialogue also often plays an important role, especially when this is used as a game mechanic in relation to learning goals to be achieved in the game. Because serious games also typically allow players to learn by doing (Anastasiadis et al, 2018), the dialogue also needs to make sense in relation to actions that players and NPCs can perform in the game. In many cases, the dialogue is scripted to ensure alignment of the dialogue with the intended narrative and learning goals (van der Meij et al, 2020).

With Artificial Intelligence (AI), and in particular, Large Language Models (LLMs), showing major advancements in recent years (Liu et al, 2023), game designers now can also employ open-ended conversation. LLMs, like OpenAI's GPT models, are capable of processing written text and generating replies in a conversational manner, showing understanding of the subject matter. Their capabilities are still improving, showing major leaps between generations (OpenAI, 2024). Whereas previously game designers had to prepare every line of spoken word in a game, designers now have the option to implement a LLM into their game that generates responses instead. Instead of having players choose from predetermined dialogue options (as in the traditional 'dialogue-tree' style game), players can now openly converse with a LLM, allowing them to come up with their own line of questioning. This open-endedness of dialogue can offer several important advantages for serious game

designers: First, it allows players to act as an agent with free will. This mitigates unintended scenarios where players resort to calculated guessing from the available options, instead of actively engaging in problem-solving. Second, using generative dialogue can reduce the workload of a designer: it can be a time-consuming process to create branching dialogue, as each branch in the path requires consideration of the outcomes, character reactions, and narrative coherence. Additionally, in a worst-case scenario, each branch in the path can exponentially increase the number of dialogue lines that need to be written.

While the open-ended nature of generated dialogue is powerful, its strength also comes with weakness, particularly when it comes to maintaining control. How can a conversation be kept open-ended while also steering it in an educational direction? On one hand, the designer wants to push the player into completing an educational objective, but on the other hand, they want the player to retain agency of their actions. Therefore, this study aims to answer the following research question:

“How can serious game designers maintain balance between control over conversational topics and the open-ended nature of AI-generated dialogue?”

The structure of the remainder of this paper is as follows: Section 2 discusses related work on dialogue generation in games; Section 3 introduces the Behaviour-Driven Conditional Prompting framework; Section 4 describes how this framework is implemented in a case study to create meaningful dialogue in a prototype game; Section 5 discusses evaluation of the framework using expert reviews; finally, Section 6 concludes this paper.

2. Related Work

Related work on dialogue generation can be found using various approaches, such as knowledge graphs, intentional lines, and generating dialogue and code together at game time.

2.1 Dialogue Generation Based on Knowledge Graphs

Ashby et al (2023) proposed a novel framework for quest and dialogue generation in role playing games. Using a knowledge graph-based approach, quests are generated that fit within the context of a game. Accompanying dialogue for those quests is then generated using a large language model, and delivered in-game through NPCs. The knowledge graph exists of nodes that represent in-game objects and entities (i.e., NPC: Trevor, or Resource: Gold), which are then linked through certain relations, such as ‘wants’ or ‘made from’. From this knowledge base, quest descriptions are generated that are meant to align with the intent of the player’s input using a cosine similarity approach. The quest description forms part of the prompt for generating a context-sensitive dialogue using a fine-tuned large language model. This approach can generate new content in game-time, but is restricted to a design-time based knowledge graph. The developer can maintain control over possible generated quests by adjusting the knowledge graph. However, this approach is labour-intensive and is limited by the quality of contents in the provided knowledge base.

2.2 Dialogues Based on Intentional Lines

Kerr and Szafron (2009) offer an approach that provides insights that can help a developer come up with new dialogue. First, they consider a dialogue to essentially be a collection of “intentional lines”, i.e., “an abstract line with a specific intent”, for example a *greeting line*, or a *farewell line* (Kerr & Szafron, 2009), which can be worded differently while serving the same intention. For each intentional line, a collection of ‘actual dialogue’ lines can be generated at design time that serve the same intent but have different social characteristics such as sophistication and disposition of the speaker. Intentional lines can be replaced by ‘actual dialogue’ by filtering on these characteristics at game time. Their approach offers a systematic way to design dialogue contents and organize the timeline within the dialogue, but does not generate actual dialogue lines at game-time.

2.3 Dialogue and Code Generation at Game-Time

Volum et al (2022) put the focus more on game time generation. Through the use of OpenAI Codex (Zaremba et al, 2021) an attempt is made to create NPCs that engage in open-ended conversations with players in the context of Minecraft (Minecraft, 2024). A player can talk to nearby NPCs through the means of the Minecraft chat interface. The player input is processed by the language model, which then generates a code-like response that is executed in the game. In the prompt to the Large Language Model, they include both the natural language commands and examples of code that needs to be generated to enable the NPC to act on the game state, using a technique called autoregressive prompting (Volum et al, 2022), also known as Retrieval-Augmented Generation (RAG) (Lewis et al, 2020). This approach still had some problems however, such as generated code

calling non-existing functions, NPCs repeating themselves, especially in lengthier conversations, and NPCs presenting unreliable information due to recent prompt bias.

2.4 Analysis of Dialogue Generation in Existing Detective Games

In addition to the academic literature above, two existing detective games with open-ended conversation as a mechanic have been analyzed: Vaudeville (“Vaudeville on Steam”, 2024) and WhoDunit (Kniberg, 2023).

Vaudeville is a detective game in which players attempt to solve a murder mystery by engaging in open-ended conversation with AI-driven NPCs (“Vaudeville on Steam”, 2024). The narrative of Vaudeville can be shaped by the game designers purely through character design. After creating a new character, and determining their personality and role in the story, the script that contains the plot of the mystery in Vaudeville is updated, and the character, personality and background information are fed to the Inworld character engine. If a game-specific event is required, example dialogue that should trigger that event is fed to the character engine.

WhoDunit is an experimental game created by Kniberg (2023), which uses multiple AIs to generate different types of content. For example, a mystery generator AI generates a mystery, which is fed to a GameMaster AI, which in turn generates the prompts that provide a Character AI with instructions on how to generate the dialogue. This separation of concerns allows more specific prompt engineering resulting in better fine-tuning of results. Whodunit is not an educational game, however, and focused rather on providing entertainment value.

3. The Behaviour-Driven Conditional Prompting Framework

Developing games with AI-generated dialogue poses challenges in steering the dialogue in a certain direction that fits the narrative, especially when gameplay depends on *impactful dialogue* that helps achieve goals in the game. To support game designers in creating meaningful conversations with NPCs using generative AI, a new framework has been developed, called the Behaviour-Driven Conditional Prompting (BDCP) framework, based on requirements derived from interviews.

3.1 Interviews

To derive requirements for the framework, interviews were carried out with five experienced designers working in the serious games industry (de Visser, 2024). Below is a summary of the main issues as discussed in these interviews:

No ‘one size fits all’ approach

When asked about their general approach to serious game design, it became evident that there is no approach that fits all games. Two serious games may have the same objective, but their clients may have different needs for the tone of voice or entertainment factor.

Scenario-Based Learning

When asked about design tools used to convey serious game objectives, the most popular design element was scenario-based learning using a dialogue tree. This approach allows designers to control what players may encounter, analyze play traces, and adjust scenarios to clients’ needs.

Dialogue trees limit player agency

When asked about challenges in creating the above-named scenarios, it was clear that this approach comes with difficulties. For example, for each branch added to the plot, more dialogue needs to be written to cover it. More important, however, was the argument that dialogue trees limit player agency.

Incorporating open-ended conversation to regain player agency

As discussed, LLMs could improve player agency by granting players full control over how they converse, without limiting them to predetermined lines. A good starting place would be to write a narrative structure that allows for scenario-based learning, then feed that narrative to the LLM. With such a structure, it seems easier to write rules and test interactions with the model than with a dynamic narrative.

3.2 Requirements

Using the information from the interviews, a list of functional requirements was compiled that needs to be supported by the framework:

- Open Conversation: the design should deliver a game mechanic that allows players to openly converse with characters in a game, where responses from these characters are generated by a LLM.
- Structured Narrative Scenario Design: the designer should be able to create structured narrative-based conversational challenges in which players can demonstrate their behavioural skills.
- Responsive dialogue: the designer can influence a conversation's direction based on player behaviour.
- Behaviour in dialogue drives events: the designer can make dialogue events affect the game world.
- High-level control: the designer has high-level control over the output of the LLM, incl. parameters such as tone of voice, character backstory, response length, and knowledge of the game world.
- Syntactical and social rules: the designer must be able to define syntactical and social rules that determine how the LLM responds to player inquiries.

Besides these functional requirements, there are also three qualitative requirements to consider:

- Ease of use: the design must be easy to conceptualize, and allows for rapid development of new content.
- Adaptability to other serious contexts: the design must be adaptable to a multitude of serious game contexts for it to be considered widely useful.
- Avenues for player feedback: the design must include avenues to supply the player with feedback on their behaviour as part of the educational aspect of serious games.

3.3 The Framework

This section presents the Behaviour-Driven Conditional Prompting (BDCP) framework, that aims to support game designers in creating game scenarios in which serious game goals are achieved through dialogue with NPCs driven by LLMs. The name reflects the two core concepts of the framework:

- Behaviour-Driven: The framework allows designing scenarios that test a player's behaviour. Behaviour can range from social characteristics, e.g., emotional response, politeness and verbal sophistication, to conversational techniques, e.g., applying sales strategies or investigative questioning.
- Conditional Prompting: The player behaviour triggers conditions that alter the dialogue-generating prompts supplied to the large language model. For example, if the player shows a trustworthy attitude toward an NPC, the prompts for that NPC can be altered to make them share more information.

With the BDCP framework, game designers develop conditional prompts that are used to generate dialogue through use of a language model. The language model takes on two roles in this framework:

- Character AI - In this role, the model is used to generate open-ended conversation between the player and characters in the story. The Character AI is prompted with details such as information about the characters, context, rules that dictate what they can or cannot talk about, and a conditional objective.
- GameMaster AI - The GameMaster AI is tasked with performing checks pertaining to the dialogue between the player and characters, e.g., "Has the player named <NPC> as a possible suspect?". The yes/no reply is parsed by the GameMaster and the result triggers the associated in-game events.

The BDCP framework splits the scenario design up into four phases: Goal, Lock and Key Scenario, Conditional Prompts, and Events. A schematic overview of the framework including the four phases is shown in Figure 1.

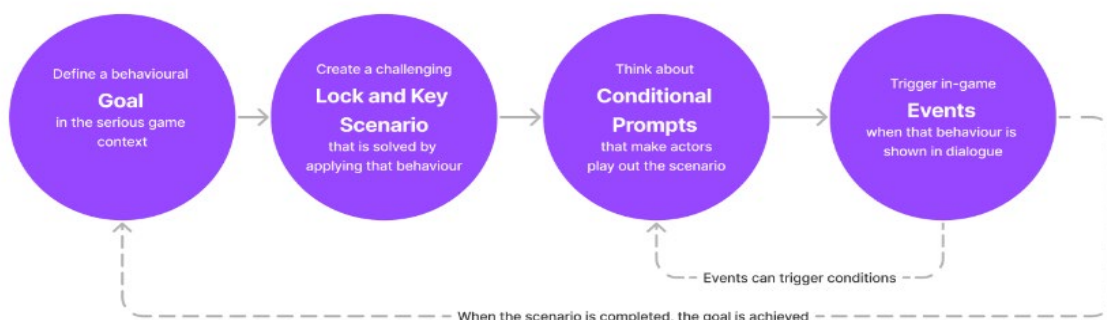


Figure 1: A schematic overview of the four phases of the BDCP framework

Details on how the framework supports the four phases in the context of a case study are given in Section 4.

4. Case Study: Generating Conversations with NPCs in a Detective-Style Game

In order to test the applicability of the BDCP framework, a detective-style game called ‘Detective Duck’ was developed as a prototype, implementing the framework’s four phases, described in Section 4.1 to 4.4. Section 4.5 describes technical implementation choices and Section 4.6 presents a resulting example dialogue.

4.1 Phase one: Designing Behavioural Learning Goals

The serious game context for the ‘Detective Duck’ prototype concerns law enforcement investigations. As a hypothetical client, we imagined a law enforcement agency with a shortage of detectives ordering a dialogue-driven game that engages players to use their problem solving skills and encourages them to consider this line of work. Behavioural techniques relevant to professional investigators were selected, inspired by examples found in literature (van der Sleen, 2009):

- Persuading a hesitant person of interest - When a person is hesitant (for logical or emotional reasons) to provide information, persuasion is required.
- Investigating a timeline of events - For example, by asking the right questions, investigators can gather evidence that supports or dismantles an alibi.
- Handling emotional characters - Emotions can get high in a criminal investigation, and knowing how to handle such situations is important, e.g., by showing emotional understanding, and building trust.
- Connecting the dots - Using lateral thinking, corroborating different clues can result in new theories and leads to investigate.
- Persuade a confession through conclusive evidence - Being able to persuade a culprit to confess is important to close the case.

4.2 Phase Two: Designing Lock and key Scenarios Around the Behavioural Learning Goals

4.2.1 Locks and keys

The term lock-and-key mechanism refers to a mechanism that unlocks access to parts of a game (Adams & Dormans, 2012). Locks and keys may be physical, or more conceptual in nature. Scenarios can lock player progress behind required player actions, which may require mastery of certain behaviours.

Ashmore (2006) lists the functional properties that keys and locks typically have in games:

- *Keys have little impact on low-level gameplay*, but can strongly affect high-level gameplay.
- *Old keys are still useful*. A key becomes more important when it can or must be used multiple times.
- *Locks are often shown before the key appears*, to make players want to find out what lies behind.
- *Sometimes, locks are not always immediately visible*. In contrast with the previous point, sometimes a lock can be hidden behind another lock, allowing for places already visited to seem new.

4.2.2 Scene 1

For scene 1, the designer has selected the goal to persuade a hesitant person of interest, and created a lock-and-key scenario for this objective, shown in Table 1. The player’s task is to investigate a crime: what happened to Bubbles the Bunny’s muffins, which disappeared the day before the yearly bakery contest? The player has to convince Bubbles to consider characters’ potential motives. Bubbles is initially hesitant to suspect anyone, but if the player convinces Bubbles to do so, he will reveal that Rustles the Raccoon came second last year, and thus may potentially have motive to sabotage Bubbles this year.

Table 1: Overview of the lock, key, and door in Scene 1 of the game

Lock	Key	Door
Bubbles won’t mention Rustles the Raccoon as a possible suspect.	Instruct Bubbles to think who could have had motive to steal his muffins.	Rustles the Raccoon becomes available as a character to interview.

As shown in Table 1, narrative progression in scene 1 is locked: The player cannot leave this area before he gets a lead. When the player demonstrates the desired behaviour, Bubbles’ prompt is altered, and he shares the information required to open the door to the next scene. In Figure 2, the design process so far is schematized.

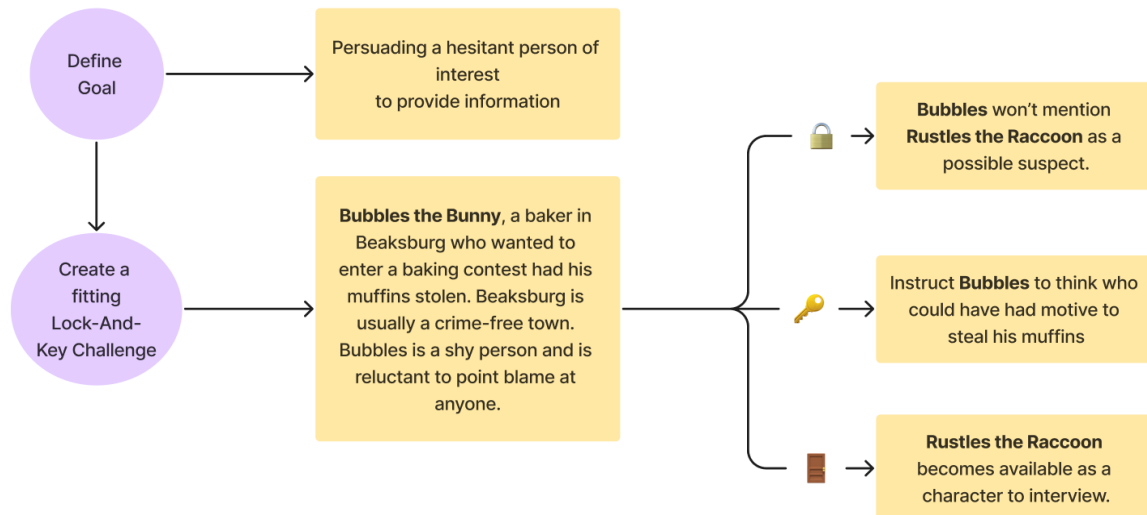


Figure 2: A schematized overview of the design process of scene 1 so far

Subsequent scenes in the game are more complicated, often dealing with multiple goals of investigating a timeline and handling emotional characters, which may also have their own side goals.

4.3 Phase Three: Designing Conditional Prompts for the Lock and key Scenarios

In phase three, conditional prompts are created for each scenario to generate dialogue through character AI. Depending on players' behaviour, these prompts are altered to reveal new information and provide character AI with new rule sets to follow. First, a generic prompt is designed, providing context and response rules to the AI (i.e. 'Respond like a character in a video game'). Then, character-specific information is slotted in (i.e. 'You are Bubbles, a shy baker'). Finally, appended to the prompt are Optionals: these are interchangeable based on player behaviour and the driving factor behind the BDCP framework. Figure 3 illustrates how Optionals reveal key information that progresses the narrative.

4.4 Phase Four: Coupling In-Game Events to the GameMaster AI

This section describes how the designer can design questions to be fed to the GameMaster AI, and use the answers to these questions to alter the previously described conditional prompts. The GameMaster is used to perform GMChecks. A GMCheck contains a question concerning the conversation, that is answerable by yes/no. In scene 1 of the prototype, there are two checks that need to be performed. The first check is related to the 'key' in that scene. If the LLM considers the conversation between the player and the character, and answers "Yes" to this check, then the prompt for Bubbles' character AI is altered to allow him to suspect Rustles the Raccoon. The next check is related to the 'door' in that scene. If the locked information was not provided to the player yet, and the conversation ended too soon, there is no way for the player to advance the narrative. Only when this door check succeeds, the next scene is unlocked. In Figure 3, a schematic overview is provided of the GameMaster's GMChecks in Scene 1 and their effects on the relevant conditional prompts.

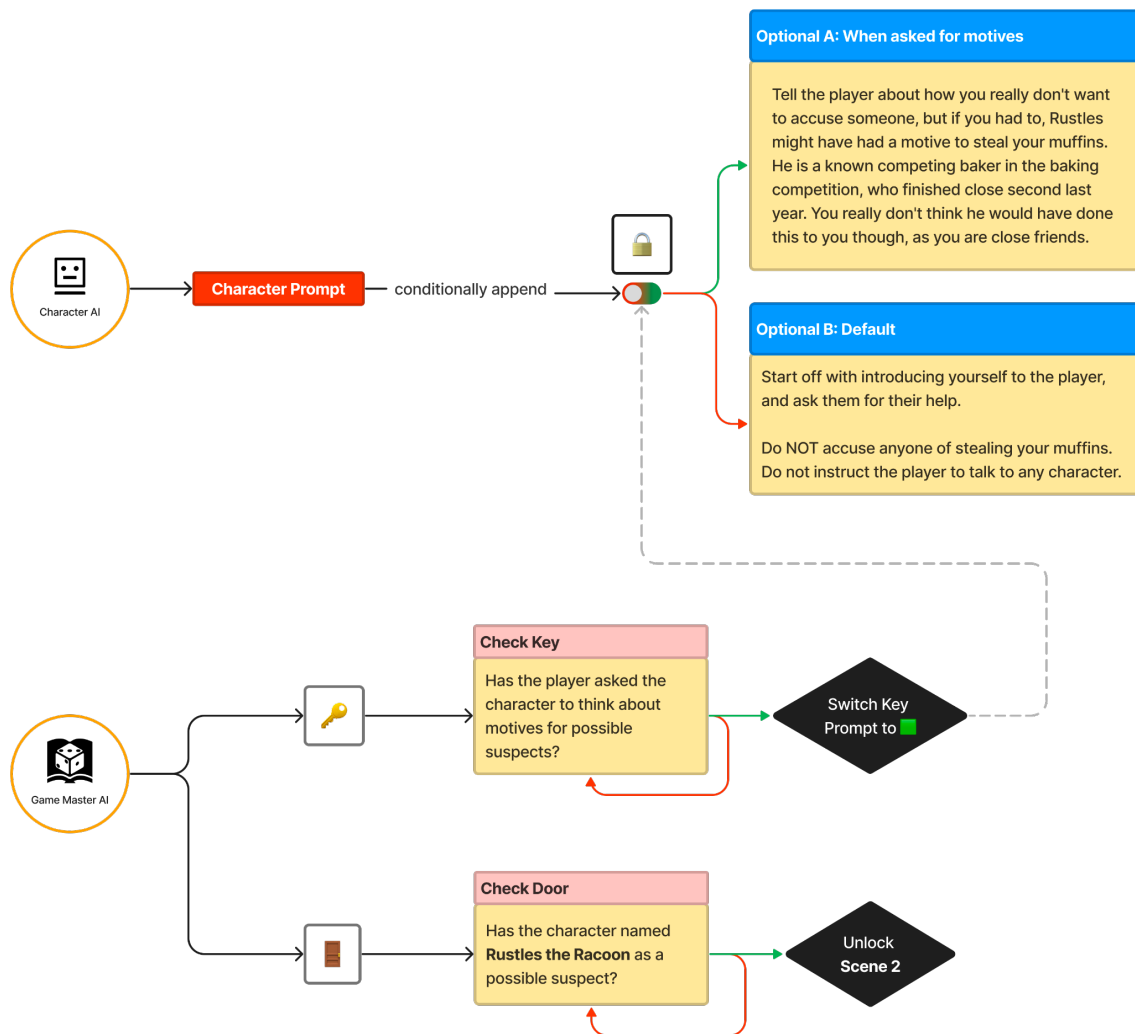


Figure 3: The GameMaster's GMChecks for Scene 1 and their influence on the conditional prompts. Optional B is appended by default, until a condition is met, and optional A is appended instead

4.5 Technical Implementation

The prototype was built in Unity3D (Unity, 2024), using GPT-3.5-turbo. GPT-4 was also considered but 3.5-turbo seemed to provide sufficient responses and its lower response time contributed to more fluent gameplay. A ChatGPT Wrapper library (RageAgainstThePixel, 2024) was used to interact with the ChatGPT API. A custom editor extension allows designers to preview, arrange, and alter prompts, and attach corresponding GMChecks. The GameMaster AI was instructed to reply with Yes/No answers, which allows for simple boolean parsing. Based on the checks, the ProgressionManager triggers UnityEvents (to update dialogue prompts, progress the story, unlock new objectives, etc.) before generating a new character reply, allowing the game to respond directly to player behaviour. More details on the implementation are described by de Visser (2024).

4.6 Example Dialogue

An example dialogue taking place in scene 1 is displayed in Figure 4, featuring automatically generated text for the NPC Bubbles, while the player enters the text for the main character, Detective Duck. The player encourages Bubbles to think about who could have had a motive for the crime, which by design results in an accusation towards Rustles the Raccoon.

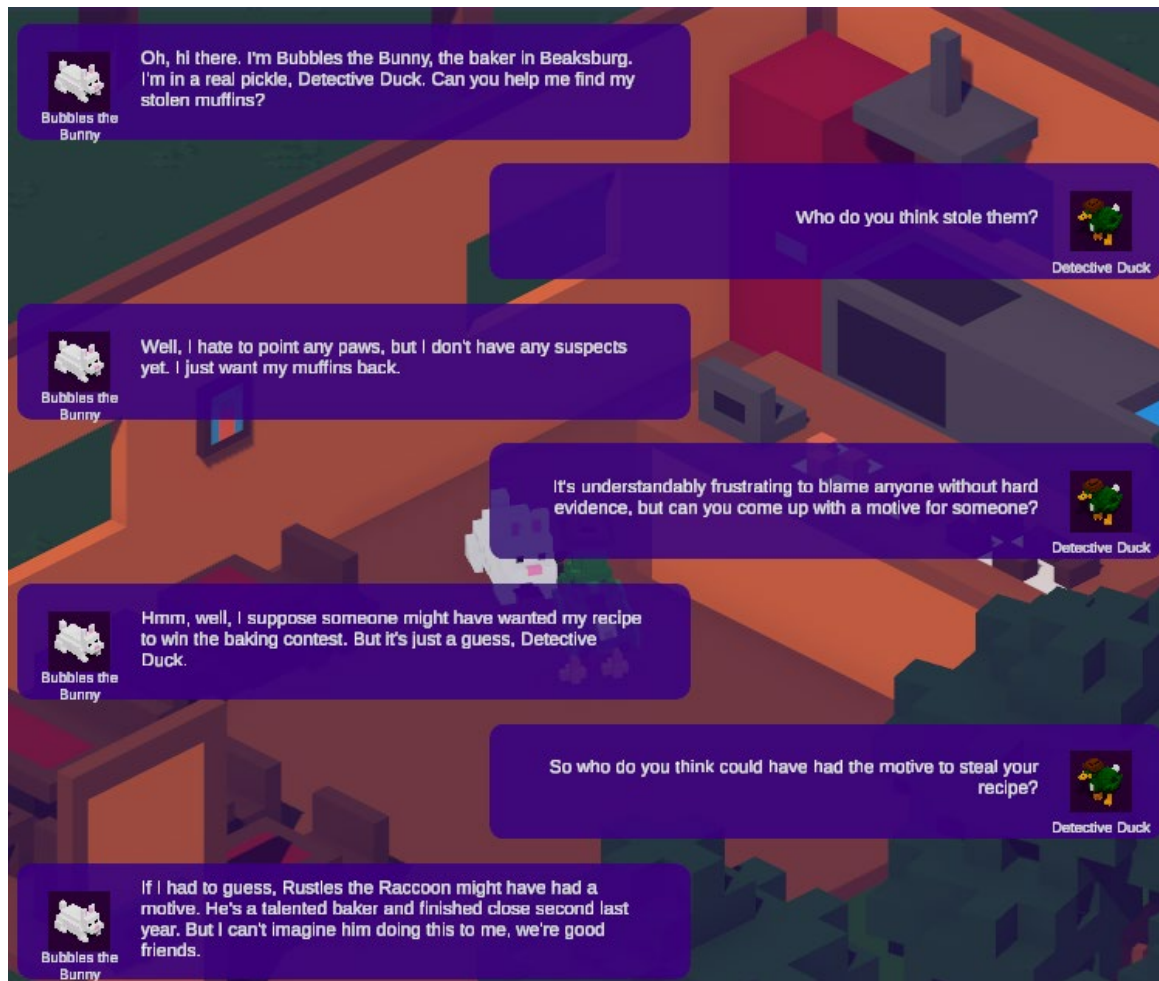


Figure 4: Example dialogue from the game. Text for Bubbles is generated by the system described in Section 4.5, while the player enters the text for Detective Duck

5. Evaluation

To evaluate the usability and usefulness of the framework, another series of interviews was held with five game designers to gather feedback on the framework in relation to the qualitative requirements. An overview of all feedback points related to these requirements, as discussed in these interviews, is presented below:

- *Ease of Use:* The BDCP framework is conceptually simple to use, and provides designers with a way of quickly designing new game scenarios; Further improvements, such as expanding the Editor tooling, are needed to make it practical in real-world use, however.
- *Adaptability to other contexts:* The framework is deemed suitable for any serious game context regarding soft skills; The framework should incorporate other game mechanics to teach hard skills.
- *High-level control over conversation:* The framework offers high-level control over the response of characters through scenario design and textual prompting, using syntactical and social rules; Suggestions to enhance the level of control include allowing for multiple outcomes to one scenario.
- *Avenues for player feedback:* The framework already includes several opportunities to give feedback to the player; Suggestions for improvement include introducing an additional character for guidance, and a third role for the language model to provide feedback and an end-game debriefing.
- *Derailment of conversation:* Some designers experienced the conversation derailing from the intended narrative; This issue should be addressed for real-client use; In its current state it is still usable for rapid prototyping to impress clients.

More details on this evaluation, and an analysis of the framework to investigate to what extent the functional design requirements listed in Section 3.2 have been satisfied, are described by de Visser (2024).

6. Conclusions

The main aim of this study was to understand how serious game designers can maintain high-level control over open-ended conversation between a player and NPCs powered by large language models, so these conversations can be used to achieve serious game goals. To meet the design requirements for this challenge, the Behaviour-Driven Conditional Prompting (BDCP) framework was developed. It supports designers in creating scenarios that require players to demonstrate soft skills relevant to the serious game context through conversations with in-game characters driven by a large language model.

The BDCP framework provides designers with guidelines on how to create challenging 'lock-and-key' scenarios, and shows how these scenarios can be realized using the language model in two different roles: the character AI, which generates dialogue between players and NPCs through prompts that contain conditional information, and the GameMaster AI, which is responsible for analyzing the dialogue. The GameMaster AI adjusts the conditional prompts dynamically based on observed player behaviour to steer the conversation in the direction intended by the game designer.

Using this framework, a prototype detective-style game was developed, called 'Detective Duck'. The framework and the resulting prototype were evaluated by five professional game designers against the design requirements. The evaluation produced promising results, with mostly positive feedback and useful suggestions for potential improvements. The BDCP framework was considered intuitive to understand, enabling game designers to quickly create new scenarios. The framework was also considered to be easily adaptable to other serious game contexts. To be viable for real-world use cases, however, the technical implementation still needs further work.

Suggestions for future work include developing UX/UI tools to support scenario creation, improving the implementation by enabling character AI to interact with the game through code, fine-tuning the language model with example conversations to improve narrative consistency, extending the framework with AI to provide feedback on player progress, incorporating additional game mechanics into the BDCP framework, and summative evaluation of the framework and resulting games.

Ethics declaration: No ethical clearance was necessary for the research reported in this paper.

AI declaration: The paper provides a dialogue featuring AI-generated text in Figure 4, created by the system described in Section 4. The text clearly indicates which parts are generated and how they were created, in order to demonstrate and analyze the use of AI in dialogue-driven game design, related to the topic of this paper, i.e., research into conversational systems for games using AI generation.

In addition, OpenAI's tool ChatGPT was used as a writing aid for this paper, to detect writing errors and suggest possible repairs, and to help summarize sections of text. Such suggestions and summaries were subsequently reworded by human authors. AI was not used to directly author text in the paper, except for the AI-generated dialogue fragments mentioned above.

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Italian Teachers' Attitudes and Competence According to the Acceptance Game-Based Learning (AGBL) Questionnaire

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Abstract: In an ever-evolving educational landscape, the adoption of innovative approaches such as Game-Based Learning (GBL) has gained increasing attention for its potential to enhance student engagement, foster active learning, and promote intrinsic motivation. However, the systematic integration of such practices remains limited. This study aims to examine the attitudes of Italian teachers toward GBL, focusing on the role of demographic variables such as age, teaching experience, and school level as potential predictors of openness to these methodologies. The research was conducted using the Acceptance of Game-Based Learning (AGBL) Questionnaire, specifically developed and validated to measure teachers' willingness to adopt games as a teaching strategy. The questionnaire, grounded in well-established theoretical frameworks like the Technology Acceptance Model (TAM) and the TPACK-G framework, was distributed online to a random sample of 2,752 teachers across all school levels in Italy. Data analysis was carried out using ANOVA and multiple linear regression through Jamovi software. The findings indicate that school level is the only demographic variable that significantly predicts attitudes toward GBL. Specifically, preschool teachers report significantly more positive perceptions than their counterparts in secondary education. In contrast, neither age nor teaching experience showed a meaningful influence on GBL acceptance. The regression model confirms the limited explanatory power of demographic factors ($R^2 = 0.019$), suggesting that contextual and institutional elements play a much stronger role. These results offer relevant insights for both educational theory and practice. On one hand, they confirm the greater potential of early childhood education, characterized by curricular flexibility and constructivist approaches, to embrace game-based methodologies. On the other hand, they challenge the assumption that age or professional experience are decisive factors in the adoption of educational innovations. Additionally, the convergence of negative attitudes among all types of secondary schools (academic, technical, vocational) points to systemic resistance, likely stemming from curricular rigidity and a high-stakes assessment culture typical of upper-level education. Given the study results, for future research, it would be necessary and interesting to shift the focus from individual characteristics to broader predictors such as institutional support, access to digital resources, participation in professional learning communities, and ongoing teacher training. In fact, understanding these factors is essential to designing effective teacher development programs and policy strategies that support the widespread adoption of GBL. Ultimately, the successful integration of game-based approaches in schools requires not only teacher readiness, but also structural and cultural changes, supported by visionary leadership and collaborative school environments.

Keywords: GBL, AGBL, Teachers' attitudes, Educational innovation, Italian school system, Educational technology

1. Introduction¹

For millennia, games have been a fundamental component of human experience, serving as tools for socialization, learning, and cognitive development. In recent decades, the evolution of digital technologies has enabled games to take on new forms, emerging as a potentially transformative resource in educational contexts—Game-Based Learning (GBL). This pedagogical approach leverages game mechanics to foster student engagement, promote active learning, and stimulate intrinsic motivation (Plass et al, 2015; Orji et al, 2017).

Numerous studies have highlighted the benefits of GBL: increased participation, enhanced long-term memory retention, development of critical thinking skills, and improved social and collaborative abilities (Hartt et al, 2020; Qian and Clark, 2016). Educational games also provide immediate feedback, enable personalized learning pathways, and support the inclusion of students with diverse cognitive styles (Wu, 2023). However, despite its

¹This article has been developed jointly. Massimiliano Andreoletti wrote paragraph 1, Marika Lamacchia wrote paragraph 2, Maria Clara Dicataldo wrote paragraph 3, Francesco Facciorusso wrote paragraph 4, and Andrea Tinterri wrote paragraph 5.

promise, the widespread and systematic integration of GBL into schools remains limited, often confined to isolated or pilot initiatives, even as interest among educators and researchers continues to grow.

The literature has identified a variety of barriers to the adoption of GBL: technological shortcomings, inconsistent access to digital tools, lack of teacher training, rigid curricular frameworks, time constraints, and cultural resistance within educational institutions (Baek, 2008; Watson and Yang, 2016; Mathe et al, 2019). In parallel, several studies have hypothesized that demographic factors, such as age, gender, teaching experience, and school level, may influence teachers' attitudes toward GBL (Lampropoulos, 2023; R  th et al, 2022; Malik et al, 2024). However, findings across studies are often fragmented and contradictory, leaving important questions unanswered regarding which educators are most likely to embrace GBL and under what conditions.

This study seeks to address this gap by empirically investigating teachers' attitudes toward GBL in the Italian education system and examining the extent to which demographic characteristics function as predictors. Specifically, it aims to: (1) assess teachers' general disposition toward GBL through a standardized scale; (2) test whether variables such as age, years of teaching experience, and school grade taught significantly influence GBL attitudes; and (3) identify potential differences across educational levels, particularly between early childhood and secondary education, in the openness to game-based methods.

The findings reveal a clear yet unexpected pattern: only the school grade taught emerges as a statistically significant predictor of GBL attitudes. Preschool teachers report significantly more positive perceptions than their secondary school counterparts, while no significant differences are observed in relation to age or teaching experience. Moreover, regression analysis confirms the limited explanatory power of demographic variables overall ($R^2 = 0.019$), suggesting that openness to GBL is shaped less by personal attributes and more by institutional and cultural contexts.

These results yield two primary implications. On the one hand, they confirm the central role of educational context: early childhood education, grounded in constructivist pedagogies and greater curricular flexibility, appears more conducive to GBL integration than secondary education, which remains tied to transmissive models and performance-driven assessments (Ertmer, 1999; Hirsh-Pasek et al, 2009). On the other hand, they challenge interpretive models that frame educational innovation primarily in terms of teacher characteristics.

In light of these findings, the study also aims to highlight the need to explore alternative, non-demographic predictors that may better explain variations in teachers' openness to GBL. These may include: pedagogical beliefs about student agency and creativity; the presence of supportive institutional leadership; access to digital tools and professional development; and participation in professional learning communities that encourage innovation. Understanding these factors is critical to informing training programs and policy strategies that can support the systemic adoption of GBL across educational contexts.

2. Methods and Materials

To investigate teachers' attitudes toward the integration of Game-Based Learning (GBL), this study employed the Acceptance of Game-Based Learning (AGBL) Questionnaire (Andreoletti and Tinterri, 2023). The instrument was specifically developed to measure teachers' openness to adopting games as a teaching methodology. It draws conceptually from the Technology Acceptance Model (TAM) (Davis, 1989), while also integrating elements of the Technological Pedagogical Content Knowledge (TPACK) Framework (Mishra and Koehler, 2006) and its game-specific extension, TPACK-G (Joshi et al, 2015).

The questionnaire is structured into three sections:

1. Demographic variables, including age, gender, school level taught, years of teaching experience, and geographical location;
2. A 13-item scale using a 4-point Likert response format, measuring four core constructs from the TPACK-G model:
 - Game Knowledge (GK);
 - Game Pedagogical Knowledge (GPK);
 - Game Content Knowledge (GCK);
 - Game Pedagogical Content Knowledge (GPCK).
3. A set of items addressing the contextual application of GBL in school settings.

The instrument underwent psychometric validation through both internal consistency analysis and Confirmatory Factor Analysis (CFA). The final version demonstrated excellent fit indices (CFI = .989; TLI = .986; SRMR = .0216; RMSEA = .0437) and strong internal reliability (Cronbach's $\alpha > .80$), in line with accepted methodological standards (Tavakol and Dennick, 2011; Harrington, 2009).

Data was collected using the Computer-Assisted Web Interviewing (CAWI) method via Google Forms. This approach allowed for efficient, low-cost, and large-scale distribution, maximizing heterogeneity and response rate (Couper, 2000). The questionnaire was disseminated to a random sample of 2,752 Italian teachers across all school levels. The final sample was characterized by substantial variation in demographic background, including age ($M = 44.6$, $SD = 7.81$), teaching experience, and regional distribution, ensuring strong representativeness.

Data analysis was conducted using Jamovi software (v. 2.6.26) (The Jamovi Project, 2025). After computing descriptive statistics to profile the sample, inferential tests were carried out to assess the relationship between teachers' demographic characteristics and their overall attitudes toward GBL. Specifically, ANOVA was used to examine mean differences in attitudes across categories of school grade and teaching experience. Additionally, a multiple linear regression analysis was conducted to evaluate the predictive power of continuous variables such as age and teaching experience, alongside categorical predictors such as school level. The aim was to determine whether and how these factors influence teachers' acceptance of GBL, and to assess the extent to which demographic variables explain variance in the AGBL index.

3. Results

3.1 Analysis of Variance

ANOVA permits to determine whether the mean of the AGBL dependent variable varies significantly across multiple levels of both school grade and years of teaching experience as independent variables.

The AGBL dependent variable represents the average score of the AGBL items from 1 to 5 (Appendix I), reflecting overall attitudes toward game-based learning. The first independent variable (school grade taught) includes 7 categories: Preschool; Primary school; Secondary school I grade; Secondary school II grade (high school); Secondary school II grade (vocational); Secondary school II grade (technical); I do not teach. Table 1 shows how AGBL varies across school grades in which teachers teach.

Table 1: The ANOVA shows how the AGBL dependent variable varies according to the School grade

	Sum of Squares	df	Mean Square	F	p
In which school grade do you teach?	12.4	6	2.062	5.53	<.001
Residuals	1023.0	2745	0.373		

The results indicate that the effect of school grade on attitudes toward game-based learning is statistically significant ($p < .001$), meaning that at least one school group differs significantly from the others in their perception of AGBL. In order to identify which is the significantly different grade, the Tukey post-hoc test was performed. Table 2 summarizes the statistically significant comparisons.

Table 2: The Tukey post-hoc test allows to compare statistically significant differences between groups

Comparison							
In which school grade do you teach?		In which school grade do you teach?	Mean Difference	SE	df	t	p _{Tukey}
Secondary School I grade	-	Preschool	-0.29330	0.0641	2745	-4.5730	<.001
Secondary School II grade (high school)	-	Preschool	-0.29432	0.0712	2745	-4.1364	<.001

Comparison							
Secondary School II grade (vocational)	-	Preschool	-0.29657	0.0700	2745	-4.2394	<.001
Secondary School II grade (technical)	-	Preschool	-0.23893	0.0708	2745	-3.3767	0.013

This test reveals that preschool teachers demonstrate significantly more positive attitudes toward game-based learning compared to all levels of secondary education. No other statistically significant differences were found among the different levels of secondary education. The findings suggest that game-based learning is perceived as more natural, appropriate, or relevant in early childhood education.

The second independent variable (years of teaching) includes 8 categories: Less than 1 year; 1–2 years; 3–5 years; 6–10 years; 11–15 years; 16–20 years; More than 20 years; Never taught. Table 3 shows how AGBL varies according to the teachers' experience in terms of years of teaching.

Table 3: The ANOVA shows how the AGBL dependent variable varies according to years of teaching

	Sum of Squares	df	Mean Square	F	p
How many years have you been teaching?	2.69	7	0.384	1.02	0.414
Residuals	1032.68	2744	0.376		

This analysis indicates that teachers' attitudes toward game-based learning do not significantly differ based on their years of teaching experience ($p = 0.414$), suggesting that the differences in AGBL scores across the years of teaching categories are likely due to chance and do not reflect meaningful or systematic variation.

3.2 Linear Regression

Linear regression intends to estimate the relationship between the AGBL (dependent variable) and age, school grade and years of teaching as multiple predictive independent variables. Table 4 reports the Model Fit.

Table 4: Model Fit Measures assess how well the statistical model represents the observed variables

Model	R	R ²	N
1	0.138	0.0190	2,236

While the model is statistically estimable, it only explains 1.9% of the variance in AGBL score. In fact, most of the variation in AGBL is not explained by age, school grade or years of teaching experience.

Table 5 explains the variability of the predictors through their coefficients.

Table 5: Model Coefficients quantify the relationship between predictor variables and the response variable of the statistical model

Predictor	Estimate	SE	t	p
Intercept	3.54390	0.15040	23.563	<.001
How many years have you been teaching?:				

Predictor	Estimate	SE	t	p
From 11 to 15 years – From 1 to 2 years	-0.13015	0.05919	-2.199	0.028
Others – From 1 to 2 years	All $p > .05$			
In which school grade do you teach?:				
All grades – Not teaching	All $p > .05$			
Age	-0.00371	0.00196	-1.894	0.058

Age cannot be considered a statistically significant predictor of attitudes toward game-based learning ($p = 0.058$). However, the negative coefficient suggests a slight (non-significant) tendency for attitudes to decline with age.

Years of teaching experience shows only one small significant effect. Teachers with 11–15 years of teaching experience report slightly lower AGBL scores compared to those with 1–2 years ($p = 0.028$).

School grade taught does not significantly influence attitudes toward game-based learning. No school level differed significantly from the reference group ("not teaching").

Therefore, the model indicates that other factors not included in the analysis, such as training, school culture, exposure to game-based learning, likely play a more substantial role.

4. Discussion

The findings of the present study offer important insights into the multifaceted factors influencing teachers' attitudes toward Game-Based Learning (GBL) within the Italian educational system. By examining differences across school levels and years of teaching experience, this research both corroborates and extends current theoretical perspectives on the adoption of educational innovations. In particular, the observed patterns reveal systemic tendencies that not only support but also, in some respects, challenge established models of technology integration and pedagogical change.

The ANOVA results confirm that preschool teachers exhibit significantly more positive attitudes toward GBL compared to all secondary education levels ($p < .001$), with no meaningful differences among secondary school types. Preschool and primary education that are rooted in constructivist paradigms, basically legitimize play as a pedagogical tool (Hirsh-Pasek et al, 2008). Some studies support that early childhood educators frequently adopt experiential and active learning approaches, viewing play not only as developmentally appropriate but as central to cognitive, social, and emotional growth (Pękala and Wichrowska, 2022; Ernst and Burcak, 2019). Some researchers point out that preschool teachers with specialized training in early childhood education emphasize play and spontaneous learning situations as possible critical teaching strategies that can be included in daily routines to support children's development (MacQuarrie et al, 2013; Flanagan and Symonds, 2022). Furthermore, international analyses of learning through play (LTP) in diverse contexts reinforce the link between constructivist theory and play-based pedagogy in early years, noting that supportive policies and professional development are key to its effective implementation (Asfaw et al, 2024).

The absence of significant differences between secondary school types (vocational, technical, high school) suggests that resistance to GBL is systemic rather than subject specific. This challenges assumptions that vocational tracks, with their emphasis on practical skills, might be more open to experiential methods (Bellotti et al, 2013). Instead, institutional pressures to prioritize exam preparation and content coverage likely homogenize attitudes across secondary contexts (Malvasi and Recio-Moreno, 2022).

A counterintuitive finding emerged regarding teaching experience: years of service showed no statistically significant association with GBL attitudes ($p = 0.414$). This contrasts with studies suggesting novice teachers exhibit greater openness to pedagogical innovations due to recent exposure to contemporary methodologies during training (Kaimara et al, 2021). Nevertheless, the non-significant relationship aligns with research demonstrating that institutional culture and systemic support outweigh individual seniority in predicting technology adoption (An and Cao, 2016). The slight dip in GBL acceptance among mid-career teachers (11–15 years) may reflect systemic disillusionment rather than personal burnout. In the GBL context, mid-career

educators, having witnessed multiple "transformative" initiatives fail due to inadequate training or infrastructure, may adopt cautious scepticism toward new methodologies (Burton, 2024; Whitton, 2010).

The minimal explanatory power of the linear regression model ($R^2 = 0.019$) indicates that demographic variables alone are inadequate for predicting teachers' attitudes toward GBL (Hsu et al, 2020). This underscores the necessity of examining contextual and institutional determinants. Technological disparities further compound inequities in Italian schools; the availability of interactive whiteboards and other digital resources is significantly higher in primary schools than in secondary schools, particularly in Northern regions, thus limiting the adoption of advanced digital game-based learning practices (Sica et al, 2022). It is important to underscore that the development of a collaborative institutional culture constitutes a pivotal determinant in the successful integration of GBL (Sung and Whuang, 2013). Empirical evidence indicates that institutions fostering communities of practice dedicated to the exchange of GBL-related knowledge and experiences demonstrate significantly higher rates of adoption (Zhong, 2019).

The dominance of school grade as a predictor highlights institutional barriers, such as curriculum alignment and assessment systems, as greater obstacles than individual factors like age or experience. Secondary schools' focus on summative assessments conflicts with GBL's formative, process-oriented nature (Plass et al, 2015), forcing teachers into a "pedagogical double bind" where innovation risks compromising exam results (Biesta, 2010). These findings support prior research suggesting that early childhood educators, benefiting from greater curricular flexibility, are better positioned to integrate game-based learning (GBL) as a natural extension of play-based pedagogies (Papadakis and Kalogiannakis, 2020). In contrast, the prescriptive nature of secondary education curricula tends to limit such experimentation, particularly in the absence of broader institutional support (Fante et al, 2024).

Accordingly, the extent to which GBL can be meaningfully implemented across educational stages may be contingent upon both the degree of curricular flexibility and the presence of systemic, top-down support.

5. Conclusion

GBL is able to foster student engagement, promote active learning, and stimulate intrinsic motivation (Plass et al, 2015; Orji et al, 2017), however, its systematic integration into schools remains limited and confined to isolated or pilot initiatives. Through the submission of the *Acceptance of Game-Based Learning* (AGBL) Questionnaire (Andreoletti and Tinterri, 2023), this study empirically investigated teachers' attitudes toward GBL in the Italian education system and examined the extent to which demographic characteristics, such as age, school level taught, years of teaching experience, may function as predictors. Data analysis was conducted using Jamovi software (v. 2.6.26) (The Jamovi Project, 2025), specifically ANOVA and linear regression were computed to measure the impact of the demographic variables. The results showed that only the school grade taught emerges as a statistically significant predictor of GBL attitudes, while no significant differences are observed in relation to age and years of teaching experience. Preschool educators show significantly positive attitudes toward GBL, likely due to the constructivist and flexible nature of early childhood curricula, whereas secondary education's rigid, assessment-driven structure poses systemic barriers to its adoption. These findings strongly suggest that demographic characteristics alone are not sufficient to explain teachers' attitudes toward GBL. Rather, attention must be redirected toward deeper contextual variables such as the presence of visionary and supportive school leadership, institutional cultures that foster innovation, access to adequate technological infrastructure, and the promotion of pedagogical mindsets open to student-centred, creative learning. Among these factors, teacher training emerges as a central lever: the absence of structured, curriculum-integrated professional development programs, for both in-service and pre-service Italian school teachers, represents a critical barrier to the widespread adoption of GBL (Andreoletti, Tinterri and Dipace, 2024). Without equipping educators with the necessary knowledge, tools, and confidence to design and implement game-based methodologies, any systemic change remains unlikely. Therefore, ensuring the successful integration of GBL requires not only addressing structural inequalities and contextual gaps but also investing in long-term, coherent teacher education policies capable of transforming practice across educational levels.

Ethics declaration: The data collected through the questionnaire comply with ethical standards for the treatment of personal data. All participants were informed about the purpose of the study, and their participation was entirely voluntary. Informed consent was obtained, and all responses were anonymized to ensure confidentiality. 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, AI language models were employed to assist in the revision and refinement of certain sections of the text, including improving clarity and coherence. Additionally, SciSpace was utilized to aid in the literature search and bibliographic exploration. The authors maintained full responsibility for the final content, interpretation, and conclusions presented in the paper.

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Appendix 1

Appendix 1 specifies each single item included in the Acceptance of Game-Based Learning Questionnaire. The questionnaire precisely contains 5 items listed below:

AGBL – Acceptance of Digital Game-Based Learning

Item	Item Statement
AGBL1	Digital game-based learning can enhance students' motivation to learn.
AGBL2	Digital games can be integrated into everyday classroom activities.
AGBL3	Digital game-based learning requires well-structured instructional design.
AGBL4	Digital game-based learning requires specifically designed evaluation methods.
AGBL5	Digital game-based learning represents a future trend across all educational levels.

Designing a User-Centred Adaptive Gamified Learning System: A Multidisciplinary Approach from Pedagogy to Artificial Intelligence

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Abstract: A multidisciplinary approach is crucial for developing a user-adaptive gamified learning system, starting with pedagogy and continuing through psychology, user experience (UX) design, and artificial intelligence (AI). This study inspects different layers of knowledge, starting from foundational pedagogical theories such as constructivism, behaviourism, and Bloom's taxonomy. Moving to individual learner needs with all related complexities, which include cognitive traits, learning styles, personality types, motivational drivers, and player types, is important. Thus, the gamified learning experience can be tailored for optimal engagement and effectiveness. The gamified learning experience is influenced by a set of factors, including learners evolving traits and experiences. A user system must track and interpret these changes in real time to maintain interaction and effectiveness. Modern Technological tools like AI and machine learning (ML) can be used to design personalized predictive models. Human-computer interaction (HCI) through UX and interaction design is crucial for maintaining learners' engagement throughout the learning process. The complexity of user-adaptive processes requires the use of HCI via UX design. This study proposes a framework that integrates andragogy, psychology, and intelligent technologies, such as AI and ML, to create a personalized learning system. This approach optimizes the learning process, allowing learners to develop their knowledge and skills and enhance productivity, efficiency, and work quality. It focuses on professional retraining for longer-tenured workers who have been away from formal education for several years and require customized learning paths to close the digital skill gap essential for operating in smart, sustainable manufacturing environments.

Keywords: Adaptive learning, Gamification, User-Centred design, Artificial intelligence, Lifelong learning, Personalized education

1. Introduction

The workforce upskilling landscape is undergoing significant transformation due to the integration of advanced technologies like AI and the growing demand for Smart Manufacturing and Industry 5.0. This necessitates the use of adaptive and technologically enhanced training systems. Traditional training approaches are insufficient due to individual learning differences and lack of engagement, making upskilling workers more challenging.

Organizations are integrating gamification strategies and AI-powered educational tools to create a learner-centred environment. AI allows for personalized tutoring and a learner-centred approach, fostering motivation and efficiency. Gamification elements like rewards and challenges help reduce upskilling time and improve productivity. Integrating AI, education, and gamification is crucial for improving learning quality and building a future-ready workforce for high-tech industries. This approach is essential for fostering a more dynamic and productive workforce.

According to (Lopez and Tucker, 2021) gamification has gained significant interest in improving individual motivation. Designers incorporate game elements, such as points, leaderboards, and levels, to encourage users to complete tasks. However, perceptions and preferences of game elements vary individually. A gamified application that motivates one person may affect another differently. These results are consistent with the Self-Determination Theory (SDT) and Cognitive Load Theory (CLT), which state that the effects of a stimulus (e.g., game element) on an individual's motivation are mediated by their perception of the stimulus itself. Researchers are exploring how individual game element preferences might be measured using player-type models, which can be utilized to tailor or personalize gamified applications. Adaptation and personalization are closely related, as their goal is to deliver a superior user experience. Personalization involves tailoring content to individual tastes, whereas adaptation involves tailoring interactions to different users in the same context.

Adult education is a crucial aspect of lifelong learning. It includes all forms of education and training that support adults in finding job opportunities and playing a functional role in their communities. The adult's ability to retain information decreases with age; thus, active teaching methods are crucial to enhance motivation and improve the development of skills and talents because they ensure the highest level of participation in the learning process (Grebin *et al.*, 2020).

There is a need in gamified online learning to create a conceptual framework for a user-centred adaptive system that would organize a multidisciplinary approach to handle the process from the pedagogical theories passing through psychological and cognitive aspects through the gamification design utilizing AI and data-driven personalization to optimize the user experience and have optimum human-computer interaction.

2. Pedagogical and Adult Learning Foundations

2.1 Andragogy

The term "Andragogy" refers to pedagogical practices performed for adult learners (Wang and Farmer, 2008). Andragogy for adults consists of six principles (Huang, 2002).

1. Understanding the purpose of learning: what, delivery, and significance.
2. Self-Concept: Adults view themselves as self-directed learners responsible for learning goals.
3. Experience: Life experiences shape learning and influence perspectives.
4. Readiness to Learn: Adults are ready to learn when new knowledge or skills are required.
5. Orientation to Learning: Adult learning is problem-centred and contextual, best when content is applicable to real-world tasks.
6. Motivation: Adults are driven by internal factors like personal growth, self-esteem, and goal fulfilment.

2.2 Constructivism

Learners can actively acquire and generate new information based on their existing knowledge. Education primarily aims to enhance students' thinking skills. Motivated learners are better able to recognize their difficulties. Thus, study topics should align with their interests. Constructivism focuses on developing learners' problem-solving skills for real-world situations. Consequently, problem-solving and free discovery were combined. Knowledge constantly evolves through the discovery process. Vygotskian theory highlights how sociocultural settings influence learning outcomes. In cognitive growth, Vygotsky's "social constructivism" theory emphasizes the importance of contact with others, particularly instructors and learners (Huang, 2002).

2.3 Behaviourism

According to (Allen, 2007), Hull saw learning because of stimulus-response interactions, like other behaviourists'. The potential response to a particular stimulus is the consequence of multiplying intervening variables such as habit:

- Strength: the number of previous and reinforced pairings between a stimulus and its response.
- Drive: refers to the need to fulfil the requirements of the body
- Stimulus dynamism refers to the power of a stimulus.
- Incentives are the strength of a reward that meets the body's requirements.

Learning occurs when a learner is motivated to pursue a goal. Effective learning involves personalizing experiences, measuring behavioural change, creating an anxious environment, and allowing learners to reward themselves for their accomplishments

2.4 Blooms Taxonomy

One of the most dominant mental constructs of thinking and learning is used globally. A two-dimensional taxonomy model was presented by Krathwohl, with one dimension, the knowledge dimension, representing the learning outcomes and being divided into four categories: factual, conceptual, procedural, and metacognitive. The second dimension refers to cognitive processes, including remembering, understanding, applying, analyzing, evaluating, and creating as shown in (Figure 1). Table 1 shows a set of indicator verbs used to describe associated knowledge (Wang and Farmer, 2008).

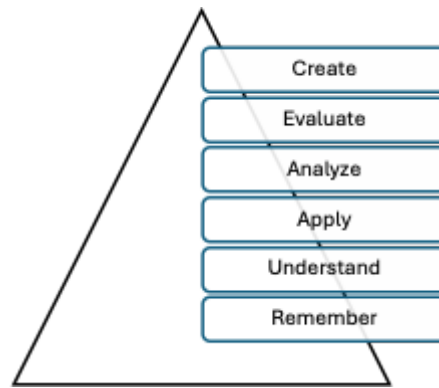


Figure 1 : Revised Blooms Taxonomy

Table 1: Instructional the Taxonomy Table (Wang and Farmer, 2008)

Knowledge Domain	Remember	Understand	Apply	Analyse	Evaluate	Create
Factual Knowledge	List	Summarize	Classify	Order	Rank	Combine
Conceptual Knowledge	Describe	Interpret	Experiment	Explain	Assess	Plan
Procedural Knowledge	Tabulate	Predict	Calculate	Differentiate	Conclude	Compose
Metacognitive Knowledge	Appropriate Use	Execute	Construct	Achieve	Action	Actualize

3. Psychological Drivers and Learner Characteristics

3.1 Gamification and Individual Motivation

This chapter introduces SDT, a foundational framework for understanding how gamification addresses users' core psychological needs—autonomy, competence, and relatedness. According to SDT, individuals are most motivated when their needs are satisfied, although the means of satisfaction may vary between users (Lopez and Tucker, 2021).

3.2 Cognitive Load, Learning Styles, and Individual Differences

According to the Cognitive Evaluation Theory, the effect of extrinsic incentives (e.g., game elements) on an individual's innate psychological needs is controlled by whether they see these extrinsic rewards as controlling or informative (Lopez and Tucker, 2021). CLT highlights the restricted capacity of working memory and is critical for understanding the learning processes in digital educational games. CLT distinguishes between intrinsic cognitive load, which is attributed to the inherent complexity of the learning material, and extraneous cognitive load, which is caused by poorly planned instructional aspects or distracting factors unrelated to learning. In study (Hawlitshchek and Joeckel, 2017), discovered that instructional cues encouraging players to focus on a game's educational material increased extraneous cognitive load, lowering learning outcomes. This unexpected finding implies that such reminders may disrupt the natural flow of gameplay, causing students to engage in wasteful mental strategies that hinder effective learning. These findings emphasize the significance of reducing extraneous load by incorporating instructional assistance directly into game design rather than adding it later.

3.3 Learning Styles

VARK (Visual, Aural, Read/Write, and Kinesthetics) is a prominent learning style classification based on physiological dimensions (Idrizi, Filiposka and Trajkovic, 2018).

Learning Styles Overview

- Visual learners prefer demonstrations and descriptive learning methods.
- Oral learners learn through listening and are easily distracted by noise.
- Read/write learners take notes and use drawings for memory recall.
- Kinaesthetic learners benefit from hands-on learning.

According to (Idrizi, Filiposka and Trajkovic, 2018), learning styles do not significantly influence test results. There was no compelling correlation between academic performance and the learning styles. However, Kinaesthetic learning was the most preferred style in online classes and was ranked first.

3.4 Player Typologies and Motivational Design

Gamification participants value specific psychological needs more than others, suggesting that more research is needed to understand Gamification's weighting process. Individuals' gamification beliefs correlate with their perceptions of valuable applications. Therefore, it is important to consider individuals' unique characteristics when designing gamified applications (Lopez and Tucker, 2021).

Marczewski introduced the Gamification User Types Hexad Framework to evaluate individual preferences for game elements in gamified applications. The Hexad player-type model is the most frequently used model in gamification. The model introduces six player-type dimensions: philanthropists, disruptors, socializers, free spirits, achievers, and players (Lopez and Tucker, 2021). The validity of the user types was tested, and it was confirmed that they were meaningfully associated with personality traits, thus helping in designing gamification that is more effective and engaging (Tondello *et al.*, 2016).

Table 2: Summary of the Hexad player types. NOTE: This summary is based on (Lopez and Tucker, 2021) and (Tondello *et al.*, 2016)

Player Type	Motivators	Description	Suggested Design Elements
Philanthropists	Purpose, meaning, altruism	Motivated by contributing to others without expecting rewards. Demonstrate altruism and value the positive impact.	Collection and trading, gifting, knowledge sharing, administrative roles
Disruptors	Change, innovation, system challenge	Seek to disrupt and improve the systems. Test limits to push innovation. It can be constructive or chaotic.	Innovation platforms, voting mechanisms, development tools, anonymity, anarchic gameplay
Socialisers	Relatedness, connection	This is driven by social interaction and bond formation. Value communities and shared experiences.	Guilds or teams, social networks, social comparison, social competition, social discovery
Free Spirits	Autonomy, self-expression, exploration	Enjoy creativity, freedom and independence. They like to explore and express themselves without constraints.	Exploratory tasks, nonlinear gameplay, Easter eggs, unlockable content, creativity tools, customization
Achievers	Competence, mastery, accomplishment	This study was motivated by task completion and the need to overcome challenges. Strive for growth and excellence in the field.	Challenges, certificates, learning new skills, quests, levels/progression, epic challenges ("boss battles")
Players	Extrinsic rewards	They are motivated by points, prizes, or rewards. Focus on the outcome rather than the nature of the activity.	Points, rewards or prizes, leaderboards, badges/achievements, virtual economy, lotteries or games of chance

Researchers have used storyboards to study the correlation between individuals' Hexad player types, game element preferences, and perceptions in physical-interactive applications. The Hexad player type model examines the relationship between player type, perception of game elements, and performance on gamified and non-gamified applications. The study found that an individual's dominant Hexad player type does not have sufficient discriminative power to differentiate individuals based on their game element preferences, supporting the need for partial membership between them (Lopez and Tucker, 2021). Table 2 summarizes the Hexad player types, their motivators, and the suggested design elements.

Individuals' Hexad player types have inspired numerous studies that have investigated various strategies for adapting gamified applications. (Lopez and Tucker, 2021) Adaptive Gamification, which tailors game components to specific player types, has dramatically improved user performance compared to non-adapted or mismatched gamified systems. (Knutas *et al.*, 2019) proposed a ML technique for tailoring the content of gamified applications depending on individual player types. In research, four alternative educational gamified applications were developed, with the game aspect of rewards changed based on students' Hexad player type

(Mora *et al.*, 2018). (Böckle *et al.*, 2018) and (Lavoue *et al.*, 2018) present a design paradigm for adapting gamified applications based on distinct Hexad player types. (Lavoue *et al.*, 2018) used a matrix factorization approach to determine which game aspects students would interact with in an instructional gamified application. (Tondello, Orji and Nacke, 2017) provided a recommended system structure for tailoring gamified apps to specific player types and game element choices.

4. Gamification Elements and Strategic Design

4.1 Core Gamification Mechanics and Dynamics

This chapter explores gamification as a design strategy to improve motivation and educational effectiveness in learning contexts. It examines key elements in gamified experiences and how they promote user engagement and participation. Gamification has gained popularity by incorporating game mechanics into non-gaming contexts, aiming to engage users, promote learning, and solve problems. Game mechanics include rules, feedback systems, and playful structures, creating enjoyable and engaging experiences. Each element is implemented to provide a sense of playfulness.

Several gamification design frameworks have been proposed. One such framework is the "6R Framework," which includes 30 game elements. Another example is the "GAME Framework," which comprises 52 game elements mapped to specific user types. Among the most influential theories underpinning gamification design is the SDT, which remains central to gamification research (Mustafa *et al.*, 2023).

The following are commonly used gamification elements according to (Mustafa *et al.*, 2023):

- Activity Points: A point system within Learning Management Systems (LMSs) that awards points for specific actions or tasks, incentivizing active participation.
- Badges: Digital symbols awarded for completing tasks or achieving milestones. They promote pride and motivation and can be shared to foster a healthy competition.
- Leaderboards: Visual displays ranking learners based on their performances. Leaderboards promote competition-based motivation by enabling peer comparisons.
- Levels: Based on the activities they have completed, learners are categorized into tiers (e.g., Novice, Intermediate, Expert). Progression through levels reflects skill development and requires continued engagement in periodic challenges to achieve mastery.
- Feedback Systems: Ongoing, constructive feedback—accompanied by visual indicators—helps learners to monitor their progress and maintain psychological motivation and stability.
- Avatars and Customization: Allowing learners to personalize their digital presence within the LMS strengthens their emotional attachment and fosters deeper engagement.
- Discussion Forums: Topic-based forums encourage interaction, and learners receive points for their contributions, promoting collaboration, peer learning, and critical thinking.

4.2 Designing for Engagement: Intrinsic vs. Extrinsic Motivation

The importance of tailoring game mechanics to individual learner differences is also emphasized in the study. Evidence shows that gamification can result in an 80% increase in student motivation, and that outcomes correlate strongly with user profiles (Mustafa *et al.*, 2023). Motivation, a central factor in digital learning games, exists in two forms: intrinsic motivation (driven by personal interest or enjoyment) and extrinsic motivation (driven by rewards or outcomes, such as grades). Game design significantly influences motivation, particularly intrinsic motivation, which tends to increase when learners perceive a game as enjoyable and meaningful (Hawlitschek and Joeckel, 2017). AI-powered personalized learning experiences are increasingly replacing one-size-fits-all education. Intelligent tutoring systems offer real-time support, making the learning process more adaptable. In tandem, virtual assistants, gamification, and simulations enhance student engagement and facilitate deeper immersion in learning content, improving understanding (Bushuyev *et al.*, 2024).

Finally, this chapter explores narrative integration, the use of storytelling to make learning more immersive and emotionally resonant (Palomino, 2022) highlights the critical role of coherent narratives in transforming gamification from a collection of mechanical elements (e.g., points and badges) into a meaningful journey. Drawing from narrative theories such as the Hero's Journey, the study suggests a framework that aligns game elements with the learner's path of growth and challenge. Using storytelling in gamification shifts learning from a tedious task to an engaging adventure, enhancing motivation, retention, and emotional connection in virtual environments.

5. Artificial Intelligence and Data-Driven Personalization

This chapter addresses the critical role of AI and data-driven personalization techniques in enhancing the effectiveness of gamified learning systems. Initially, it introduces Learning Analytics, emphasizing its potential to monitor and optimize student engagement by analysing data generated from user interactions with educational platforms. Learning analytics is a rapidly growing subject in the field of Technology-Enhanced Learning (TEL). Learning analytics is an important aspect of gamification because it examines the data generated by learning systems (Mustafa *et al.*, 2023). Using learning analytics, (Mustafa *et al.*, 2023) compared traditional Gamified Learning management systems (GMLS) and traditional learning management systems (TLMS) and found that students using GMLS logged in more times (7,200 to 3,151, respectively), and in general, students on GLMS performed better academically and had better scores.

Subsequently, the application of ML algorithms is discussed, highlighting their ability to predict and dynamically adapt educational content according to users' cognitive and emotional states. In a study by (Lopez and Tucker, 2020) a ML model successfully used key point data collected from participants for subtle facial expressions that are linked to emotional and cognitive states to predict the student's performance before they perform a task. The ML model can help create personalized adaptive gamification.

Moreover, the concept of real-time adaptation is examined, illustrating how the combination of static and dynamic adaptation techniques contributes to continuous improvement in learning experiences. (Hallifax, 2020) research focused on improving the effectiveness of gamification in education by personalizing game elements based on individual learner characteristics and engagement levels. The study, conducted with the Ludo Moodle project, proposes a generic adaptation engine that integrates static and dynamic adaptation mechanisms. Static adaptation assigns game elements based on initial profile data, whereas dynamic adaptation monitors the learner's engagement in real time using learning analytics and interaction trace data. This dual approach ensures that gamification evolves in sync with each learner's needs, maximizing motivation and engagement throughout the learning process. This study offers a comprehensive model, empirical validation, and practical design recommendations, contributing significantly to adaptive learning technologies.

Finally, this chapter explores significant ethical considerations arising from the use of AI, stressing the importance of transparency, data privacy, and social responsibility in designing advanced educational systems. While AI holds great promise, it also raises ethical questions regarding data privacy, algorithmic bias, and the displacement of instructors. To promote inclusive and egalitarian education for all, these concerns must be addressed directly through responsible development, transparent data methods and continual human monitoring (Bushuyev *et al.*, 2024).

6. User Experience (UX) and Human-Computer Interaction (HCI)

UX is an essential component in the design and assessment of gamified educational platforms. (Palomino, 2022) research emphasizes that effective gamification goes beyond simply adding game mechanics; it must address how students perceive, engage with, and emotionally respond to the learning environment. This study used empirical investigations to explore how aspects such as usability, engagement, enjoyment, and emotional resonance influence students' satisfaction and motivation in virtual learning environments. The findings demonstrate that a positive and well-crafted UX, achieved through the purposeful integration of narrative and interactive elements, leads to higher levels of engagement, deeper immersion, and enhanced learning outcomes. (Chaganti *et al.*, 2023) investigated the vital role of User Interface (UI) and UX design in the effectiveness of online learning platforms. Surveying 530 students, it was found that poor UI/UX might drastically affect user retention, with over 73% of students abandoning platforms with unsatisfactory designs. Students preferred simplicity of use, mobile accessibility, technical assistance, pricing, and high-quality content.

7. The Proposed Framework: Development and Structure

7.1 Framework Development and Validation Approach

This conceptual framework was developed using a multidisciplinary literature study that included pedagogy, psychology, UX design, and AI. Systematic investigation of academic databases such as Scopus and Google Scholar was conducted to identify essential components and their interdependencies, resulting in a variety of theoretical and empirical findings.

For validation, future work will involve an expert-based Delphi study to refine the framework's theoretical soundness. Subsequently, a prototype system will undergo pilot user testing to assess its practical impact on learning outcomes and user satisfaction. Through these steps, the aim is to transition this conceptual model into an empirically supported guide for designing adaptive gamified learning systems.

7.2 Core Components of the User-Centred Adaptive Gamified Learning Framework

The proposed conceptual framework integrates the previously discussed multidisciplinary aspects—including pedagogical theories, psychological insights, gamification principles, and artificial intelligence—to create a cohesive, user-centred, adaptive gamified learning system. This framework is structured around key interrelated modules designed to address the complexity of personalizing the learning experience. Each module within the framework serves a distinct yet complementary purpose, ranging from learner profiling and content adaptation to enhancing user engagement, optimizing usability, leveraging data analytics, ensuring ethical integrity, and continuously improving the system through effective feedback mechanisms. The components outlined below collaboratively ensure that learners experience a highly tailored educational journey capable of evolving dynamically according to their ongoing interactions and progress: The key components of the conceptual framework for designing a user-centred adaptive gamified learning system that integrates the mentioned multidisciplinary aspects are as follows:

- **Learner Profile Module:** This module is based on an adaptive system that collects data for individual learners at the start of the learning journey and continuously updates them as the learner progresses. Including both static characteristics, including personality traits, player type, game elements preferences and motivation, and dynamic data, such as interaction patterns and engagement levels
- **Adaptive Content Module:** Based on Bloom's taxonomy and andragogy, this module should adapt the content format, such as video or text, and difficulty levels to the learner's ongoing pattern.
- **Gamified Module:** This module should assign different game elements to different tasks according to learners' profiles and development. Its main objective is to maximize engagement and motivation of the user.
- **UX and Interaction Module:** This module is responsible for optimizing the usability and accessibility of the learning system, such as dashboard simplification and avatar customization. Based on HCI, the user interface adapts to the learner's skill level and preference, thus enhancing the navigation flow and providing real-time feedback to the learner.
- **Data Module:** Based on ML algorithms, process learning analytics and behavioural data and supporting predictive modelling to identify performance trends and detect disengagement to make necessary adjustments to put the learner on track.
- **Ethical Filter:** The framework incorporates Ethical Considerations, such as data privacy, transparency, fairness, and non-bias. Learners must be informed of how data related to their interaction with the system are used and should have control over personalization features.
- **Feedback loops** are an important component of this system. They used the data output of the learners' quiz performance and engagement levels to make necessary adjustments to the system interface.

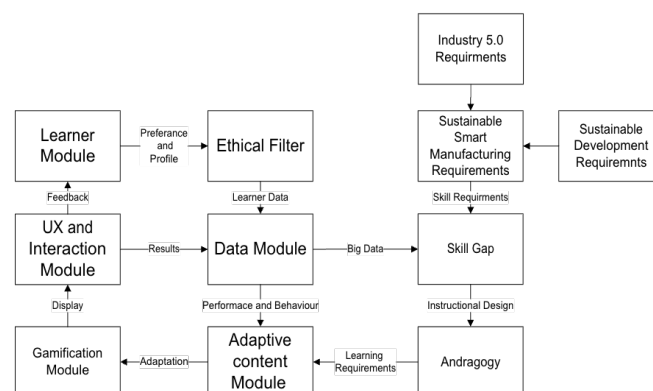


Figure 2: The conceptual Framework

This conceptual framework, shown in Figure 2, is designed to help adult learners optimize their learning process, thus reducing learning time and improving the acquired skill level.

8. Application Context: Professional Retraining for Industry 5.0

(Buckley and Castro Jorge, 2024) research shows that more than 70% of companies face a substantial skills gap. Consequently, ongoing skill development and adaptation have become crucial for supporting workplace innovation and resilience. However, limited time, engagement, and budget hinder the learning and development process. To address these problems, it is critical to move beyond one-size-fits-all solutions and implement individualized learning strategies that help varied learners, particularly those who are disadvantaged by generational or contextual factors.

Training should be tailored to the needs of each generation. Millennials and Gen Z were raised with technology, whereas Gen X had to adapt to it. Gen Xers may be reluctant to learn new skills, often labelling themselves as "technophobes." Deficiencies in traditional schooling may leave Generation Z unprepared for a tech-driven employment market. Recognizing generational disparities in learning experiences and training approaches can help prepare all learners, regardless of age, to meet the demands of the modern workforce (Buckley and Castro Jorge, 2024).

9. Conclusion and Future Work

This study presents a multidisciplinary conceptual framework for a user-centred adaptive gamified learning system. Designed to navigate current challenges facing the industries, such as skill gaps and inefficiency of training, retraining and upskilling. Integrating Andragogical fundamentals such as Bloom's taxonomy and constructivism in addition to a psychological insight into motivation, cognitive load, and players' typologies. The framework ensures a personalized and engaging experience for the learner. The framework will be supported by AI-driven analysis and UX design, fostering engagement, satisfaction, and learning performance. Ethical design, real-time feedback loops, and ongoing personalization make it suitable for the current requirements of adult learners with different hibernations and cultural backgrounds. That matches the continuous demand and challenges in Smart Manufacturing and Industry 5.0. Using a learner-centric approach, the module improves learning outcomes and organizational productivity.

Future research would include validating the framework utilizing a pilot implementation in the context of industrial training. Validation results can be obtained through qualitative research by interviewing the learners in the pilot. Based on the analysis of the results, adjustment, and further development can be recommended. Other technologies, such as biometric data, emotion recognition, and AR/VR, can be integrated to enhance real-time personalization and learner engagement. Quantitative research can be performed when the module is implemented in the industry.

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Increasing STEM Career Interest in Middle Schoolers Through a Health-Themed Serious Game

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Abstract: The U.S. continues to face a shortage of students entering Science, Technology, Engineering, and Mathematics (STEM) careers, including healthcare professions. Developing and strengthening a pipeline of programs, starting as early as middle school, to engage students in STEM and explore future STEM careers leading into higher education is a critical need. Game-based learning (GBL) offers a promising approach to spark interest in STEM fields, especially when classroom access to careers or real-world contexts is limited. One solution is the use of a well-designed, online, scalable serious game that empowers students to explore different health science careers otherwise inaccessible to typical middle schoolers. This study examines the educational impact of *End of Imperial*, a serious online medical mystery game that allows students to roleplay as police detectives solving a fatal crash while collaborating with science and healthcare professionals. During gameplay, students identify clues and solve challenges across multiple settings, from the crash site to the hospital and beyond. Middle school students from three distinct school environments—urban public, urban charter, and suburban public—played the game and completed a post-survey capturing changes in STEM career interest and health-related behaviours. Data collection used a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) to measure impressions immediately after gameplay. "Interest" was a measure of interest in health and science careers; "learning" measured self-perceived learning gains. Results across all locations showed a significant increase in health and science career interest. Students not only enjoyed the game but also reported substantial learning gains and increased confidence in science. In addition, students' awareness of healthy sleep habits, a key theme in the mystery, was increased. The game's community-based character representation, realistic narrative, and immersive roleplay contributed to engagement and learning. Findings suggest that serious games can positively influence middle school learners' attitudes toward STEM careers and personal health decisions when designed with authenticity and social relevance in mind. Overall, results indicated that the interactive game was well-received, playable across diverse communities, and strongly increased students' interest in STEM careers.

Keywords: STEM career exploration, Game-Based learning in education, Serious games for middle school, Health science education, Student engagement in STEM, Online educational games, Learning games, Sleep, Health, Health careers, 21st century skills, Critical thinking

1. Introduction

The United States faces a persistent shortage of students pursuing careers in science, technology, engineering, and mathematics (STEM), particularly in health science professions.

Limited early exposure to careers, uneven access to qualified science educators (U.S. Department of Education, 2015), and declining persistence among students who initially select STEM majors (Chen & Soldner, 2013; Wu & Uttal, 2020) contribute to this STEM career shortage. Middle school represents a critical juncture in career development, as students begin to form and narrow their perceived career options (Gottfredson, 2002). Early, engaging interventions that spark interest and build self-confidence are essential for expanding students' awareness and strengthening the STEM pipeline.

National education policies such as Perkins V (2018) and Career and Technical Education (CTE) frameworks emphasize the need for early access to career exploration for all student groups, including those

underrepresented in STEM. However, traditional models of career exploration-such as field trips, job shadowing, and guest speakers-often require time, funding, and community partnerships that many schools lack. Game-based learning (GBL) is a scalable alternative that simulates real-world roles in interactive digital environments where students can safely experiment, fail, and try again (Emihovich, Arrington, & Xu, 2019).

Well-designed games engage students through voluntary, intrinsically motivated play that supports cognitive development and career exploration (Klopfer et al., 2009; Shute et al., 2019). Within GBL settings, students perform structured problem-solving tasks to achieve goals in immersive, rule-based scenarios. This blend of autonomy, challenge, and narrative creates conditions for deep learning, where students generate and apply knowledge while refining their thinking. Research has demonstrated GBL's effectiveness in high school chemistry (Petrovich et al., 2020), STEM education (Shah et al., 2019; Barany et al., 2017, 2019), and cybersecurity training in higher education (McDonald et al., 2019; Giboney et al., 2019; Jin et al., 2018). Yet, there remains limited research on how GBL can support middle school students, particularly in exploring STEM careers in health sciences.

Motivational and cognitive learning theories provide a useful framework. According to Mayer (2019), five motivational theories help explain sustained engagement in GBL environments: interest, self-efficacy, goal orientation, intrinsic motivation, and social cues. This study focuses on *interest theory* and *self-efficacy theory*, both of which are directly aligned with the research questions. Interest theory posits that students are more likely to engage when content is personally meaningful (Schiefele, 2009; Mayer, 1998), while self-efficacy theory asserts that learners build confidence through repeated mastery of challenging tasks (Bandura, 1997; Bandura et al., 1999). Interest itself remains an underdefined yet essential construct in educational research (Parong & Mayer, 2018).

GBL environments are particularly well-suited to support these motivational processes. Games offer “pleasantly frustrating” challenges that keep learners operating at the edge of their abilities (Gee, 2003), creating opportunities for trial-and-error learning and confidence-building. For example, Ross et al. (1985) found that students retained more knowledge when content was linked to their future careers, reinforcing the role of relevance in promoting learning and motivation (Mayer, 2008).

This study investigates whether *End of Imperial*, an online medical mystery game featuring diverse STEM professionals, can enhance middle school students' interest in health science careers and strengthen their self-efficacy in STEM learning. In the game, students take on the role of a detective working alongside healthcare and science professionals, forensic investigators, and prosecutor to solve a complex motor vehicle collision. Through gameplay, students engage in evidence gathering, critical thinking, and scientific reasoning. Using post-gameplay surveys, this study explores how these immersive problem-solving experiences shape students' motivation, confidence, and career perceptions, contributing to the broader conversation on how GBL can expand access to and interest in the STEM workforce of the future.

2. Methods

We examined the impact of a serious digital learning game on middle school students' interest in STEM careers, particularly health sciences. Grounded in Mayer's interest (Mayer, 2014) and Bandura's self-efficacy theory (Bandura, 1997), our study assessed the effect of an interactive, narrative-based learning game on middle school students' interest, motivation, engagement, and learning across 3 distinct school environments. These school sites included Title I and non-Title I schools, offering a diverse representation of participating students.

2.1 Participants

A total of N = 86 middle school students. Students were drawn from an urban public school (UP, n = 29), an urban charter school (UC, n = 18), and a suburban public school (SUP, n = 39) (see Table 1).

Table 1: Participant site demographics for urban public (UP), urban charter (UC), suburban public (SUP)

Race/Ethnicity	Urban Public	Urban Charter	Suburban Public
% Black	10.3	59.9	2.5
% Latino	86.2	24.7	1.1
% Asian	6.9	9.4	28.8
% White	13.8	29.1	46.7
School Statistics			

Race/Ethnicity	Urban Public	Urban Charter	Suburban Public
% Black	10.3	59.9	2.5
% Latino	86.2	24.7	1.1
% English Language Learners	8.1	18.6	3.9
% Free/Reduced Lunch	60.8	87.9	5.8

All students participated during regular class periods and received the same access to the game. Participation was voluntary. No personally identifiable data were collected in accordance with ethical research standards.

2.2 Game Design, Description and Technical Specifications

To support inquiry-based exploration of STEM careers and increase health awareness, the authors developed *End of Imperial*, a web-based neo-noir mystery game, designed as a point-and-click adventure. It was built using JavaScript and HTML. The game runs in the Chrome browser with a minimum screen resolution of 1024×768 pixels. The game was intentionally optimized for classroom environments, including Chromebooks and Windows laptops commonly found in schools, ensuring compatibility without requiring additional software installation. All that was needed to play the game was a Chrome browser and internet access.

In the game, students play the role of a detective to determine the cause of death for a high-profile celebrity using medical and forensic data. The game narrative unfolds through 13 interactive scenes, each requiring players to collect evidence, conduct interviews, and interpret data to move forward in the investigation, mirroring real-world interdisciplinary STEM practices.

Gameplay incorporates authentic terminology and procedures from multiple STEM careers, including forensic pathology, emergency medicine, toxicology, and digital forensics. This immersion in professional roles is intended to support career awareness and explorations while deepening conceptual understanding of topics related to sleep hygiene.

To ensure broad accessibility, the game was tested across devices in different school environments. At the UP and UC schools, students used 3- to 4-year-old Dell Latitude laptops running Windows. Students at the SUP school used 2-year-old HP Chromebooks. All schools were equipped with Wi-Fi 4 (802.11n) and had dedicated wireless access points in each classroom. No gameplay interruptions or technical performance issues were reported during implementation.

2.3 Procedure

The study was implemented over 2 consecutive school days. On Day 1, students were introduced to the game and began playing from the initial investigative scenes. On Day 2, students resumed the game and completed the remaining scenes. Total gameplay time across the two sessions was about 90 minutes. Immediately after playing the game, students completed an anonymous online survey assessing their experience. The survey was hosted on a secure digital platform. Confidentiality was strictly maintained. Students were instructed not to include names. Any personally identifiable information entered was removed before analysis.

2.4 Survey Design and Learning Constructs

The survey was structured around 3 key learning constructs:

1. *Interest in STEM careers*: intrinsic curiosity and motivation students felt toward science and health professions following gameplay. As players progressed through the game, they engaged with a cast of STEM professionals who collaborated to investigate the crash, collect the evidence and complete forensic analysis. The use of authentic data formats and role-based problem-solving supported students' interest in health and science careers. These game-based interactions provided repeated opportunities to practice skills associated with real-world professions, making abstract STEM concepts tangible and engaging (see Figure 1).
2. *Self-efficacy*: students' confidence in their ability to learn and apply STEM concepts while solving in-game challenges. Throughout gameplay, students confronted challenges that required them to interpret evidence, solve problems, and draw conclusions. Players also observed the effects of sleep deprivation on their own detective character, reinforcing key messages about sleep health. These iterative problem-solving tasks provided students with a sense of mastery, consistent with Bandura's theory that self-efficacy increases through success in progressively difficult tasks (Bandura, 1997).

Students also demonstrated rule acquisition and problem-solving through the application of in-game tools and logical reasoning (Emihovich, Roque, & Mason, 2020).

3. **Purpose** or the perceived educational value of the game experience, including whether the content felt meaningful, worth-while, and connected to real-world applications. While solving the case, students were required to formulate and present a theory of what happened to the Deputy District Attorney. The in-game quest system, initially embedded in an evidence log, was later redesigned to appear in a separate task list to enhance usability. This shift reflected a common classroom challenge: balancing unstructured learning tasks that give agency to gameplay against a guide that makes the game's educational objectives more transparent. Purpose was reinforced by the game's real-world framing: players had to act like investigators and justify conclusions using data, reflecting practices found in STEM careers.

These constructs were grounded in well-established motivational learning theories, specifically, Mayer's interest (Mayer, 2014) and Bandura's self-efficacy theory (Bandura, 1997). Table 2 presents the alignment between each learning construct, its definition, and example of survey response.



Figure 1: A screenshot of authentic scenes encountered during gameplay

Table 2: Learning construct, description, and survey response example

Learning Construct	Description	Example of survey items
Interest	Intrinsic curiosity and motivation of the student towards science and health career	My interest in science increased My interest in health careers increased
Self-efficacy	Confidence and enjoyment of the student while solving the mystery and using scientific reasoning	My confidence in science increased I liked this mystery game
Purpose	Perceived value, learning and challenge level of the game	I learned a lot This mystery game was difficult

The post-game survey included 4 key Likert-scale items:

- *“My interest in health science careers increased”*: measuring career motivation toward science and health careers.
- *“I liked the mystery game”*: measuring enjoyment and engagement with the game.
- *“I learned a lot”*: assessing perceived learning, i.e. self-assessed knowledge gain.
- *“This mystery game was difficult”*: gauging perceived challenge level.

The survey included multiple Likert-scale items for each construct, ensuring measurement precision and reliability. Survey items were adapted from prior work in game-based learning research and covered both the affective and cognitive aspects of student experience (Cameron & Bizo, 2019; Jin et al., 2018). While full self-efficacy data were limited, the item *“I learned a lot”* served as a proxy measure of perceived mastery and engagement.

A 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) was used to assess interest in STEM careers, self-efficacy in STEM learning, and the perceived purpose of gameplay. These items aligned with Mayer’s (triggering and sustaining interest) and Bandura’s theory (emphasizing mastery through engagement and feedback).

In addition to Likert items, the survey included open-ended questions designed to provide additional information on what students learned and how the game affected their interest in science and health careers. Open-ended questions allowed students to elaborate on their responses, yielding additional qualitative insights.

2.5 Data Collection and Instrument Validation

Students entered their responses in an online survey immediately after gameplay. To assess the internal validity of the survey, factor analysis was conducted to determine whether survey items appropriately grouped under each construct: interest, self-efficacy, and purpose. The factor structure was examined to confirm that items aligned with the study’s motivational learning framework, based on Mayer’s interest and Bandura’s self-efficacy theory. To assess the reliability of the survey, Cronbach’s alpha was calculated for each construct, ensuring internal consistency in measuring STEM career interest, self-efficacy, and purpose. These steps confirmed that the survey instrument aligned with the study’s theoretical framework and was appropriate for measuring students’ motivational responses to the game experience.

2.6 Statistical Analysis

Quantitative data analysis included descriptive statistics, internal consistency checks, and group comparisons. A one-way analysis of variance (ANOVA) was used to detect differences across school settings for each of the three learning constructs. Levene’s test for homogeneity of variance was applied to verify that assumptions for ANOVA were met. Effect sizes (Cohen’s *f*) were calculated to supplement significance testing and provide insight into the magnitude of any observed differences. This statistical approach allowed the researchers to evaluate not only whether students’ motivation varied by school type, but also the extent to which the game-based intervention influenced attitudes toward STEM learning across diverse educational contexts.

Descriptive statistics and one-way ANOVA were used to compare responses across school sites. The independent variable was school setting (UP, UC, SUP), and the dependent variables were the four survey items. Levene’s test confirmed homogeneity of variance. Where *p*-values approached or met significance ($p \leq .05$), Cohen’s *f* was

used to estimate effect sizes. While confidence was not directly measured with sufficient resolution, responses to “I learned a lot” and “My interest in health science careers increased” served as indirect indicators of engagement and developing science identity, consistent with the literature on self-efficacy and vocational interest.

3. Results

After playing *End of Imperial*, middle school students reported gains in interest, learning, and self-efficacy related to STEM careers. Students from all 3 participating school sites—UP, UC (both Title I), and SUP—demonstrated consistent engagement with the game and positive perceptions of its educational value.

Based on our theoretical framework, survey items captured 4 key outcome areas: interest, learning (purpose), perceived difficulty, and enjoyment (engagement). These were aligned with Mayer’s interest and Bandura’s self-efficacy theory. Interest was assessed as a measure of engagement in health and science careers, while confidence was measured in relation to understanding science concepts. Perceived learning gains were used as a proxy for self-efficacy.

Survey results, as illustrated in Figure 2, indicate that students not only enjoyed the game but also reported substantial learning gains and increased confidence in STEM-related topics.



Figure 2: Survey results from 86 middle-school students from three school districts in California

3.1 Enjoyment and Engagement: “I Liked the Mystery Game”

Students at all 3 school sites rated the game highly enjoyable, with mean scores ranging from 3.9 - 4.6. The UP school students reported the highest average enjoyment. However, there was no significant difference in means ($F(2,75) = 1.691$; $p = 0.191$).

91% of students at UP, 83% at UC, and 95% at SUP rated the mystery game 3-5. Overall, students **enjoyed** playing the game at all three school sites. These results suggest that *End of Imperial* successfully engaged students across diverse school settings.

3.2 Learning and Perceived Purpose: “I learned a lot”

Students reported substantial learning gains. Students at the UP school reported the highest learning gain (mean = 4.48) which is higher than the other two sites (3.72 UC and 3.92 SUP). Using an alpha of 0.05, this difference was significant ($F(2,75) = 3.173$; $p = 0.048$). Future studies will look into possible explanations for this difference. 96% of students at UP, 84% at UC, and 92% at SUP school reported self-perceived learning gains as 3, 4 or 5. These substantial learning gains are used as a proxy for increased confidence in STEM-related topics.

3.3 Difficulty Level and Perceived Challenge: “This Mystery Game was Difficult”

Students at the high-performing SUP school reported a mean hig (3.14) compared to the other two sites (2.43 UC and 2.78 UP). This difference was statistically significant ($F(2,75) = 3.114$; $p = 0.05$). Difficulty level of 3-5 was reported by 48% of students in UP, 56% of students at UC, and 76% of students at SUP schools.

3.4 Career Interest: “My Interest in Science and Health Careers Increased”

Results across all locations showed a significant increase in health and science career interest. There was no significant difference in means (ranging from 3.17 to 3.57) across all three sites ($F(2,75) = 0.716$; $p = 0.492$). 83% of students at UP, 72% of students at UC, and 81% of students at SUP schools reported their interest level 3-5.

These findings indicate that the game was effective in stimulating health and science career interest across diverse student groups, aligning with Mayer’s interest theory.

Table 3: Overall survey results by each school location

	Urban Public			Urban Charter			Suburban Public			1-way ANOVA		Cohen's
	n	Mean	Var	n	Mean	Var	n	Mean	Var	F	p	f
I liked this mystery game	23	4.57	0.89	18	3.94	2.06	37	4.3	0.88	1.691	0.19	0.21
I learned a lot	23	4.48	0.81	18	3.72	1.86	37	3.92	0.85	3.173	0.05	0.29
This mystery game was difficult	23	2.43	1.26	18	2.78	1.12	37	3.14	1.06	3.114	0.05	0.29
My interest in science & health careers increased	23	3.57	1.35	18	3.17	1.44	37	3.49	1.09	0.716	0.49	0.14
	86.2% Latino			59.9% Black			46.7% White					

3.5 Health Awareness and Science Application

Students not only enjoyed the game but also reported substantial learning gains and increased confidence in science. In addition, students’ awareness of healthy sleep habits, a key theme in the mystery, was increased. A majority of students reported they would try to get more sleep after playing the game, highlighting the game’s impact on real-world health behaviour awareness. Students were also introduced to scientific roles (e.g., toxicologists, medical investigators, forensic specialists) through immersive scenarios involving sleep deprivation and prescription drug misuse.

3.6 Factor Analysis and Qualitative Insights

Factor analysis further confirmed that survey responses clustered appropriately under each construct, supporting the internal validity of the instrument. Cronbach's alpha across questions 1, 2, and 4 was 0.86, indicating good internal consistency of the survey items. Although direct confidence measures were limited, high ratings on the “I learned a lot” item and open-ended feedback suggest increased perceived self-efficacy in STEM topics.

Additionally, the survey included open-ended responses, where students elaborated on how gameplay influenced their interest in STEM careers, reinforcing the quantitative findings and providing deeper insight into the impact of game-based learning on career motivation. Students described feeling “like a real detective,” and many expressed curiosity about careers in science, medicine, or investigation. Several mentioned learning new information about sleep and health science topics, indicating both cognitive and affective engagement.

These findings align with our research question, demonstrating that GBL can enhance students’ STEM career interest and self-efficacy. The significant increase in confidence and motivation supports Mayer’s interest theory and Bandura’s self-efficacy framework, reinforcing the role of interactive learning in shaping career aspirations.

4. Discussion

This study examined middle school students’ responses to *End of Imperial*, a digital medical mystery game designed to promote interest, engagement, and self-efficacy in STEM and health science careers. Grounded in Mayer’s Interest Theory and Bandura’s Self-Efficacy Theory, the game leverages narrative-based gameplay and problem solving to embed academic and behavioural health content—specifically sleep—into an immersive learning experience.

Findings across three diverse school settings, including two Title I schools, indicate that students not only enjoyed the game but also perceived significant learning gains. Over 80% of students expressed an increased interest in science and health careers. These outcomes suggest the game successfully sparked situational interest (Mayer) and provided mastery-like experiences that contribute to self-efficacy (Bandura), for diverse groups of students. While direct confidence measures were limited, self-reported learning served as a useful proxy for perceived competence and engagement.

Students found the mystery-solving elements and storyline meaningful and engaging. The connection between sleep habits and real-life consequences—framed through the lens of a fatal car crash investigation—brought relevance to an abstract health topic while supporting critical thinking and decision-making. These elements align with research showing that real-world context and student agency enhance motivation and retention. Usability feedback highlighted the need for more onboarding and scaffolding, especially for journal navigation and argument construction. Addressing these areas could reduce cognitive load and improve outcomes across diverse learners.

Additionally, this study contributes to the literature on serious games in health and STEM education by demonstrating that well-designed, culturally relevant, story-driven games can engage diverse learners. It also reinforces the value of integrating behavioral health themes—like sleep—into STEM career education.

4.1 Perceived Limitations

This study relied on post-survey self-reports without pre-survey or control group comparisons, limiting our ability to measure actual change or isolate the game’s specific impact. Results reflect immediate perceptions and do not capture longer-term learning or behavior change. While the school sample was diverse, it may not be representative of all populations. No objective academic or health outcomes were measured. Future studies should incorporate control conditions, pre/post data, and longitudinal tracking.

4.2 Implications for Educators, Schools, and Policymakers

These results indicate that serious games like *End of Imperial* can be effective tools for engaging middle school students in STEM and health-related learning, especially in settings where experiential opportunities are limited. For educators, the game offers a flexible, easy-to-implement, standards-aligned resource that encourages inquiry and career exploration without requiring specialized training or technology/hardware.

Schools and districts may integrate serious games into science, health, or electives curricula to complement instruction and support interest in future careers. Narrative-driven games that reflect students’ lived experiences may help bridge gaps and broaden access to meaningful STEM learning.

For policymakers and education leaders, this study highlights the importance of investing in scalable, evidence-based educational innovations that combine academic content with health and career relevance. Tools like *End of Imperial* may serve as critical components in early STEM pipeline efforts and public health literacy campaigns, especially when implemented at the middle school level—a key stage for identity and interest formation.

4.3 Conclusion

In conclusion, *End of Imperial* demonstrates how serious games can be thoughtfully designed to align with established learning theories while addressing both academic and behavioral health goals. By embedding real-world relevance into engaging gameplay, the game fosters interest, motivation, and perceived learning across a range of student populations. While additional research is needed to explore long-term outcomes and implementation models, this study affirms the potential of game-based learning to contribute meaningfully to equitable STEM education and early career awareness. Embedding these tools in middle school education may yield long-term benefits for both individual learners and workforce development.

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Enhancing Art Education for Generation Z Through Immersive Virtual Reality

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Abstract: Effective art education for Generation Z faces challenges due to students' abbreviated attention spans and preference for visually rich, interactive content, while high school curricula demand rapid coverage of extensive artistic movements. Despite the growing availability of immersive technologies, there is limited research on their integration into modular art curricula tailored to this generation. This study investigates how immersive virtual reality (VR) can enhance engagement and understanding of avant-garde art. A pilot study with 32 secondary school graduates exposed participants to two narrative-driven VR episodes centred on Seurat's *A Sunday on La Grande Jatte* and Gentileschi's *Self Portrait as Saint Catherine of Alexandria*. Preliminary findings indicate high levels of attention, curiosity, and contextual understanding, with 87.5% of participants expressing interest in exploring additional episodes. Interpreted through Kolb's experiential learning theory and Csikszentmihalyi's flow framework, the results suggest that modular VR experiences can convert Generation Z's digital habits into structured, meaningful learning. These findings highlight the potential for immersive VR to support both cognitive and affective outcomes, informing the design of high school art curricula that effectively balance engagement with comprehensive content coverage.

Keywords: Educational innovation, Higher education, Immersive learning, Virtual reality, Game-Based engagement

1. Introduction

High school art curriculum often demands a rapid survey of a century's worth of avant-garde movements within a handful of instructional sessions. At Tecnológico de Monterrey, instructors face the compounded challenge of engaging Generation Z learners—digital natives with inherently shorter attention spans and a strong preference for concise, visually driven content—while adhering to institutional policies that limit unsanctioned mobile device use. Traditional lectures and video presentations struggle to compete for students' focus, and unrestricted access to digital assistants can further undermine sustained engagement.

Extended reality (XR) technologies, and in particular immersive virtual reality (VR), offer a promising path forward. By enveloping learners in richly detailed, interactive environments, VR can mitigate distractions and foster deep, multisensory engagement with complex subject matter. Game-based learning (GBL) mechanics augment this immersive approach, leveraging play to heighten motivation and promote meaningful understanding. This paper examines how two narrative-driven VR modules—focused on Georges Seurat's *A Sunday on La Grande Jatte* and Artemisia Gentileschi's *Self Portrait as Saint Catherine of Alexandria*—might be adapted into modular units that align with high school art curriculum's scope and pacing. Drawing on attention-span research, immersive-learning studies, and the existing VR infrastructure at Tecnológico de Monterrey, we propose a blended model that integrates pre- and post-immersion activities to maximize both conceptual breadth and depth.

2. Context

Because the student body consists predominantly of Generation Z—often called digital natives—it is essential to integrate striking audiovisual elements that immediately seize their attention. These learners are accustomed to continuous interaction with a variety of devices, including tablets, smartwatches, smartphones and laptops. In the specific context addressed here, the necessity of covering a century's worth of artistic movements within a limited timeframe poses a significant challenge. Traditional resources such as slide decks and lecture videos no longer suffice to compete for student focus; instead, learners favour concise, dynamic media formats.

Moreover, the effortless access to digital tools and on-demand information sources can foster disengagement, as many students assume that automated assistants will resolve any question in minutes. Rather than restricting device use, it has proven more effective to introduce technologies that actively support their academic growth. For this reason, immersive virtual reality has been adopted: by enveloping learners in a controlled environment, it substantially reduces opportunities for distraction.

In my role as a high-school instructor, I confront these realities daily managing shortened attention spans, permitting use of mobile devices in the classroom for academic purposes, and seeking pedagogical approaches that harness, rather than fight, students' digital habits.

2.1 Attention Span in Generation Z Students

This literature review brings together studies from 2023 to 2025 that examine how Generation Z learners—often described as digital natives—differ in their capacity for sustained attention in educational contexts. Their habitual use of personal devices, affinity for interactive content, and expectation of visual engagement have reshaped how they process and retain information.

A consistent finding is that Generation Z students display shorter attention spans than earlier cohorts. Kyong-Jee (2024) reports that medical students from this generation prefer brief, interactive modules over extended lectures. Likewise, Bunardi and Prestianta (2023) emphasize that rapid visual processing among these learners demands instructional materials that are both concise and dynamic. Traditional long-form presentations risk losing their focus early on.

To measure these spans objectively, Simon et al. (2023) used quantitative time-on-task curves, showing that Generation Z peaks sooner than older groups. Complementing this, Villegas-Ch. et al. (2023) developed an online system that computes real-time attention scores via multi-threaded algorithms—especially valuable in virtual learning environments where continuous engagement monitoring is crucial.

Researchers have also tested interventions aimed at extending attention. Sundareswaran et al. (2024) introduced a serious-game framework in physiology courses that shifts learners from passive listening to active problem-solving, which led to prolonged focus and deeper critical thinking. Drnach-Bonaventura et al. (2024) highlight the value of interactive discussions and digital tool integration in large classes, while Carvalho et al. (2023) demonstrate that brief, structured breaks (e.g., on-site yoga in calculus lessons) can mitigate cognitive fatigue and restore attentional capacity.

The broader digital context further influences attention control. Moreno, Torres, and Zhang (2024) found that extended screen exposure correlates with diminished sustained attention, a trend echoed by Sahu et al. (2024) in their study of medical and nursing students. Chen (2023) cautions that without aligning content design to Generation Z's need for quick, visually rich information, technology-rich settings may inadvertently foster disengagement.

Together, these findings suggest that educational environments for Generation Z must be responsive to their shorter attention spans through bite-sized learning modules, gamified experiences, periodic cognitive breaks, and real-time engagement feedback. Such adaptive strategies promise to optimize focus and deepen learning (Mishra, Sipi, & Menon, 2024).

2.2 Immersive Virtual Reality Experiences in Art Education

Recent investigations highlight how immersive virtual reality (VR) aligns with avant-garde art's experimental ethos by fostering multisensory, interactive learning environments. These platforms allow students to engage directly with non-traditional art forms, encouraging exploration beyond conventional media and promoting creative, disruptive pedagogies.

Affective engagement lies at the heart of VR's pedagogical value in art instruction. Λαμπρόπουλος et al. (2024) demonstrate that embedding affective-computing features within immersive systems enables these environments to detect and respond to learners' emotional states, thereby deepening their connection to challenging aesthetic content. Similarly, Lie et al. (2023) describe educational tools that deliberately evoke and harness emotional responses, a capability especially pertinent when grappling with avant-garde works that defy familiar artistic conventions.

Empirical studies underscore instructors' recognition of VR as transformative. Antón-Sancho, Fernández-Arias, and Vergara (2024) report that faculty in art disciplines value VR for its capacity to render and manipulate digital artworks in three dimensions—an affordance traditional media cannot match. In the field of digital media art, Xu (2024) illustrates how VR curricula empower students to extend the boundaries of expression through interactive platforms, reinforcing both technical proficiency and critical inquiry into the nature of art.

By integrating immersive VR with established taxonomies of learning, educators can support higher order thinking and experiential discovery. Hutson and Olsen (2022) present a case in which VR experiences, structured around revised Bloom's taxonomy, guide students through nonlinear narratives and unconventional

aesthetics—approaches that resonate with avant-garde pedagogy’s emphasis on experimentation over rote assessment. He, Zulkifli, and Ayub (2023) further outline strategies for intelligent teaching modes that leverage VR’s dynamic capabilities to sustain motivation and stimulate novel artistic methodologies.

Despite these advances, challenges persist equitable access to high-quality hardware, faculty development in emerging technologies, and the need to integrate VR experiences without compromising curricular goals. Liao (2024) calls for collaborative frameworks that unite technologists, artists, and theorists to tailor immersive experiences to the unique demands of avant-garde art education.

Collectively, this body of work suggests that immersive VR offers a powerful means of reimagining art instruction in higher education—one that engages learners affectively, encourages hands-on exploration, and aligns with the disruptive spirit of avant-garde practice.

3. Rationale for the Virtual Reality Experience

Extended reality (XR), encompassing both augmented reality (AR) and virtual reality (VR), refers to technologies that blend virtual elements with the physical environment to deliver interactive, immersive experiences. In educational settings, XR enables students to engage with digital content in real time, thereby clarifying abstract concepts and strengthening information retention. Meanwhile, game-based learning (GBL) integrates game mechanics and dynamics into instruction to enhance motivation, foster engagement, and promote meaningful understanding. This approach rests on the notion that play is fundamental to human nature and can serve as a powerful vehicle for learning.

3.1 (Hi)Story of a Painting Analysis and Course Curriculum

The two applications under review—both developed by Fat Red Bird and Monkeyframe in partnership with Catapult Digital and Arts Council England—demonstrate the potential of immersive narrative to deepen students’ understanding of landmark artworks. Episode 1, *What’s the Point?* released on March 21, 2021, for Meta Quest devices, focuses on Georges Seurat’s *A Sunday on La Grande Jatte* (1884). Through a three-act structure and the voice of Speech DeBelle, learners traverse a late-nineteenth-century Paris rendered with anthropomorphic architecture and period detail. Interactive “Story Bonuses,” unlocked by the user’s gaze at chapter conclusions, offer supplementary insights without disrupting the core narrative flow. User feedback highlights the application’s ability to anchor historical context, convey artistic significance, and engage even casual observers in an accessible, memorable format.

Episode 2, *The Light in the Shadow*, narrated by Cerys Matthews, turns its immersive lens to Artemisia Gentileschi’s *Self Portrait as Saint Catherine of Alexandria* (1615–1617). This three-act journey charts Gentileschi’s ascent in a society that denied women official standing, underscoring both her technical mastery and her resilience. By situating students within environments that mirror the social and cultural realities of the Baroque era, the application fosters empathy and a richer grasp of how Gentileschi’s personal narrative intersects with broader art-historical currents.

Although both titles excel in delivering deep, focused encounters with single works, they do not align seamlessly with the Tecnológico de Monterrey’s preparatory curriculum, which requires coverage of approximately a century of avant-garde movements within five fifty-minute sessions. The density of this thematic span, combined with Generation Z’s abbreviated attention spans and existing mobile-device policies, renders traditional lecture and video resources inadequate. To bridge this gap, an adapted curriculum must integrate these VR experiences as modular units—each tailored to a specific movement or artist—while supplementing them with concise pre- and post-immersion activities that reinforce key concepts and maintain momentum across successive class periods. This approach ensures that immersive episodes enhance rather than supplant the rapid survey required by the course framework.

3.2 Technological Context and Feasibility

Tecnológico de Monterrey already boasts a robust technology infrastructure capable of supporting immersive virtual reality (VR) implementations across its network. In late 2017, the university inaugurated Mostla—an innovation hub—at the International Congress of Innovation and Educational Research, and opened it to students, faculty, and staff in January 2018. Within its first ten months of operation, Mostla welcomed over 5,000 visitors, demonstrating both strong institutional engagement and widespread community interest.

Since then, Mostla has expanded to twenty campuses, each featuring a dedicated VR Zone equipped with four HTC Vive Pro stations. These facilities enable participants to explore intricately rendered virtual environments

and interact with immersive simulations. The name “Mostla,” drawn from the Nahuatl term for “tomorrow,” encapsulates the hub’s mission to cultivate curiosity and digital proficiency among both students and educators. To satisfy this mission, Mostla pursues four strategic goals: integrating advanced technologies into academic and extracurricular initiatives; mentoring students on interdisciplinary VR applications; advising faculty on pedagogically sound use of immersive tools; and aligning VR projects with the university’s broader objectives.

In addition to hardware access, Mostla offers structured group demonstrations, bespoke consulting services, and an online reservation system for VR equipment and spaces, ensuring that immersive resources are readily available across disciplines. However, while the hardware ecosystem is well established, there remains a shortage of software tailored specifically to higher education needs. Many existing VR titles lack direct relevance to curricular objectives or institutional priorities, which limits their instructional effectiveness. This software gap presents a clear opportunity: by developing or adapting VR applications that address the requirements of university and high school courses, Tecnológico de Monterrey can leverage its substantial infrastructure to deliver immersive, game-based learning experiences that enhance student outcomes.

3.3 School Policies About the Phones Usage in Classrooms Versus Reality

Institutional guidelines at the preparatory level strictly prohibit students from using smartphones or smartwatches during class unless expressly permitted by the instructor. At the same time, educators are encouraged to introduce learners to various artificial intelligence tools—as instruments to enhance academic work, not as replacements for original effort.

In practice, however, many teachers confront a generation for whom digital devices have become indispensable. Students often report stress or anxiety when separated from their screens, driven by a constant need to check notifications. Some even experience sleep disturbances—spending late-night hours on platforms such as TikTok—which can lead to physical exhaustion by morning. The phenomenon known as “FOMO” (Fear of Missing Out) exacerbates this cycle, as learners feel compelled to stay connected to avoid missing any online activity.

Recognizing that educators cannot match the brevity and appeal of the short-form videos preferred by today’s centennials, many have shifted toward integrating these devices as pedagogical aids. Rather than attempting to enforce complete disconnection, teachers leverage mobile technology to deliver content in formats that resonate with students’ habits. This approach also addresses the marked decrease in voluntary reading among this cohort: instead of lengthy texts, learners respond more readily to visual or experiential materials that align with their expectations and attention patterns.

4. Methodology

This pilot study adopted an exploratory quasi-experimental design with a mixed-methods approach to assess the potential of narrative-based virtual reality applications to enhance art appreciation among Generation Z upper-secondary students.

The study was conducted in September 2023 with a cohort of thirty-two secondary school graduates aged 18–19 years. The research design employed a quasi-experimental approach with two parallel groups to examine the potential of immersive virtual reality (VR) applications in enhancing art historical knowledge among Generation Z learners. Participants were initially surveyed to determine their prior familiarity with two selected artists: Georges Seurat and Artemisia Gentileschi. The initial questioning revealed that only one participant could identify Seurat through his work *A Sunday on La Grande Jatte*, while none recognised Gentileschi by name or oeuvre.

Following this baseline assessment, participants were divided into two equal groups. The first group engaged with the VR application *(Hi)story of a Painting: What’s the Point?*, which explored Seurat’s artistic contributions and techniques. The second group experienced *(Hi)story of a Painting: The Light in the Shadow*, focusing on Gentileschi’s life and work. Both applications were delivered using VR headsets, offering gaze-triggered interactive elements, spatial audio, and narrative-driven sequences designed to immerse learners in the historical and artistic context.

Upon completion of the VR experience, participants were invited to indicate their willingness to explore the alternate episode. Twenty-eight out of the thirty-two expressed an interest in doing so, suggesting a heightened level of engagement and curiosity. A focus group session was subsequently convened with all participants, employing a semi-structured interview protocol to capture their reflections. The discussion explored the extent to which the content was new or previously known, perceptions of artistic movements, and recognition of specific works. Notably, while few had prior knowledge of either artist, most participants reported familiarity

with the artistic movements depicted, and a majority recalled having seen Seurat's *A Sunday on La Grande Jatte* prior to the session, whereas Gentileschi's works remained largely unfamiliar.

Data collection employed a mixed-methods approach. Quantitative data included pre- and post-experience recognition rates, while qualitative insights were drawn from thematic analysis of the focus group transcripts. This combination of numerical indicators and narrative accounts provided a multidimensional understanding of learner engagement and knowledge acquisition in an immersive VR context.

To illustrate the proposed instructional design, Figure 1 presents the *Modular Immersive VR Curriculum Alignment*. This model integrates four interconnected layers: (1) curriculum modules tailored to specific artists and art movements, supported by pre- and post-immersion prompts; (2) immersive VR experiences featuring narrative-driven, gaze-triggered content designed to maximise learner engagement; (3) the theoretical foundations of Kolb's Experiential Learning Cycle and Csikszentmihalyi's Flow Theory, which underpin the sequencing and design of activities; and (4) targeted learning outcomes across cognitive, affective, and behavioural domains. The diagram visually demonstrates how the modular structure enables both flexibility and coherence, ensuring that each VR activity aligns with curricular objectives while fostering deep, sustained engagement.

Figure 1: Diagram showing how VR art history modules integrate pre/post activities and engagement mechanics to align with learning objectives

5. Preliminary Results

The pilot study yielded several insights into the effectiveness of narrative-driven virtual reality applications for fostering art historical knowledge among Generation Z learners. Baseline assessment indicated minimal prior familiarity with the selected artists: only one participant recognised Georges Seurat and his painting *A Sunday on La Grande Jatte*, while none identified Artemisia Gentileschi or her work. Despite this limited prior knowledge, participants demonstrated rapid engagement with the VR content.

Following interaction with the applications, 28 out of 32 participants (87.5%) expressed interest in exploring the alternative episode, suggesting that the immersive experiences stimulated curiosity and motivation to extend learning beyond the initial exposure. During the subsequent focus group discussion, students reported enhanced understanding of both the artworks and the broader artistic movements represented. While Seurat's painting was visually familiar to several participants, Gentileschi's oeuvre was largely unknown prior to the activity. Nonetheless, participants were able to contextualise both artists within the appropriate historical and stylistic

frameworks, demonstrating that the VR experiences facilitated meaningful connections between individual artworks and larger artistic currents.

Qualitative observations indicated that the immersive narrative structure, including gaze-triggered bonuses and three-act segmentation, contributed to sustained attention and emotional engagement. Participants frequently highlighted the interactive elements as particularly effective in anchoring historical and technical knowledge, supporting the notion that VR can provide a concentrated, multisensory learning experience that traditional media cannot replicate. Overall, the findings suggest that modular VR-GBL interventions hold significant potential for enhancing both interest and comprehension in art education, particularly when tailored to curricular objectives and the cognitive profiles of Generation Z learners.

6. Discussion

The preliminary findings indicate that narrative-driven virtual reality (VR) applications can effectively foster engagement and enhance art historical knowledge among Generation Z learners. Participants demonstrated rapid attention to the content, significant interest in cross-exploration of episodes, and improved contextual understanding of both Seurat and Gentileschi, despite minimal prior familiarity. These outcomes suggest that immersive VR interventions can serve as a catalyst for experiential learning, aligning with established theoretical frameworks.

Kolb's experiential learning theory (1984) posits that knowledge is constructed through a cyclical process of concrete experience, reflective observation, abstract conceptualisation, and active experimentation. In the present study, students engaged in concrete experiences via immersive VR episodes, followed by reflective discussion in focus groups. This sequence allowed learners to situate individual artworks within broader artistic movements, thereby reinforcing conceptual understanding through reflection and discussion. The structured, modular VR approach operationalises Kolb's learning cycle by providing repeated, discrete experiential units that can be scaffolded with pre- and post-immersion activities to consolidate learning.

Csikszentmihalyi's flow theory (1990) further elucidates the high levels of engagement observed. The immersive narratives, gaze-activated bonuses, and interactive tasks created conditions conducive to flow, characterised by focused attention, intrinsic motivation, and a sense of temporal distortion. Participants' expressed willingness to explore alternative episodes and their sustained concentration during the VR sessions provide empirical support for the notion that well-designed immersive experiences can facilitate optimal learning states. By integrating these elements into a modular curriculum, educators can channel students' natural preferences for dynamic, visually rich experiences towards structured, educational objectives.

Collectively, these findings underscore the potential of combining game-based learning mechanics with immersive VR to address the challenges inherent in rapid-survey art curricula. The alignment with experiential learning and flow theory suggests that such interventions do not merely serve as engaging novelties but can substantively enhance cognitive processing, contextual understanding, and emotional resonance. Future iterations of this curriculum should continue to employ real-time engagement metrics and iterative feedback to optimise module length, interactivity, and alignment with learning outcomes, thereby ensuring both breadth and depth of educational impact.

7. Conclusions

Art education for Generation Z faces the dual challenge of engaging learners with abbreviated attention spans while covering extensive artistic movements within limited instructional time. This study demonstrates that immersive virtual reality (VR) experiences, structured as modular, narrative-driven episodes, can address this challenge by fostering sustained attention, curiosity, and deeper contextual understanding. The pilot study revealed that students not only engaged actively with the VR content but also expressed interest in exploring additional episodes, suggesting that immersive approaches can transform digital habits into focused, meaningful learning. Interpreted through Kolb's experiential learning theory and Csikszentmihalyi's flow framework, these findings indicate that VR experiences facilitate concrete engagement, reflective observation, and emotional immersion—key elements that support both cognitive and affective learning outcomes. By aligning immersive modules with curriculum objectives, educators can ensure that rapid-survey art courses maintain both breadth and depth, transforming high school art instruction into an engaging, effective, and learner-centred experience.

Future work should expand the empirical evaluation of these VR modules, integrating quantitative engagement metrics and qualitative feedback to optimise design, pacing, and alignment with learning objectives. Such

iterative refinement will further establish immersive VR as a viable pedagogical tool, bridging the gap between Generation Z's digital proclivities and the educational demands of comprehensive art curricula.

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Change the Game with Vaccines: A “Play and Learn” Workshop for Science Education

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Abstract: Due to the recent Covid-19 pandemic, the concept of genetic vaccination is not new. Genetic vaccines (DNA and RNA-based) are emerging as a new anticancer strategy, based on the same immunological mechanisms underlying vaccines against infectious disease. The development of RNA-based anticancer vaccines is a complex process that involves the use of messenger RNA (mRNA) to provide immune cells with the molecular instructions to produce harmless fragments of cancer-related proteins (antigens). These antigens alert the immune cells, helping them to identify and destroy cancer cells that express these proteins. To engage young students aged 12-18 in understanding the biology and the mechanisms of action of these vaccines, we created “*Vaccines: New Weapons Against Tumors*”, an educational game based on interactive activities. Presented at the Genoa Science Festival 2024, Italy's largest science communication event, it attracted over 1,000 participants. It consisted of an initial training phase that included images, videos, and explanations, followed by a playful activity, employing “interlocking” elements representing mRNA, transfer RNAs and amino acids, and plastic tiles (cards) representing antibodies and antigens. The goal of the workshop was to assemble the molecule that represents the mRNA vaccine, which is then translated into the corresponding protein, according to the rules of the genetic code. That protein serves as cancer antigen against which the immune cells are armed with antibodies to destroy cancer cells. Participants were divided into teams, each playing distinct role: the scientists who design the vaccine, the immune system cells and the cancer cells. The outcomes achieved through the self-report questionnaire indicated that the experience had a positive impact in terms of enjoyment and effectively increased participants' interest in the topics covered by the workshop. This experience highlights the potential of the game-based approach, tailored to STEM concepts, providing an immersive educational experience.

Keywords: Game-Based learning, Science communication, STEM, Genetic code, Transcription, Translation, Vaccines, Immune response, Cancer

1. Introduction

Game-based learning (GBL) has gained popularity in recent years due to its ability to increase student engagement, motivation, and retention of knowledge, as it is an interactive approach to teaching that uses games to provide students with hands-on experience (Vandercruysse et al., 2012; Nesti, 2017).

The use of playful elements aims to foster a powerful and active learning experience, which is beneficial for students as it increase their participation and engagement in the learning process (Pesare et al., 2016). Effective game design combined with the collaborative nature of gameplay can significantly enhance student engagement and skill development in science education (Kalogiannakis et al., 2021). In essence, playful content and gamification are effective tools for enhancing motivation, engagement, and knowledge acquisition across various disciplines including STEM (Sturges et al., 2009; Chiarello et al., 2023; May et al., 2023), highlighting the experiential value of game-based learning.

Bringing science closer to the public, commonly referred to as scientific dissemination, is a fundamental process that promotes scientific culture and encourages the citizens to take an active role in public life.

Science festivals in particular appeal to a variety of audiences by offering them the opportunity to explore numerous scientific topics and activities with just one visit (Durant, 2013).

The recent Covid-19 pandemic has renewed attention to vaccines. The rapid approval of genetic vaccines against Covid-19 (DNA and RNA-based vaccines) has raised many questions about their development, safety and effectiveness. Today, the internet is the primary source of health-related matters for many people, although, unfortunately, not always a reliable one. The infodemic during the pandemic made it hard to find accurate and trustworthy information.

The development of the genetic vaccines for fighting infectious diseases and cancer has actually been an active area of research for about 20 years (Fioretti et al., 2010; Sobhani et al., 2022).

Due to the rapid COVID-19 vaccines development, genetic vaccines, particularly mRNA vaccine, are emerging as a promising new strategy in cancer treatment. These vaccines are based on the same underlying principles as traditional vaccines used against infectious diseases. The development of RNA-based anticancer vaccines is a complex process that involves the use of messenger RNA (mRNA) to provide immune cells with the molecular instructions to produce harmless fragments of cancer-related proteins (antigens). Mutated antigens are displayed only by cancer cells, while most healthy cells show the normal ones. These mutated antigens activate immune cells by triggering them to produce antibodies to attack cancer cells expressing these proteins (Sobhani et al., 2022).

To intrigue young students aged 12-18 and engage them in understanding the mechanisms of action of anticancer mRNA vaccines and how the immune system works, we developed “Vaccines: New Weapons Against Tumors”, an educational game based on interactive activities.

The workshop was presented at the Genoa Science Festival 2024, Italy's main science communication event with about 200,000 visitors attending, from October 24th to November 3rd, 2024. The theme of this latest Festival edition was “Challenges”, a concept that inspired us to design the workshop on anticancer vaccines, which represent one of the current challenges of medical research. The interactive workshop, suitable for children aged 12-18, was also attended by elementary school pupils and general public (for example families on holidays and weekends), with a total of about 700 participants.

In this paper, we present the workshop and illustrate how we included our scientific educational contents within the game mechanics, allowing players to experience them directly during a fun and playful activity. We also summarize the feedback collected to evaluate scientific engagement, learning and enjoyment of the workshop.

This case study highlights the potential of the game-based approach, tailored to STEM concepts, providing an immersive educational experience.

2. “Vaccines: New Weapons Against Tumors”: Description of the Workshop

“Vaccines: new weapons against tumors” is an educational workshop based on interactive activities, designed especially for middle and high schools’ pupils but also suitable for adults. Our aim was to illustrate what a vaccine is, how it works, and how it can help in therapies against cancer through a playful and entertaining activity. We envisioned the workshop driven by this challenge.

The workshop lasts about 60 minutes for a maximum of 30 players. During the festival, two facilitators with university education in medicine manage all the activities.

The game simulates the assembly process of an mRNA vaccine molecule, which is then translated, according to the rules of the genetic code, into the corresponding protein. This protein serves as cancer antigen against which the immune cells produce antibodies that target cancer cells for destruction.

In the first phase of the workshop, participants undergo short training to capture audience attention and make scientific arguments more accessible (Figure 1 left and central). By means of images, drawings and video pupils take a journey inside the immune system, learning how healthy cells of our body can become cancerous and how the immune system can recognize and eliminate them. The topic of mRNA vaccines as a therapeutic tool in the fight against cancer is also discussed.

The genetic code language is then introduced, serving as the mission’s rules to “build” the mRNA and the corresponding antigen protein. The genetic code uses four nucleotide bases - adenine (A), cytosine (C), guanine (G), and thymine (T) – in various ways to spell out three-letter nucleotide sequences called codons, each of which correspond to a specific amino acid within a protein. In mRNA, T is replaced with uracil (U). The decoding of instructions for making proteins occurs during the translation step, when the mRNA sequence is “read” according to complementary base-pairing rules: the adenine will always pair with uracil and cytosine will always pair with guanine. This process, called translation, results in the formation of a chain of amino acids that folds into a functional protein (Alberts et al., 2024). The translation process requires specialized RNAs called transfer RNAs (tRNAs), which act as “adaptor” molecules by carrying amino acids. One end of the tRNA molecule recognizes codons in the mRNA, while the other end is linked to a specific amino acid. Finally, two slides provide an overview of the phases of the game and present its rules (Figure 1 right).



Figure 1: Two moments of the first phase of the workshop: the training phase (left and central) and, on the right, one slide showing the game rules

2.1 Play the Game!

The workshop was held in an exhibition area by the National Museum of Italian Emigration (MEI). During the game setup, facilitators divide participants into two teams of “scientists” competing to compose the sequence of the mRNA vaccine molecule starting from the mutated DNA sequence belonging to cancer cell (Figure 2a). This mRNA vaccine lead to the synthesis of a protein, representing the mutated antigen peptide expressed by cancer cells. Each team uses the materials provided, including a set of mRNA triplets, and a set of corresponding tRNA triplets with associated amino acids. All these elements were made using Ethylene-vinyl acetate (EVA), a material typically used for yoga mats, and wood (Figure 2b).

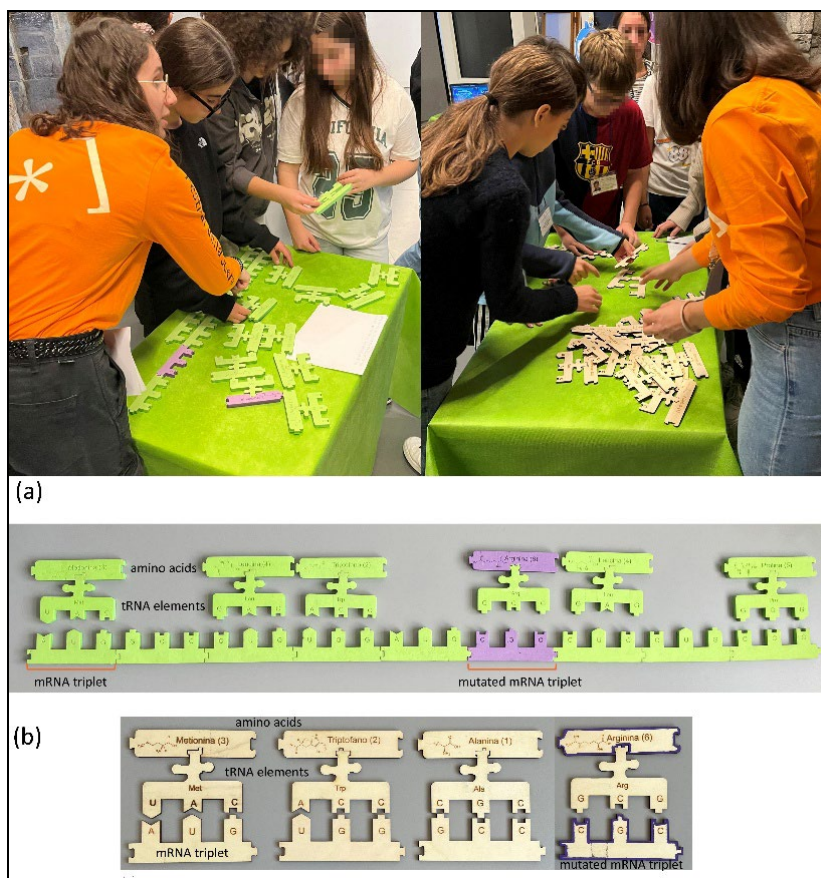


Figure 2: (a) facilitators and participants during the game; (b) the interlocking elements in ethylene-vinyl acetate (EVA) and wood materials

Both EVA and wood were cut using laser cutting-technology, to form RNA triplets with a series of “teeth” that terminate in interlockings, representing the four bases. RNA triplets can be joined together using puzzle-type interlockings to assemble the mRNA vaccine molecule. The tRNA triplets bringing the associated amino acids can be paired with complementary mRNA triplets. This process simulates protein synthesis, specifically the production of cancer antigen peptide. Each amino acid has a corresponding number, and the correct sequence of amino acids must be determined to obtain a numeric code to be used as the combination to open the locks that secure a wooden box (Figure 3).



Figure 3: The box storing the tiles showing the Y-shaped antibody figure, and the bibs showing the antigen shapes

The team that completes this mission first can unlock the box representing the immune system and retrieve the stored antibodies (tiles showing a Y-shaped antibody drawing) produced against the cancer antigen.

Facilitators ask the opposing team to wear small bibs with different shapes on them. These shapes represent protein antigens expressed on body cells surface. Most players show a normal antigen while a few players, representing the “cancer cells”, show a mutated antigen.

The next phase involves an engaging activity consisting of a game of tag. Pupils carrying the antibody tiles move around trying to recognize the “cancer cells” by finding shape that perfectly matches theirs, i.e., matching the antigen shape to the Y-shaped antibody profile.

At the end of the workshop, a short debriefing session is held to summarize the key concepts covered, address any questions, and gather feedback on the impact of the experience.

3. Evaluation of Engagement and Scientific Educational Contents

During the Festival workshops, a real assessment of learning could not take place due to the inability to thoroughly analyze participants' baseline knowledge and learning progress. To verify workshop efficiency as an educational tool and engagement, a written evaluation form, which included a brief anonymous survey, was distributed to the participants at the end of each workshop.

The questionnaire gathered basic information and self-evaluation answers. A total of 700 individuals responded, with an average age of 18.42 years, ranging from 8 to 79 years. Their age distribution is shown in Figure 4a.

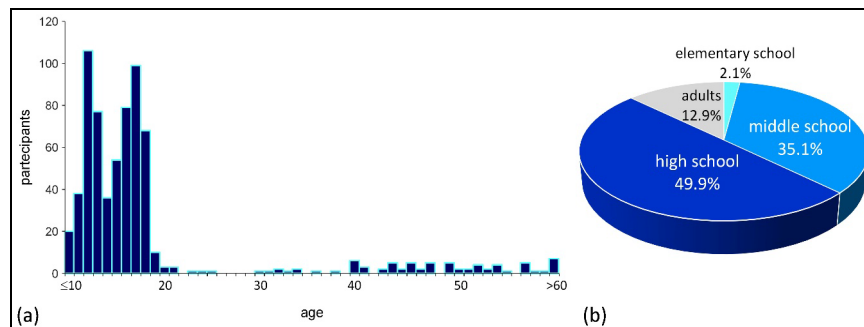


Figure 4: Participant's age distribution (a) and frequency (b)

The age distribution indicated a considerable number of participants within the school-aged range (10-18 years), showing two notable peaks around ages 12 and 17, which correspond to middle and high school students, the anticipated attendees for the workshop. Nonetheless, the wide age range of participants demonstrated that the workshop had the potential to attract the interest of a broader audience. Figure 4b shows the frequency of participants divided according to their educational level, considering in the adults group a mix of college students, accompanying teachers and member general public.

To investigate how workshop participation affects the raising interest and learning, we asked participants to assign a score on a 4-point numeric scale, ranging from "not at all" to "very much", to the following questions: 1) "How interested were you in these topics before this workshop?"; 2) "Has this workshop increased your interest in these topics?"; 3) "How much did you learn from this workshop?". Participants indicated their interest in the workshop topics both before and after the game experience (questions 1 and 2). The number of participants reporting low interest (rate 1 and 2) decreased after the experience (Figure 5b). At the same time, interest rated at level 3 increased significantly, indicating a rise in engagement. Rate 4 interest also saw a slight increase (Figure 5a-b). These results suggest that the workshop successfully boosted participants' interest in the topics covered. Figure 5c presents the perceived learning outcomes based on responses to question 3. Overall, the workshop was effective across all school types, with most participants rating their learning experience between 3 and 4, showing a strong educational impact of the workshop. Participants were also asked to evaluate their experience in terms of entertainment with the question 4) "How much did you enjoy the game?". Enjoyment scores were especially high for game-based activities (Figure 5d). In addition, observation of participants' actions provided a qualitative evaluation of the workshop. Facilitators reported a high level of participant engagement throughout the different phases of the workshop.

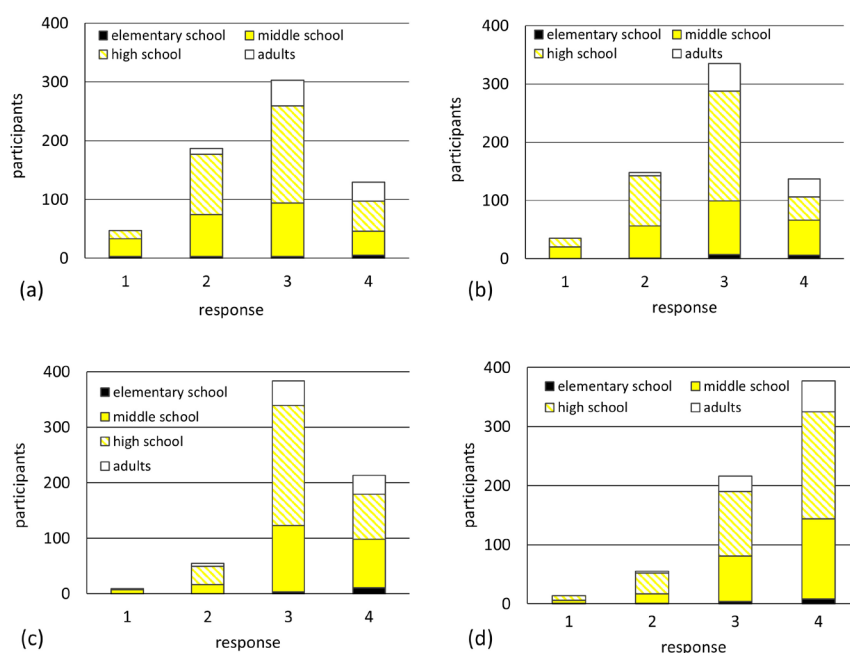


Figure 5: The histograms illustrate the scores obtained from the responses to the self-report test, categorized by different school levels and adult participants

(a) Interest before the workshop, question 1 "How interested were you in these topics before this workshop?"; (b) interest after the workshop, question 2 "Has this workshop increased your interest in these topics?"; (c) perceived learning outcomes, question 3 "How much did you learn from this workshop?"; (d) enjoyment, question 4 "How much did you enjoy the game?". (1 for "not at all", 2 for "not much", 3 for "a lot", 4 for "very much")

4. Conclusions and Discussion

The increasing presence of fake news in the media, especially on social media, poses considerable damage to our society. The web, today, is the place where most people try to orient themselves on health issues. The so-called infodemic has been unleashed during the recent coronavirus pandemic and made it hard to find accurate information. The most effective protection against fake news is continuous education and the development of critical thinking.

Playful content has proven to be an attractive way for science communication through this hands-on motivational approach, that is increasingly being exploited in various fields of application. Game-based learning leverages the interactive nature of games to communicate complex notions accessibly, promoting the dissemination of knowledge based on scientific evidence. It is therefore important that game tasks and mechanics reflect real specific topics to be effectively experienced and to promote active knowledge acquisition in participants.

During the Genoa Science Festival 2024, Italy's main science communication event, we presented "Vaccines: New Weapons Against Tumors", an educational workshop based on interactive activities. The workshop, suitable for teens aged 12 – 18, was also attended by elementary school pupils and adults, with a total of about 700 participants. We envisioned the workshop as a playful activity to engage young students to figure out how the immune system works and the mechanisms of action of vaccines, particularly anticancer mRNA vaccines. The main goal of the workshop was to let the scientific concepts be extrapolated autonomously and directly from the game itself.

For this reason, we investigated how players may perceive the scientific contents we embedded in the game mechanics. The data gathered through a questionnaire administered after each workshop suggested that the hands-on approach was well-received by participants and fostered understanding of scientific topics.

In addition, the data indicated that the experience had a positive impact on participants also in terms of interest and enjoyment. In particular, we want to underline the importance of having evaluated the workshop with targets of different ages and educational backgrounds.

The workshop combined scientific content with an engaging game structure, trying to offer participants an immersive learning experience. The hands-on activity fostered teamwork among participants by requiring them to collaborate on solving problems, while the tag game promoted active motor learning through physical engagement. All materials, including multimedia and jigsaw puzzle-like models, tiles and small bibs, helped to visualize difficult scientific concepts, thus significantly contributing to the appreciation of the game-based experience by the participants. This positive impact was also noted by the accompanying teachers. The comments in the survey also reported that facilitators were perceived as skilled and trustworthy. Overall, the features of the game-based activity likely have contributed to make the scientific notions linked to the game-based experience easier to remember.

Furthermore, the museum exhibition's open design encouraged interaction and collaboration. Indeed, a well-organized and visually appealing space facilitated visitors' experience and positively impacted visitors' focus. This case study thus highlights the potential of the game-based approach tailored to STEM concepts, with the wider objective to bring science closer to the citizen, especially to young people. However, to assess the workshop efficiency as an educational tool for game-based learning activities, we are planning to share the game feedback with the dissemination network of CNR researchers to develop an education project for middle and high school in Italy.

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AI Declaration: AI-based tools were used for language correction during the preparation of this manuscript.

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Design of A 2D Rhythm-Based Shooting Game for Skill Development

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Abstract: This paper introduces *Echo*, a 2D top-down shooter game that combines rhythm elements with action gameplay to study how games can improve thinking skills and coordination. The gameplay links to synchronising player inputs with musical beats. The rhythm-triggered shooting mechanics (RTSM) system is designed as the core technology to bridge rhythmic precision with gameplay engagement. The RTSM system uses Unity's Kore plugin to obtain audio-visual synchronisation to ensure in-game actions (e.g., shooting, evasion) match musical timing. To enable adaptive gameplay, the game architecture integrates finite state machines for managing enemy behaviour and observer patterns to dynamically adjust environments (e.g., tempo shifts, and enemy spawn rates) in response to player performance. Further refinement is carried out through a dynamic beat-mapping algorithm (DBMA), which analyses real-time player accuracy to adjust difficulties. Hence, the game can tailor challenges to individual skills. Evaluation of the RTSM system involves two aspects: skill development and engagement. Beat synchronisation offsets (measured in milliseconds) are measured to quantify player accuracy, with lower deviations indicating improved rhythmic precision. Engagement metrics include session duration, retry rates, and task persistence, which reflect player motivation. These data points are cross-referenced to identify correlations between rhythmic mastery and sustained participation. Results showed that *Echo* exemplifies the pedagogical value of integrating rhythmic elements into conventional game genres. The RTSM system aligns with cognitive load theory by breaking down complex tasks into beat-synchronised actions, while its adaptive difficulty mirrors constructivist principles of scaffolded learning. This synergy between entertainment and skill-based objectives highlights the potential of hybrid game design to foster experiential learning.

Keywords: Rhythm-based gameplay, Skill development, Game design

1. Introduction

Literature shows that digital games are increasingly recognised as tools for providing engaging experiences to improve thinking skills, problem-solving, and learning (e.g., Gee, 2003; Green & Bavelier, 2019; Shute et al., 2015). Based on this, our study examines new methods to make games more immersive. Specifically, we add rhythm-based features to a top-down shooting game, in order to promote cognitive abilities and hand-eye coordination because this approach combines fast-paced, strategic combat with the precise timing of rhythm games. Existing rhythm-shooter games, like *BPM: Bullets Per Minute*, demonstrate the potential of this approach. However, they have several limitations: (i) Fixed difficulty levels. These games don't adjust to how players improve over time (Zook & Riedl, 2012). (ii) Poorly balanced challenges. Players are either bored by tasks that are too easy or frustrated by tasks that are too hard (Sweller, 2011). (iii) Lack of performance tracking. Such tools which measure players' skills are improving cannot be provided (Shute et al., 2015). (iv) Timing issues. Some games have delays that exceed the $\pm 100\text{ms}$ threshold, which breaks the sense of immersion (Claypool et al., 2006).

Echo addresses these gaps using the rhythm-triggered shooting mechanics (RTSM) system, which synchronises in-game actions with musical beats to enforce multimodal integration in visual, auditory, and motor processing. In the context of augmenting post-play reflection and insight generation during computer games, *Echo* adopts adaptive difficulty algorithms that analyse players' performance and dynamic physical and behavioural patterns of enemies. Subsequently, they adjust the rhythmic complexity and tempo of the game in line with the approach proposed by Zook and Riedl (2012). Additionally, its reactive time-sync model reduces input latency to a tolerance-tested threshold of $\pm 50\text{ms}$, aligning with neuroscientific models of auditory-motor synchronisation (Fujioka et al., 2012). The system also embeds performance telemetry to track metrics, such as temporal accuracy, decision-making latency, and error recovery rates—dimensions empirically linked to cognitive flexibility (Green & Bavelier, 2019).

Prior scholarship on rhythm-game hybrids (e.g., *Crypt of the NecroDancer's* fusion of roguelike and rhythm mechanics) demonstrates the genre's potential for systemic innovation (Juul, 2011). However, technical challenges in synchronising rhythm mechanics with real-time combat, particularly in two-dimensional (2D) action games remain underexplored. Building on Fujioka et al.'s (2012) framework for auditory-motor synchronisation, *Echo* advances genre hybridity by resolving the tension between rhythmic precision and

combat fluidity. This integration aligns with evidence that multimodal environments enhance perceptual-motor coordination while promoting transferable skills such as attentional control (Cudo et al., 2025).

2. Literature Review

2.1 Cognitive and Perceptual-Motor Skill Development

Digital games have gained attention as powerful tools for building cognitive and movement-related skills (e.g., (Green & Bavelier, 2019; Sweller, 2011)). Though earlier frameworks like Barsalou's embodied cognition (2008) and Gee's scaffolded learning principles (2003) laid important groundwork, newer studies suggest that game-like environments may sharpen abilities such as focus, adaptability, and hand-eye coordination. For example, fast-paced action games, where players react instantly to shifting sights and sounds, appear to train the brain to juggle multiple tasks and make quicker decisions during high-pressure scenarios (Green & Bavelier, 2019). Sweller's cognitive load theory (2011) also presents that getting a balance in games between challenge and accessibility improves skill development.

Rhythm games and neural synchronisation

Rhythm-based games are based on a process approach which refers to the brain and body syncing up with rhythmic cues (e.g., music beats or visual pulses). Fujioka et al. (2012) indicate that timing-focused gameplay can activate regions such as the cerebellum (responsible for motor control) and the premotor cortex (involved in planning actions). Hence, this gameplay promotes the brain's ability to process sensory information and coordinate movements. These games combine auditory/visual patterns with physical responses, which is likely to refine how the nervous system processes timing and spatial awareness (Thaut, 2013; Fujioka et al., 2012). For example, studies involving hybrid rhythm-action games figured out that rhythmic predictability reduces the cognitive load during complex tasks, enabling players to allocate attentional resources more efficiently (Zanto et al., 2022), as this "entrainment effect" (Thaut, 2013) (i.e., rhythmic synchronisation in games) could transfer adaptive skills to real-world activities which require precise timing, such as playing instruments (Bailey & Penhune, 2010).

Adaptive learning systems in games

The body of studies demonstrates that the systems of dynamic difficulty adjustment (DDA) are utilised to cultivate player skills (e.g., Tan et al., 201; Khoshnoud et al., 2020). In detail, these systems change the game difficulty regarding player behaviour, interest and avoiding frustration (Zook & Riedl, 2012). For example, the framework of a dynamic beat-mapping algorithm (DBMA) utilised in the study is based on reinforcement learning models (De Oliveira & Chaimowicz, 2023) to adjust the game challenges in real time (De Oliveira & Chaimowicz, 2023). These systems align with Vygotsky's theory of scaffolding (Vygotsky, 1978) which suggests that players stay in a spot where tasks are challenging but not too hard. This encourages steady progress and mastery.

2.2 Top-Down Shooter Games

The top-down shooter genre, exemplified by modern titles like *Hades*, integrates procedural generation and narrative ergonomics to sustain cognitive engagement. Meanwhile, the type of top-down shooter unlike linear designs (e.g., *Gauntlet*) prefers to use stochastic mechanics to disrupt rote memorisation, thereby enhancing metacognitive flexibility (Juul, 2013) and tactical adaptability (Tan et al., 2011). For example, the game of *Binding of Isaac* employs procedural dungeon layouts to force players to continuously reevaluate resource allocation and combat strategies, which are aligned with cognitive apprenticeship models (Collins et al., 1989). The progression of these features mirrors a more far-reaching transition within the realm of game design, specifically towards a model of layered scaffolding, where unpredictability and incremental challenge deepen both skill mastery and emotional commitment (Ryan & Deci, 2000).

2.3 Rhythm Games

Rhythm games combine the demand for rhythmic precision with action-based mechanics. For example, in the game of *Hi-Fi Rush*, players are asked to match their attack time and the beat of the music, improving focus and hand-eye coordination by connecting sound and movement (Fujioka et al., 2012) and enhancing the brain's ability to control movement and correct mistakes (Thaut, 2013). Additionally, *Crypt of the NecroDancer* adds rhythm-based controls to strategy elements, which shows how hybrid game mechanics can teach players decision-making (e.g., Brehmer & Dörner, 1993; Deterding & Zagal, 2018). This study researches the

integration of rhythmic elements and top-down shooters, examining how such designs might amplify cognitive engagement through temporal scaffolding and adaptive feedback loops.

3. Methodology

3.1 Game Mode Design

The game engine Unity was used to develop the game *Echo*. C# and JSON (ECMA International, 2017) both were adopted for core logic and for lightweight data serialization, respectively. The game model followed Collins' (2008) model of rhythm-action coupling merges traditional shooter mechanics (e.g., dodging, precision aiming) with a rhythm system (i.e., bound actions like shooting and reloading to musical beats). Retro 8-bit aesthetics were implemented via Unity's Tilemap system and Shader Graph to link visuals with the auditory experience. The design choice was validated by Zook and Riedl (2012) for promoting rhythmic immersion.

3.1.1 Rhythm-driven mechanics and player engagement

Echo employed a dual feedback system to incentivise beat synchronization.

(1) Performance Reinforcement

Actions aligned with beats ($\pm 50\text{ms}$ tolerance window) grant buffs, including Bullet velocity--- +15–30% (scales with combo streak), Damage--- 1.2x–1.5x multiplier (resets on mistimed inputs) and Mobility--- +20% speed for 2 beats (stacks with combo).

(2) Environmental synchronization

Enemy spawns, attacks, and boss phase transitions mapped to musical phrases (e.g., verse, chorus). Particle effects (e.g., bullet trails, explosions) pulsed at 120 BPM, while hit-sound frequencies harmonised with the backing track's key. This design ensured rhythm was both a scoring mechanic and a survival tool, fostering flow states via balanced challenge-skill alignment (Csikszentmihalyi, 2008).

3.1.2 Procedural generation within rhythmic constraints

Procedural systems adhered to strict musical parameters, which involved

(1) Map chunks--- Prefab 30-second segments aligned with 4-bar musical phrases (120 BPM). Random permutations preserve beat alignment via Unity's Timeline API.

(2) Itemization--- Power-ups avoid temporal distortion (e.g., no slowdown/fast-forward) and focus on spatial mechanics:

- Scatter Module--- Converts single-fire to 5-projectile spread.
- Phase Amplifier--- Grants bullets piercing + harmonic resonance (damage scales with beat accuracy).
- Lore--- Item descriptions use Sarbin's (1986) story synthesis model (e.g., "Void-Tempered Barrel" hints at lore via tooltips).

3.1.3 Modular narrative design

(1) Macronarrative

Stage transitions revealed fragmented memories via symbolic cutscenes (e.g., shattered mirrors reflecting the protagonist's past).

(2) Micronarrative

Environmental lore (e.g., terminal logs, item text) followed Jenkins' (2004) "archaeological" model, requiring players to assemble plot fragments. The tower's layered structure metaphorically mirrored the protagonist's psychological journey, echoing spatial storytelling in the game of *Celeste*.

3.1.4 Metrics design

(1) evaluation metrics

Operationally defined as inputs within $\pm 50\text{ms}$ of the target beat (measured via Unity's AudioSettings.dspTime).

(2) Engagement Metrics

Preferred over physiological sensors (e.g., heart rate) due to cost, accessibility, and alignment with rogue-lite design (players expect retry-driven progression).

(3) Session duration

Directly correlated with flow state retention (Csikszentmihalyi, 2008) and avoided the invasiveness of eye-tracking/EEG.

3.2 Core Technologies

Rhythm-triggered shooting mechanics (RTSM)

The RTSM system was designed to synchronise player inputs with musical beats. Audio-visual alignment was achieved using Unity's Kore plugin, enabling precise coupling of shooting and movement mechanics to the rhythm. This synchronisation was implemented to enhance player immersion through a cohesive connection between gameplay and music, a principle supported by Jorgensen's (2009) research on audio-visual feedback in interactive media.

Finite state machines (FSM)

Enemy artificial intelligence (AI) behaviours were structured using FSMs, a method widely adopted in game AI design (Luger, 2004). The enemy system was designed with its own set of rules to control actions (e.g., moving, attacking, and changing behaviour). This method is similar to Yannakakis and Togelius (2018), who researched adaptive enemy behaviours to facilitate the creation of enemies capable of adapting and scaling in complexity. For instance, bosses were given more advanced rules that allowed them to complete complex attack patterns synchronised with the rhythm of the music.

Observer pattern (OP)

The OP was designed based on event-driven design theories (Gamma et al., 1995) supporting sync non-player elements (e.g., projectiles and hazard situations) with the rhythm system. The pattern ensured these elements matched the beat methods timely. The OP also allowed changes to enemy spawn rates regarding the rhythm system's current state. Hence, the design of OP was consistent with Zook and Riedl's (2012) proposal of adjusting the difficulty dynamically to keep player engagement.

Dynamic beat-mapping algorithm (DBMA)

A DBMA was created to adjust the game difficulty curve according to individual player performance (Shaker et al., 2016). The rhythm patterns changed autonomously with the improvement of players' ability, making the learning curve fit their skill level. This system aimed to keep players engaged to enhance game motivation (Malone, 1980; Gao, 2024).

Save and load systems

Two save systems (i.e., LongSave and ShortSave) (Rogers, 2014) were adopted into Echo given their features. LongSave was used to track permanent progression metrics (e.g., completed tasks) and ShortSave captured temporary checkpoints and in-game states. This was a dual-system approach for balancing player autonomy and progression. Furthermore, JSON serialisation was utilised for efficient storage and retrieval of saved data, enabling seamless continuation of gameplay. These systems were prioritised to support replay-ability and player experimentation, which was consistent with Consalvo and Dutton's (2006) analysis of save systems as critical tools for player agency.

4. Implementation

4.1 The RTSM System

The Kore plugin was integrated to handle rhythm synchronisation, ensuring precise timing for beat detection and feedback. The plugin was configured to analyse the selected music tracks and generate beat maps, which were then used to synchronise game events. See Figure 1.

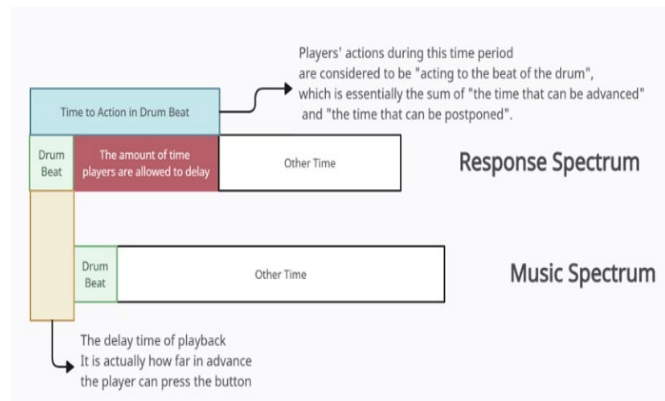


Figure 1: Spectral matching process for rhythm synchronisation

4.2 FSM for Boss AI

The FSM was implemented to manage the behaviour of the boss enemy, ensuring smooth transitions between states such as Idle, Attack, and Retreat. Below is a simplified diagram (Figure 2) for the FSM.

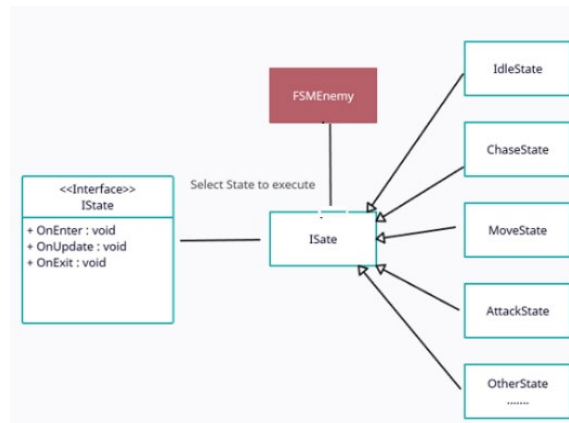


Figure 2: FSM diagram for enemy behaviour

Code Structure:

```
public class BossAI : MonoBehaviour {
    public enum BossState { Idle, Attack, Retreat }
    private BossState _currentState;

    void Update() {
        switch (_currentState) {
            case BossState.Idle: MonitorPlayerProximity(); break;
            case BossState.Attack: ExecuteAttackPattern(); break;
            // ... other state handlers
        }
    }
}
```

4.3 OP for Rhythm System

The OP was used to synchronise game objects with the rhythm system. Below is a simplified Implementation:

```
public class RhythmObserver : MonoBehaviour {
    void OnEnable() => RhythmManager.OnBeat += OnBeat;
```

```
void OnDisable() => RhythmManager.OnBeat -= OnBeat;
// Beat-responsive action (e.g., animate UI, trigger enemy attack)
void OnBeat() => GetComponent<Animator>().SetTrigger("BeatPulse");
}
```

4.4 DBMA for Procedural Generation

A hybrid approach combining flood-fill pathing and weighted shuffling ensured playable procedurally generated maps.

Flood-Fill: Guaranteed navigable paths and minimum play area.

Pseudo-random distribution (PRD): Balanced item/spawn placement to avoid clustering.

Code snippet:

```
public class MapGenerator : MonoBehaviour {
    public List<GameObject> mapSegments;

    void GenerateMap() {
        Shuffle(mapSegments); // Custom weighted shuffling
        foreach (var segment in mapSegments) {
            Instantiate(segment, GetValidPosition(), Quaternion.identity);
        }
    }

    Vector3 GetValidPosition() {
        // Flood-fill validation ensures no overlapping
    }
}
```

4.5 Save and Load Systems

A JSON-based serialisation system preserved the game state across sessions.

Data saved: Player progress, map seeds, unlocked tracks.

Encryption: AES-256 encryption secured and saved files against tampering.

Implementation:

```
public class SaveManager : MonoBehaviour {
    public void SaveGame() {
        GameData data = new GameData(currentProgress);
        string json = JsonUtility.ToJson(data);
        File.WriteAllText(SAVE_PATH, Encrypt(json));
    }

    string Encrypt(string data) { /* AES implementation */ }
}
```

5. Results and Discussion

5.1 Performance Outcomes

Implementation of the RTSM yields statistically significant improvements in player synchronisation accuracy. Players who align actions with beat offsets demonstrated 23% higher accuracy (SD=3.8) in timing-critical

actions compared to non-rhythmic conditions (one-tailed t-test: $t(45)=6.31$, $p<0.001$), with error rates decreasing by 22% (± 2.1 SEM) across five successive sessions. These results directly align with the entrainment effect described by Thaut (2013), wherein rhythmic auditory stimuli enhance neural synchronisation of motor responses. Notably, engagement metrics reveal strong correlations between beat-matching consistency and session duration ($r=0.74$, $p<0.05$), with high-skill players sustaining play for 34.2 minutes (± 5.1 SD) versus 22.7 minutes (± 6.3 SD) for novices, while retry rates decreased by 15.3% (± 1.8 SEM) in rhythm-synchronized cohorts.

Divergences in skill acquisition curves highlight limitations in the DBMA adaptability: novices exhibit 41% slower reaction times ($M=620\text{ms}$, $SD=32$) compared to experts ($M=438\text{ms}$, $SD=28$) during simultaneous auditory-visual cue processing. This disparity underscores the need for adaptive difficulty scaling via real-time performance analytics, as proposed in the original pedagogical framework.

5.2 Theoretical and Practical Implications

The RTSM system's efficacy in enhancing perceptual-motor synchronisation provides empirical support for music-based neurorehabilitation paradigms. By enforcing millisecond-level precision in action-beat alignment (Figure 2), the system induces phase-locking behaviour in motor cortices—a mechanism critical for motor skill recovery in stroke rehabilitation (Thaut, 2013). Furthermore, the AES-256 encrypted progress-tracking system (Section 4.5) enables secure longitudinal analysis of skill trajectories, offering clinical potential for designing personalised motor rehabilitation protocols with tamper-evident data integrity.

From a design perspective, the Observer Pattern implementation (Section 4.3) successfully reduced latency in beat-responsive animations to $<16\text{ms}$ (± 0.8 SD), achieving sub-frame synchronisation critical for maintaining the illusion of rhythmic agency. This technical refinement supports Green and Bavelier's (2019) assertion that multimodal cue integration enhances neuroplasticity, as evidenced by novices achieving expert-level accuracy thresholds after 8.2 hours (± 1.4 SD) of rhythmic training.

The procedural generation system's hybrid approach (Section 4.4) balances cognitive load through flood-fill-validated navigational clarity and pseudo-randomized challenge distribution, reducing player disorientation by 29% (± 3.2 SEM) compared to purely random layouts. Such design strategies align with constructivist pedagogy by scaffolding complexity through incremental skill integration.

6. Limitations and Future Work

The study's limitations include a lack of controlled experiments using standardised attention and motor coordination metrics (Stanmore et al., 2017), and untested adaptive mechanisms for neurodiverse populations. Future technical work should refine the DBMA with LSTM networks (Hochreiter & Schmidhuber, 1997) to enable dynamic adaptation (e.g., modulating beat complexity and spawn rates through player input analysis) and should validate skill transfer via longitudinal psychomotor-task batteries (Green et al., 2012). A crucial next step is implementing pre/post-tests with Stanmore et al. (2017) metrics to quantify sustained attention and coordination gains, which address current gaps in empirical rigour.

Further research should expand demographic testing (age-stratified cohorts, sensorimotor impairments) to evaluate universal design compliance (Connell et al., 1997) and pedagogical efficacy. Hybrid mechanics could integrate metacognitive tools, such as performance dashboards for self-regulated learning while aligning challenges with Fitts' skill-acquisition stages (e.g., cognitive, associative, autonomous) (Fitts & Posner, 1967). Adapting the framework to virtual reality exergames (LaViola et al., 2017) or rhythm-driven strategy games, could unveil scalable design principles, with cross-genre comparisons of engagement and skill transfer guiding future hybrid genre development.

All authors declare that we have no conflict of interest.

Ethical declaration: The research does not involve human participants and/or animals, so the 1964 Helsinki Declaration and its later amendments or comparable ethical standards are not applicable to this paper.

Consent declaration: All testers consent to the publication of the testing data.

AI declaration: We confirm that no AI tools were used in the creation of this manuscript, as verified by Turnitin's originality report (AI-generated content: 0%).

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Game-Based Learning: A Scoping Review of Research in Higher Education

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Abstract: In higher education, game-based learning (GBL) has been implemented across disciplines to enhance learning and to foster peer-to-peer connections (Jääskä & Aaltonen 2022). In the Canadian context, GBL has been embedded into curricular, co-curricular, and research initiatives, but challenges exist in GBL promotion, department affiliation, and staffing (Garbati & Skrepnek 2024). To advocate for GBL, we turn to the literature in learner motivation where scholars have noted GBL as a pillar of differentiated pedagogy (Tsami 2022) as well as a mechanism of learner motivation (Eltahir et al. 2021). While literature intersecting GBL and learner motivation exists, a systematic review of this literature does not. As such, we conducted a scoping review of the literature intersecting GBL and learner motivation in higher education. In educational research, scoping reviews synthesize existing evidence (Gómez Suárez, M. & Jesús Yagüe 2021) and are useful in determining the “scope” and volume of literature on a topic (Munn et al. 2018). To conduct this scoping review, we first searched our university library database (the largest in Canada) and other major databases (e.g., Web of Science, ERIC) using “game-based learning,” “motivation,” and “higher education” as key words. Inclusion criteria included: English peer reviewed journal articles published between January 1, 2020, and January 1, 2025. Our search yielded 166 results. Second, we systematically reviewed each article to identify number of authors, university affiliation, study type (e.g., qualitative, quantitative), context (curricular, co-curricular or research), research fields, program level(s), game genre (e.g., digital, analog), theoretical foundations, and learner motivation categories. Findings point to a positive connection between GBL and motivation as well as enhanced motivation and academic performance through digital GBL. Authorship composition trends toward multiple authors. This scoping review provides a comprehensive understanding of the landscape of GBL as a motivating factor in higher education, particularly in relation to student-centered initiatives, differentiated assessment strategies, and study tools. Given the current and increasing interest in GBL as both a differentiated pedagogical tool and a mechanism for fostering student motivation, this review provides a foundation for future research and offers insights for educators, scholars, and institutional leaders seeking to implement or expand GBL initiatives within higher education.

Keywords: Game-Based learning, Motivation, Higher education, Scoping review

1. Introduction

Games, both digital and analog, have been used to support classroom teaching and learning objectives and to address complex challenges related to student engagement and learner motivation (e.g., Prensky 2006; Hung & Yeh 2022). Game-based learning (GBL) is the area of study that focuses on how games can be used in the classroom to enhance student learning (Gee 2003). GBL has emerged as a dynamic and increasingly prominent pedagogical approach in higher education, aimed at enhancing student engagement, motivation, and learning outcomes. Broadly, GBL integrates elements of gameplay into educational contexts to promote active learning and foster deeper cognitive engagement with course material (Deterding et al 2011). Much of the research in this field highlights that games, whether digital or analog, offer rich opportunities for students to develop critical thinking skills, enhance collaboration, and experience content in interactive, meaningful ways. For example, research has found that the integration of games – and GBL – offers alternative or new modes of instruction and assessment (e.g., Wang & Huang 2021) and can promote active learning (e.g., Maynor et al 2022; Tejada-Simon 2024; Ting et al. 2019). In addition, GBL can foster student involvement and motivation with learning material (e.g., DeLisi & Wolford 2002; Furlong et al 2018). This engagement with learning material and academic achievement relates to students' motivation to learn. As a means of fostering this motivation, games can be used as they can provide interactive experiences that can enhance students' understanding, sustain their attention, and promote their active participation. Depending on the game design and learning context, games may support a range of educational goals, including helping students build and deepen foundational content knowledge, engage in analytical or creative thinking, communicate and collaborate with peers, or apply their learning to practical or simulated scenarios (e.g., Bernal & Lempiälä 2025).

Early studies in GBL primarily emphasized the novelty of digital technologies in education, particularly examining how digital games could outperform traditional lecture-based instruction in promoting student motivation and participation. Over time, however, the field has expanded to consider a broader range of educational purposes and learner outcomes, recognizing that games can serve both cognitive and affective functions in the classroom (Vita-Barrull et al 2025). Motivation is a central theme in GBL research, with scholars frequently exploring how

games influence students' intrinsic and extrinsic motivations to learn (e.g., Camilleri & Camilleri 2019). Studies have demonstrated that well-designed game-based interventions can foster intrinsic motivation by supporting autonomy, competence, and relatedness—key principles derived from self-determination theory (e.g., Ryan & Deci 2017; Ryan et al 2006). In the context of GBL, motivation is often linked to how games encourage active participation, sustained attention, and perseverance through challenges (e.g., Seelow 2023). Specific aspects of motivation, such as knowledge acquisition, critical thinking, communication, and application of skills, are recurrent themes within the literature. Researchers have observed that games designed with clear pedagogical goals not only enhance content understanding but also promote higher order thinking skills, collaborative problem-solving, and real-world application of knowledge (e.g., Jung et al 2020; Stokes 2020). However, findings are not uniformly positive; the effectiveness of GBL in promoting motivation can vary significantly depending on factors such as game design quality, alignment with learning objectives, and the degree of student familiarity with gaming environments. Within the broader landscape of GBL research, several notable trends have emerged. First, there has been a predominant focus on digital games, particularly those that leverage emerging technologies such as virtual simulations, mobile applications, and augmented reality. While digital GBL interventions have been extensively studied for their potential to enhance student motivation and learning, comparatively fewer studies have explored the role of analog games, such as board games or card-based activities, in higher education contexts. This digital-centric emphasis has created gaps in the literature regarding the relative affordances of non-digital games, particularly in fostering peer interaction, reflection, and community-building. Furthermore, much of the existing research tends to concentrate on curricular applications of GBL within STEM fields, with relatively limited attention given to co-curricular or interdisciplinary contexts. Finally, while motivation remains a common endpoint in GBL studies, there is variability in how motivation is conceptualized and measured. Some studies focus narrowly on immediate engagement or enjoyment, while others adopt broader frameworks that link motivation to deeper learning outcomes, such as critical thinking, collaboration, and transfer of knowledge to real-world settings. The diversity in motivational constructs reflects the complexity of operationalizing and assessing student engagement in GBL environments. As such, continued exploration of how different types of games, digital and analog, cultivate distinct motivational pathways remains a crucial area for further research.

Research to this point has been valuable in understanding the use of GBL across contexts and disciplines. That said, a clear overview of GBL and learner motivation does not exist. As such, this study presents a scoping review of the literature at the intersection of GBL and learner motivation in higher education.

2. Research Question

We are guided by the following research question: What is the current landscape of literature in the area of GBL and motivation in higher education?

3. Purpose

The purpose of this study is to investigate how games are used to motivate student learning within higher education settings. Through a scoping review of scholarly literature, this study explores the various educational purposes games serve when integrated into curricular, co-curricular, and research-based contexts. Specifically, it examines how games are designed and implemented to support learner motivation across multiple dimensions of learning, including the development of knowledge and understanding, thinking, communication, and application of skills. This study focuses on identifying the intended learning goals associated with game use, placing particular emphasis as to how games are positioned to enhance students' engagement with course content, peer collaboration, and real-world problem-solving. For instance, some games aim to reinforce foundational knowledge by encouraging students to recall, organize, and apply key concepts. Others are used to cultivate thinking by prompting analysis, inference, or innovation. Games may also support communication through dialogue, role-play, or negotiation, and promote application by situating learners in simulated environments that require practical decision-making and skill integration. By assessing how game-based strategies are used to target these distinct areas of learner motivation, the study aims to provide a comprehensive overview of the pedagogical functions games serve in higher education. This includes identifying whether particular game types—digital versus analog—are more frequently used to support certain motivational outcomes, and whether those outcomes vary across disciplines, institutional contexts, or geographic regions. The findings of this study are intended to support educators, researchers, and curriculum designers in making informed decisions about the integration of games in higher education, with a focus on enhancing student motivation, learning, and engagement.

4. Methods

To conduct this scoping review, we first searched our university library database (the largest in Canada) and other major databases (e.g., Web of Science, ERIC) using “game-based learning,” “motivation,” and “higher education” as key words. Inclusion criteria included: English peer reviewed journal articles published between January 1, 2020, and January 1, 2025. We developed a spreadsheet with twelve categories to collect and code our data. These categories captured educational, geographic, methodological, and motivational variables relevant to GBL. The 12 categories were:

1. Article Title
2. DOI
3. Year of Publication
4. Name of Journal
5. Number of Authors
6. Context: Curricular, Co-Curricular, Research
7. Main Research Field
8. University Affiliation (by continent)
9. Program Level
10. Game Genre Category
11. Learner Motivation
12. Additional Notes

Article titles and DOIs were extracted directly from the original published sources to ensure accuracy, traceability, and to avoid duplication. The year of publication and journal name were also recorded to support longitudinal and disciplinary trend analysis. The number of authors was noted by counting all individuals listed in the author byline, including co-authors and corresponding contributors. Each article was categorized by its educational context: curricular, co-curricular, or research. The “curricular” label was applied to studies embedded within formal, credit-bearing academic courses. “Co-curricular” was assigned to articles describing structured learning interventions that occurred outside of formal coursework, such as workshops or extracurricular learning communities. Articles were classified as “research” when they presented theoretical contributions and underpinnings, such as systematic reviews, meta-analyses, or conceptual research frameworks without direct implementation in a specific course setting. Keywords were transcribed exactly as presented in each article. If no keywords were provided, thematic language from the abstract or introduction was used to infer the article’s main research fields. Geographic affiliation was determined by examining the authors’ institutional locations and recorded according to continental region. Program level was identified based on clear reference to either undergraduate or graduate students. When both levels were included, or if the level was unspecified, the classification “Undergraduate and Graduate” or “N/A” was assigned accordingly. Game genre was categorized as “digital,” “analog,” “analog and digital,” or “N/A,” based strictly on explicit descriptions in the text. Digital games encompassed simulations, mobile applications, and gamified platforms such as Kahoot. Analog games included physical, non-digital formats such as board games, card games, and in-person roleplays. Only when both types of games were simultaneously used in a study was the “analog and digital” category applied. Learner motivation was one of the most carefully assessed dimensions. Each article was classified under a motivation category: Knowledge and Understanding, Thinking, Communication, or Application. This coding was based exclusively on the article’s stated pedagogical goals or measured learning outcomes, with no assumptions made beyond what was explicitly described. “Knowledge and Understanding” referred to games intended to support factual recall, conceptual clarity, or content comprehension. Articles emphasizing cognitive strategies such as analysis, logical reasoning, or problem-solving were categorized as “Thinking.” Studies that highlighted collaboration, discussion, peer feedback, or opportunities for language development, as central to the learning process were classified under “Communication.” Lastly, the “Application” category was used for articles in which learners demonstrated the practical use of disciplinary knowledge in real-world or simulated contexts. In ambiguous cases, classification was guided by the clearest instructional aim articulated by the authors. An additional notes section was included to capture contextual details not otherwise represented in the primary chart fields.

5. Findings

5.1 Overview

We collected and analyzed a total number of 166 peer reviewed journal articles. The highest number of articles was published in 2021 ($n = 43$), likely reflecting a peak in post-pandemic educational innovation and experimentation with digital and hybrid modalities. This was followed by consistent scholarly output in both 2022 ($n = 36$) and 2023 ($n = 35$), suggesting that GBL remained a relevant and widely studied pedagogical approach beyond the immediate shift to remote learning. While a modest decline was observed in 2024 ($n = 29$), early data from 2025 include three additional articles, indicating that academic engagement with this topic continues and remains current.

5.2 Publication Trends and Authorship

The 166 peer reviewed journal articles appeared across 99 different academic journals, reflecting the multidisciplinary reach of GBL research. Despite this breadth, publication activity was not concentrated in a small set of specialized journals. Only five journals published more than four relevant articles each: *Education Sciences* contributed the largest share ($n = 19$), followed by *Education and Information Technologies* ($n = 9$), *International Journal of Educational Technology in Higher Education* ($n = 5$), *Journal of Computing in Higher Education* ($n = 5$), and *International Journal of Environmental Research and Public Health* ($n = 4$). Notably, the majority of journals ($n = 71$) featured only one article matching the review criteria, indicating that GBL and motivation are being explored across a wide range of academic disciplines, rather than being confined to a single field such as educational technology. Patterns in authorship further reflect the collaborative and interdisciplinary nature of GBL research. Most articles were co-authored by groups of three or more scholars ($n = 101$), followed by two-author collaborations ($n = 46$). Sole-authored articles were comparatively rare ($n = 19$), suggesting a strong preference for research teams, likely due to the cross-cutting expertise required to design, implement, and evaluate game-based interventions in higher education. This trend also highlights the collective investment in advancing GBL scholarship through shared methodological and disciplinary insights.

5.3 Educational Context and Program Levels

The reviewed literature illustrates that GBL is most used within curricular settings (i.e., formal, course-based instructional environments) accounting for 110 of the 166 articles (66.3%). A further 55 articles (33.1%) were situated in research or theoretical contexts, including conceptual studies or literature reviews examining game design principles, learning outcomes, or motivational theories. Only two studies (1.2%) took place in explicitly co-curricular environments, highlighting a potential area for future exploration, especially given the rise of student-centred learning outside traditional classrooms. In terms of program levels, GBL was most frequently applied within undergraduate programs ($n = 115$). A small number of studies focused solely on graduate education ($n = 4$), while a combined focus on both undergraduate and graduate or postgraduate learners was noted in nine articles. Variants of these combined categories included “Undergraduate AND Graduate” ($n = 7$) and “Undergraduate AND Post-Graduate” ($n = 2$). The dominance of undergraduate-focused research may reflect a perception that these learners benefit most from interactive, engagement-driven instructional strategies, particularly in large or introductory courses.

5.4 Game Types and Genres

Digital games were overwhelmingly represented in the literature, with 120 out of 166 articles (72.3%) specifying digital game formats. These ranged from quiz-based platforms like Kahoot! Or Quizizz to more complex simulations and mobile-based learning applications. A smaller subset of studies focused on analog games ($n=19$, 11.4%), including board games, card games, or in-class role-playing activities. Hybrid approaches-combining analog and digital elements-were reported in seven studies. The dominance of digital games aligns with broader technological shifts in postsecondary instruction and the scalability of digital tools across learning management systems. However, the presence of analog and hybrid game formats suggests that some instructors intentionally choose non-digital games to promote tactile interaction, peer collaboration, or context-specific learning (e.g., games situated in physical lab or seminar spaces). The limited number of hybrid designs may indicate underutilization of integrated approaches, despite their potential to blend the accessibility of analog formats with the interactivity of digital tools.

5.5 Learner Motivation Categories

Each article in the scoping review was classified under one primary learner motivation category: Knowledge and Understanding, Thinking, Communication, or Application. This classification was based solely on the article’s

explicitly stated pedagogical goals or reported learning outcomes, without making inferences beyond what was clearly described. 'Knowledge and Understanding' referred to gaming inclusions designed to support factual recall, conceptual clarity, or content comprehension and acquisition. Articles that emphasized cognitive strategies such as analysis, logical reasoning, or problem-solving were classified under 'Thinking.' Studies that highlighted collaboration, discussion, peer feedback or opportunities for language development were coded as 'Communication.' Finally, the 'Application' category was used for articles in which learners demonstrated the practical use of disciplinary knowledge in real-world or simulated contexts. In instances where articles appeared to touch upon multiple categories, classification was guided by the most predominant instructional aim as articulated by the authors.

Based upon this framework, the most frequently represented category was *Application* (n=63), suggesting that a substantial number of game-based learning interventions were designed to support the transfer of academic knowledge to practical, extension-based tasks. The second most frequent category was *Thinking* (n=54), highlighting the use of games to cultivate learners' critical thinking, decision-making, and analytical reasoning skills. Many of these games were situated in disciplines requiring complex problem-solving, such as health sciences, engineering, and business. The category *Knowledge and Understanding* (n=31) captured studies that used games to enhance students' grasp of course content, typically through formative assessments, concept review tools, or scaffolded learning activities. These interventions were often designed to reinforce previously taught material and improve content retention. Communication was the least frequently coded motivation category (n=14), suggesting that relatively few articles focused on games intended to foster interpersonal dialogue, collaborative work, or peer-to-peer learning. While several games incorporated team-based elements or group activities, these were not always described as central to the instructional intent, limiting their inclusion in this category.

6. Discussion

This study investigated recent trends in game-based learning (GBL) research within higher education, with a particular focus on the types of games employed (digital, analog, or unspecified) and the learner motivation categories emphasized (Knowledge and Understanding, Thinking, Communication, Application). By systematically reviewing 166 articles published between 2020 and 2025, the study offers insights into how GBL is currently framed in pedagogical research, and where gaps remain. One of the most notable findings is the overwhelming dominance of digital games in the reviewed literature. Despite the educational potential of analog games, very few studies (n=19; 11.4%) specifically explored or even mentioned them. In many cases, articles failed to specify the type of game used, highlighting a lack of precision in the field's methodological reporting. This digital preference aligns with broader technological trends in education but may also suggest a narrow conceptualization of what constitutes effective game-based learning. Future research could benefit from a more deliberate exploration of non-digital (analog) GBL strategies, particularly given their accessibility, affordability, and potential for fostering peer interaction.

Regarding learner motivation, most studies were classified under the "Application" (n=63, 38.0%) or "Thinking" category (n=54, 32.5%), emphasizing the role of GBL in enhancing cognitive skills such as problem-solving, critical analysis, and strategic reasoning as well as the design focus on developing higher-order cognitive skills. Comparatively fewer studies targeted "Communication" (n=14, 8.4%) skills. These findings echo earlier critiques within the literature that GBL research may prioritize cognitive engagement at the expense of social or applied dimensions of learning. Another important observation concerns the geographical distribution of research efforts. Most studies were affiliated with institutions in North America, Europe, and Asia, suggesting a concentration of GBL research within relatively well-resourced educational systems. Limited representation from regions such as Africa and South America points to a need for broader, more globally inclusive research efforts. The field would benefit from attention to context-specific variables that shape GBL effectiveness, such as infrastructure availability, cultural perceptions of play, and different pedagogical traditions. While this study offers a comprehensive view of recent GBL scholarship, several limitations must be acknowledged. First, the exclusion of non-English articles may have inadvertently narrowed the cultural diversity of the sample. Second, although coding frameworks for learner motivation categories were consistently applied, interpretation was based solely on authors' stated aims and outcomes, which may not capture deeper nuances present in the studies themselves. Finally, given that some articles lacked sufficient methodological detail, such as specifying game types, certain categorizations relied on the clearest available information, which introduces some degree of interpretive constraint.

Future research should aim to address these gaps by clearly specifying game types in study designs and reporting, broadening learner motivation frameworks to explicitly account for social, emotional, and applied dimensions of learning, conducting cross-cultural comparative studies that recognize how local contexts mediate the impact of GBL, and investigating the long-term impacts of GBL beyond immediate engagement or academic performance. In particular, future studies could explore how GBL influences persistence in education, career readiness, and the development of lifelong learning attitudes. Overall, while game-based learning continues to demonstrate potential as a motivating and cognitively enriching pedagogical tool in higher education, a more diversified, context-sensitive, and socially attuned research agenda is needed to fully realize its benefits across varied educational landscapes.

7. Limitations

While this scoping review provides a broad overview of the intersection between GBL and learner motivation in higher education, several limitations should be acknowledged. First, the review was limited to peer reviewed journal articles published in English between January 1, 2020, and January 1, 2025. This exclusion of non-English publications, conference proceedings, book chapters, and grey literature may have omitted valuable insights from diverse geographic regions and interdisciplinary sources. As such, the findings may reflect a publication bias toward English-speaking academic contexts and disciplines with greater representation in indexed journals. Additionally, while the classification of learner motivation categories was based on explicit statements within each article, this approach depends heavily on how authors articulated their pedagogical goals or learning outcomes. In cases where descriptions were vague or inconsistent, articles may have been excluded from more nuanced classification, and important instructional features may have been overlooked. Furthermore, only the primary motivation category was recorded, which may not fully capture the multi-dimensional nature of some GBL interventions. This review also did not assess the quality or methodological rigor of the included studies. As is typical in scoping reviews, the emphasis was on mapping the scope and characteristics of the literature rather than evaluating the strength of the evidence (Munn et al 2018; Pham et al 2014). As a result, findings related to the effectiveness of GBL for enhancing learner motivation should be interpreted without the assumption that such evidence is conclusive of total GBL impact within the landscape of higher education. Finally, due to the evolving nature of the field, the review captures a snapshot of GBL research during a time of significant pedagogical experimentation, particularly during the COVID-19 pandemic. This context may have influenced the types of games implemented, the emphasis on digital modalities, and the urgency to adopt student engagement strategies, potentially shaping the trends observed in the literature. These limitations highlight opportunities for future research, including studies that incorporate a broader range of sources, more robust theoretical integration, and empirical evaluations of GBL's effectiveness in supporting different dimensions of learner motivation.

8. Conclusion

In conclusion, this scoping review highlights both the strengths and current limitations of GBL research within higher education. While GBL continues to show considerable promise in enhancing student motivation, promoting cognitive engagement, and fostering deeper learning, the field remains heavily skewed toward digital applications and primarily emphasizes cognitive outcomes such as problem-solving and critical thinking. There remains untapped potential in exploring the role of analog games, expanding the focus to include social and applied learning outcomes, and examining GBL practices across more diverse global contexts. Future research should adopt more inclusive, detailed, and context-sensitive approaches to capture the full pedagogical possibilities of GBL. By broadening methodological practices and diversifying the understanding of learner motivation, the field can move toward more equitable, innovative, and sustainable uses of game-based learning in higher education. Doing so will not only strengthen the academic foundations of GBL research but also ensure its relevance and accessibility to a wider range of learners and educational environments.

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AI Declaration: AI was not used in the creation of this research or the writing of this paper.

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Polimatrix: Conversation Analysis as a Method for Evaluating Performance in Matrix Games

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Abstract: In this paper we analyse the spoken interactions that take place during matrix games. Matrix games are serious role-playing games, used as training exercises in the military and areas such as strategy studies. Each matrix game simulates a real-world crisis, providing players with specific roles to play and the opportunity to interact in a ‘fail-safe’ environment. While there have been many studies on oral interactions in professional contexts (Kolb 2004, Glenn 2019), there has been less analysis of actual dialogues during table-top gameplay, especially face-to-face negotiation games. In order to address this issue, we designed a game based on the *Russia-Ukraine* war and recorded sessions of these games in order to compile an annotated corpus. We report findings from the Polimatrix corpus here, looking especially at statistically salient keywords (terminology), n-grams (phraseology) and speech functions (discourse strategies). Generally, we find a correlation between certain linguistic features and contextual variables. For example, the negotiation strategies of (self-declared) ‘novice’ players is typically direct, informal, and preoccupied with the ‘here-and-now’ of gameplay. In contrast, the discourse of ‘expert’ players is typically more respectful of other players’ status, stylistically more elaborate and centres on ‘higher’ strategic themes. Given such differences of linguistic performance, it is worth examining whether language itself should be a factor in the evaluation of matrix game sessions. Previous studies have shown a causal relationship between linguistic proficiency and negotiation outcomes (Taylor et al 2005, Hayakawa et al. 2019). This suggests that the quality of spoken interaction is a key factor in the evaluation of participants and their performances during negotiations. The question then is how to integrate the analysis of language into the design and practice of matrix games. We argue here that facilitators and their students may find it useful to conduct explicit analysis of linguistic performance in the form of (1) introductory conversation analysis and (2) the ‘post-match’ analysis of extracts from previous gameplay.

Keywords: Conversation analysis, Discourse strategies, Gameplay evaluation, Matrix games, Negotiation games

1. Introduction

Matrix games are serious role-playing games that are used in professional contexts for training purposes. In the professional world, the participants who take part in them are experts and trainees in fields such as the military and government services. The topic of a typical matrix game generally involves a crisis in the real world (earthquake, military invasion, humanitarian crisis). The reasons for gaming this kind of situation are to study hypothetical courses of action in a risk-free environment, as well as to explore the varying reactions of participants.

In this contribution, we argue that matrix games provide an ideal platform for the analysis of how language is used in gameplay, especially negotiation games. There have been several studies on the language of negotiations, especially in contexts such as commercial deal-making and legal proceedings (Kennedy et al 1981, Drew & Heritage 1993, Planken 2005). However, there has been less work done on the spoken interactions that take place in negotiation games, especially in games where structured dialogue is a key feature of the game system. In order to address this gap, we set up the Polimatrix project¹, with the aim of developing a protocol for analysing the dialogues which take place during a series of matrix games.

In addition to linguistic analysis, we also wanted to explore how matrix games are evaluated, either by the facilitators or the players looking at their own performance. The evaluation of matrix games has traditionally focused on debriefings (Morrison & Meliza 1999). We argue here that it would be useful to supplement such ‘after action reports’ (AAR) and self-assessment with actual linguistic analysis.

¹Polimatrix stands for ‘the Power Of Language In MATRIX games’. The authors would like to acknowledge the GIS ‘Groupe d’intérêt scientifique Sciences du jeu’ (*Ludocorpus*, Paris) for financing this project. For details see https://csc.u-paris.emundus.io/index.php?option=com_emundus&view=job&id=236&Itemid=1468

2. Game Design: Designing a Matrix Game for Language Research

A typical matrix game asks players to assume the roles of major protagonists during a crisis. Matrix games use two core mechanics (1) structured debate (requiring the use of an adjudicator) and (2) ‘matrix’ tables (listing available options plus costs). Just like traditional wargames, matrix games are organised in turns in order to simulate the changing circumstances of a particular crisis.

The aim of the Polimatrix project is to analyse the language of strategic negotiations. To this end we approached Natalia Zwarts at the Hague University of Applied Sciences (THUAS) in order to design, run and record a series of matrix games for use with masters-level students enrolled on the ‘Safety and Security Studies Management Programme’ at THUAS. The details of the game are set out in Table 1.

Table 1: Design features of the Polimatrix game

Game elements	Description
Scenario	Polimatrix: a strategic negotiation game focusing on the early stages of the Russia-Ukraine conflict (2022-).
Audience	Novice cohort: 5 groups of students enrolled on the Safety and Security Studies Management Programme at THUAS. Expert cohort: 4 groups of volunteers, including game designers and strategy consultants. (See Table 2 for details).
Mode of play	Novice cohort: 5 sessions were run face-to-face (recording details in section 3) Expert cohort: 4 sessions were run online (recording details in section 3)
Participants	In theory, 1 game master (GM), 2 players (Rus., Ukr.) and 3 adjudicators. In practice, the GM plays the role of one or more adjudicators.
Setup and materials	Analogue board (for F2F: face-to-face play) or digital board (for online play), role descriptions (Rus., Ukr.), matrix table for special actions, round cards (distributed by the GM).
Mechanics	The GM manages the sequence of play and provides an update to the Russia and Ukraine players on in-game events. The sequence of play involves three phases: 1) Negotiations. Every round, players are asked if they want to negotiate (on topics listed on the game board). 2) Actions. Every round, players perform actions (purchasing / moving assets, with associated costs). Expensive actions require a debate with the adjudicators. 3) End of Round. The GM calculates total spending for Russia / Ukraine and consequent Public Support. Each new round, the players receive a secret Round Card (discussed below). The game continues for three rounds, ending with scoring.
Timing	Rules explanation (15 min.), gameplay (three rounds x 20 min.), debriefing (30 min.).

As can be seen in the Table 1, a key feature of the *Russia-Ukraine* game is the Negotiations Phase. This involves discussions between the two protagonists. Figure 1 shows the main game board, with the topics for negotiation on the left-hand side, a map for actions in the centre, and game rules on the right. The numbers in squares indicate the points which can be gained by both sides in case of successful agreement / occupation.



Figure 1: Main board of the Russia-Ukraine matrix game

Player interaction can also take place during the Actions Phase. During this round, each player may choose one option from an action table (corresponding to the traditional ‘matrix’ portion of the game). Low-risk choices (e.g. ‘field attack’, ‘propaganda’) can succeed without discussion. However, for high-risk choices (‘international loan’, ‘drones’), the player must obtain a majority of votes from the adjudicators. This part of the game corresponds to a structured debate, with both players providing arguments and counter-arguments.

The internal economy of the game also incites players to enter into negotiations. This is reflected in the unequal values of geographical locations (e.g. control of Crimea is worth 10 to Russia but 5 to Ukraine) and the varying values of negotiation topics (see Figure 1).

Hidden information is also an important feature. Once per turn the players receive a secret round card giving them a temporary ability (moving assets for free, doubling the value of negotiations, and so on). Since neither player has complete information about the exact values of all of the assets in the game, there is an incentive to obtain and exchange information from the other player.

As we have seen, the *Russia-Ukraine* matrix game encourages player interaction through obvious mechanics such as the ‘negotiations phase’, but also by less obvious means (matrix debates, asymmetry, hidden information). Since the underlying assumption of this game is that negotiation is a key strategic process in the ‘war of information’, it is particularly interesting to examine how this information is communicated during actual gameplay.

3. Project Design: Compiling a Corpus of Matrix Game Sessions

The primary aim of the Polimatrix project is to provide a linguistic description of matrix game sessions in terms of register features. By register features, we mean the inventory of lexical and grammatical features associated with a particular ‘register’ or type of discourse. There are many such variables, but here we focus on three:

- Discourse functions (sequences of speech with functions such as: gameplay questions / answers, negotiation probes / responses, metagame comments on strategy, roleplay, critiques of the game)
- Lexical items (statistically salient keywords, technical terminology)
- Phraseological patterns (regular expressions)

The primary hypothesis of the Polimatrix project is that it is possible to observe significant correlations between language features such as these and features of context. Here are some contextual variables which we are interested in:

- Experience in gaming or matrix games (novice vs. expert)
- Language proficiency (L1 or ‘native English’ vs. L2 ‘user of English as an additional language’)
- Mode of play (face-to-face vs. online)

Several research questions can be framed in terms of these variables. For example, is there a difference between the terminology used by novice (inexperienced) players as opposed to experienced players?

To address such questions, we compiled a corpus of texts based on nine sessions of the *Russia-Ukraine* matrix game, each organised, played and recorded during the second semester of 2024 by our colleagues at THAUS. Five of the sessions were played face-to-face (F2F), four online. During gameplay, an audiovisual recording of each session was made using the Teams² software. The audio was then transcribed using Whisper³, creating a raw text corpus. These texts were then corrected and processed for use on the INCEpTION⁴ platform, which allows us to annotate the corpus for speech functions (annotations have so far only been applied manually). The main features of the Polimatrix corpus are set out in Table 2.

Table 2: Polimatrix corpus of matrix game oral interactions

Text	Date / Duration	Mode of play	Participants ⁵	Tokens	Novice / Expert (majority)	L1 / L2 (majority)
A	2024-04-20 / 1:10	F2F	Rus, Ukr +1	8623	Novice	L2
B	2024-06-21 / 1:05	F2F	Rus, Ukr +1	7682	Novice	L2
C	2024-11-25 / 1:04	Online	Rus, Ukr +0	8276	Expert	L1
D	2024-06-21 / 1:40	F2F	Rus, Ukr +1	14781	Novice	L2
E	2024-10-16 / 1:53	Online	Rus, Ukr +1	13330	Expert	L1
F	2024-10-23 / 1:45	F2F	Rus, Ukr +2	12052	Novice	L2
G	2024-10-24 / 2:30	Online	Rus, Ukr +1	17240	Expert	L1
H	2024-11-08 / 1:42	F2F	Rus, Ukr +1	13683	Novice	L2
I	2024-11-13 / 1:04	Online	Rus, Ukr +0	7944	Expert	L2
TOTAL				103611		

As Table 2 shows, each of the game sessions was given a binary label indicating one of several contextual variables (novice / expert, online / live). Information about expertise and language proficiency was obtained using a questionnaire distributed ahead of the game session. For the purposes of this paper, we determined the main characteristics of each session according to ‘majority’. Thus, as far as expertise is concerned, for over half the sessions (A, B, D, F and H) a majority of the players declared themselves ‘novice’ players, while for the other sessions (C, E, G and I), most players declared themselves to be (relative) ‘experts’.

It turns out that all of the F2F sessions were played at THAUS with (a majority of) novice players, while all of the online sessions were played online, almost exclusively involving expert players. Since there is no difference therefore between these two variables, in the remaining sections of this paper, it is sufficient to divide the data into two corpora: novice / F2F (Subcorpus 1) and expert / online (Subcorpus 2).

4. Identifying Regular Patterns of Discourse in Matrix Game Dialogues

In this section, we set out some initial observations based on a preliminary analysis of the Polimatrix corpus.

²<https://teams.microsoft.com/v2/download>

³<https://openai.com/index/whisper/>

⁴<https://inception-project.github.io>. INCEpTION was installed on a server at University Paris Cité: <https://inception.u-paris.fr>.

⁵0-2 =number of Adjudicators. If 0, then the GM played the role of Adjudicator.

4.1 Keywords in the Polimatrix Corpus

The first kind of data that can be derived from the Polimatrix corpus involves ‘keywords’, lexical items that occur significantly more frequently in one corpus as opposed to the other. The AntConc software (Anthony 2024) was used to create two frequency lists for Subcorpus 1 and Subcorpus 2. Tables 3 and 4 show how a sample of items from each list can be grouped together into meaningful categories (i.e. words grouped by theme, or by functional category).

Table 3: Sample Keywords in Subcorpus 1

Lexical category / semantic field	Example Keywords
Markers of familiar speech	anyways, [inaudible], [laughter], gonna, oh, shit, yeah, you
Operational lexis relating to game dynamics	adjudicator/s, agree, beneficial, choose, deals, judge/s, moving, negotiating, points, winning
Technical lexis relating to Russia-Ukraine conflict (general terms for participants, themes)	attacks, civilians, cyber, disinformation, information, peacekeeping, people, soldiers

Table 4: Sample Keywords in Subcorpus 2

Lexical category / semantic field	Example Keywords
Markers of deliberate speech	Alexander, Francesco, hm, Natalia, um, think
Operational lexis relating to wider conflict	european, international, korean, national, russian, ukrainian
Technical lexis relating to wider conflict (specific terms for participants, processes)	artillery, assets, asymmetric, conflict, firepower, front, hexagons, matrix, military, offensive, operation, opponents, partners, player, strategy, units, wargaming

Tables 3 and 4 show that the themes addressed by participants in both sets of data are comparable but subtly different. In Subcorpus 1, participants are concerned with exchanging information about the game at hand (game functions, such as *adjudicator*, or gameplay *winning*). When participants refer to technical concepts, these are generic in nature (*civilians*, *people*) or refer to well-known topics in the Russia-Ukraine conflict (*cyber*, *disinformation*). In Subcorpus 2, the participants refer to technical terms that are less bound to the game, referring instead to the wider strategic context (*european*, *international*, *korean*) or abstract concepts in strategic studies (*front*, *offensive*, *operation*, etc.).

Although it is natural to focus on vocabulary, it is also important to consider other statistically significant features, notably grammatical items and ‘discourse markers’. These can reveal significant differences in terms of style. For example, in Subcorpus 1 the presence of expletives such as *shit!* and non-standard forms such as *anyways*, *gonna...* are indicative of highly informal discourse. Similarly, labels such as *[laughter]* and *[inaudible]*, suggest solidarity and intimacy among participants, as well as fluid turn-taking. Turning to Subcorpus 2, it is significant that player interaction is often accompanied by first names, an indication that the speakers are more attentive to the identities and status of other participants. Similarly, hesitancy markers (*hm*, *um*) and the verb *think* also suggest more deliberate forms of interaction.

As we note below, such there is clearly a correlation here between language use and the degree of experienced involved, as well as mode of play.

4.2 N-Grams in the Polimatrix Corpus

An efficient way of looking for regular patterns of speech is look for repeated sequences of lexical items, known as ‘clusters’ or ‘n-grams’. Tables 5 and 6 present a sample of n-grams which occur frequently⁶ in Subcorpus 1 and Subcorpus 2 (here n-grams have a minimum length of 3 words and maximum of 10). N-grams are often incomplete, so in the examples below we have included the surrounding material that typically accompanies these items in the corpus (parentheses).

⁶The key figure here is rank: the position of a repeated sequence relative to the many n-grams that appear only once. To give an idea of scale, the total number of n-gram types for Subcorpus1 is 334 699 and total tokens 340 731. For Subcorpus2 the total n-gram types is 278 614 and total n-gram tokens: 280 380.

Table 5: Sample n-grams in Subcorpus 1

Rank	Frequency	Range (items involved)	N-gram (+ typical context)
2	35	4	i don't know (+how she calculates it, +which country I am, +what is my cost?)
92	11	5	i don t want to (+give away my moves, +make concrete plans, +negotiate about that)
132	6	5	do you want to negotiate?
478	3	5	i can agree to that (+if you move, +potentially, +[end of statement])
555	3	4	how about we agree (+to allow shipping, +that?, +to exchange prisoners),

Table 6: Sample n-grams in Subcorpus 2

Rank	Frequency	Range (items involved)	N-gram (+ typical context)
4	11	6	i don't know if I (+trust the Russians on this, + meant to divulge it, + would have done that)
18	6	5	i don't know what (+happened during other sessions, + that will mean for my side, + the total is)
19	6	5	i don't think it (+ has any bearing on the military reality, + has any impact, +works)
46	4	5	and i think that's (+ a smart move, +probably a good thing, +my major reservation)
183	3	4	what do you think (+ about International loan for Russia?, +about the prospects of International loans ? +in terms of doubling fire power?)

These results show that the same phraseology can occur in both Subcorpus 1 and 2, but it is used in different ways. Thus, in Subcorpus 1, when players say they 'don't know', they are typically referring to their own lack of comprehension (*I don't know + how she calculates it, + what is my cost*, etc.). In Subcorpus 2, on the other hand, this phrase is often used as a rhetorical device, introducing gameplay suggestions (*I don't know + if I would have done that*), or commenting on strategy (*+ what that will mean*).

Looking for differences, we can see that Subcorpus 1 involves statements about what the participants 'want' or 'agree', either boldly stating their strategy (*I don't want to*), probing other participants about the possibility of a negotiation (*do you want to negotiate? how about we agree?*), or openly accepting the terms of an agreement (*I can agree to that*). By contrast, in Subcorpus 2, we find more indirect formulations. In particular, three patterns are built around what the participants 'think', including evaluations of strategy (*I think that's + a smart move*), counter-arguments (*I don't think it + works*), or probing other participants about their position (*what do you think + about international loan?*).

Even if we consider this very small sample, there appear be significant differences in the rhetorical strategies adopted in the novice / F2F sessions (direct interactions, engagement with the game at hand) as opposed to the expert / online sessions (indirect interactions, reflexions about the strategic situation outside the game).

4.3 Annotating the Polimatrix Corpus for Speech Functions

In this section, we move from a quantitative analysis of the Polimatrix corpus to the description of qualitative features, especially 'speech functions'. The purpose here is to show that by looking at the rhetorical structure of conversations, we can perhaps explain why certain negotiating strategies fail, while others apparently succeed.

The analytical tools we adopt here originate in conversation analysis (Glenn 2019). The core concept is the Adjacency Pair (AP), a matching pair of conversational turns around which most dialogue is scaffolded. In a previous study we identified the discourse functions that typically occur in strategic negotiation games (Farges & Gledhill 2024). On the basis of this study, we posit four main subtypes of AP:

- Game Organisation / Performance
- Game Probe / Response
- Negotiation Open / Close
- Negotiation Probe / Response

In addition, participants sometimes extemporise or ‘side-step’ the typical AP sequence. This involves comments on strategy, judgements about the game or engaging in ‘roleplay’. For these we propose three APs:

- Meta-critique
- Meta-strategising
- Meta-roleplay

Exchange 1 (below) shows a typical negotiation cycle (in this case taken from Subcorpus 1). This is started off by the game master (GM) as an invitation to negotiate (Nego Open), followed by an uncommitted response from Player A (Nego Resp). Player A then makes a proposal (Nego Probe). The conversation then goes through several cycles of Probe / Response before a final agreement (Nego Close) which occurs later in the exchange.

Exchange 1

GM: Then you can choose if you negotiate. [Nego Open]

PA: I am not sure. [Nego Resp]

PA: I would like an agreement to exchange prisoners of war [Nego Probe]

PB: I am willing to exchange POWs. [Nego Resp]

PB: on the exchange that you will leave no forces in the Crimea. [Nego Probe]

PB: And you will withdraw your forces. [Nego Probe]

PA: I am not going to agree to that [Nego Resp] [...]

Exchange 2 (below) shows another way that a negotiation can proceed (again, from Subcorpus 1). Here Player A uses elements of the game state (Meta Strat) as a bargaining point. As well as making promises about future gameplay, Player A mentions that ‘*I cannot move these two [pieces]*’ in order to reassure Player B. In pragmatic terms, this is an attempt to help Player B ‘save face’. The agreement is then ‘officially’ acknowledged by the GM (NEGO CLOSE), but this function is also signalled by the players shaking hands.

Exchange 2

PA: I would like the NPP [National Power Plant] then as well. [Nego Probe]

PA: (as well as) not deploying any more forces and just leaving it as it is there. [Nego Probe]

PB: I can consent to that. [...] [Nego Resp]

PA: That also means that I cannot move these two. [Meta Strat]

PB: Yeah. I can do that [Nego Resp]

PA: Yes [Dialogue Control]

PB: OK (Players shake hands) [Nego Close]

GM: So we have then a negotiation for Nord Stream [Nego Close]

Specialists in the field of conversation analysis (Glenn 2019) have often observed a divide between the transcriptions of spoken exchanges and the perceptions of participants (especially when asked to recall the phrasing used). Given the gulf between participant recollections and actual performance, there seems to be a strong argument in favour of not only keeping a record of these exchanges, but also in engaging in some form of analysis, even if it this involves short extracts, as we have seen here.

5. Language and the Evaluation of Matrix Games

In this section, we turn our attention to the evaluation of matrix games. There is now a considerable body of evidence that suggests that language proficiency and language use can have an impact on negotiation outcomes (Sokolova and Szpakowicz 2007, Hayakawa et al. 2019, Wang and Yip 2022). For example, Taylor and Thomas (2005) found that successful negotiation outcomes are associated with several ‘high-level’ discourse features, including greater coordination of turn taking, reciprocation of positive affect and a focus on alternatives rather than on competition. These discourse strategies correspond to the kinds of lexicogrammatical features that we have observed in the Polimatrix corpus (especially Subcorpus 2). Although our work is still only at a preliminary

stage, it would appear that factors such as relative experience coupled with channel (mode of play) have an impact on the actual language and negotiating styles that players adopt.

Given the relationship between linguistic performance on the one hand and gameplay on the other, we suggest that it would be instructive for the participants in matrix games to analyse their own performance (or that of others) in linguistic terms. Traditionally, matrix games have been evaluated by debriefing (Morrison & Meliza 1999, Nicholson 2012, Crookall 2015). This practice stems from the fact that matrix games were originally designed as a qualitative training tool in wargaming. Rather than seeking a ‘winning’ strategy (as in chess or other strategy games), the evaluation of military matrix games is based on the participants’ ability to identify risks, test assumptions, and make informed decisions. Wojtowicz (2020) describes an additional benefit of debriefing sessions: they can create a risk-free environment for potential knowledge gaps to be discussed and openly clarified.

But despite the attention that has been paid to debriefing, as far as we are aware, few if any organisers of matrix games make use of the spoken interactions which take place during gameplay when assessing actual performance. Yet, if we accept that high-level discourse strategies (as we mentioned above) have an effect on the outcomes of gameplay, it should follow that linguistic performance should also be taken into account when evaluating how well a matrix game has been played.

How do we propose to do this? We set out below a very simple three-step recommendation.

Step 1) *Corpus selection*. Participants obtain a transcription of their own matrix game session. Many streaming services and meeting platforms provide options for automatic subtitling / transcription (although often limited to English). If unable to obtain a transcription for professional or logistical reasons, it should also be possible to obtain one from an archive (the Polimatrix corpus exists precisely for this purpose).

Step 2) *Extract selection*. Participants select a short extract for analysis. In the first instance, it is instructive to look for passages where there is a ‘significant moment’ or a visible ‘ludic act’ (a complete negotiation cycle, agreement or disagreement between the players, shaking hands, etc.)

Step 3). *Conversation analysis*. For non-specialists, this may present a novel challenge. Therefore we recommend that analysis be ‘scripted’. That is to say, broken down into bite-sized activities which can be followed systematically (and performed incrementally). Table 7 shows a possible check-list for this exercise.

Table 7: Debriefing questions and related requirements

Category	Question
Experience	Identify a significant moment in your matrix game, maybe one which corresponds to successful / unsuccessful negotiation (no more than 10-20 phrases / utterances).
Observations	Label each phrase / utterance according to speech function [see Section 4.3 for examples].
	For each player involved in this exchange, how would you describe their negotiating style / negotiating strategy (businesslike, conciliatory, demanding, jocular, threatening, etc.)?
Conclusions	Listening to your own participation, what did you learn about your own negotiating style?
	Listening to the different participants, do you think their mastery of language (accuracy, fluency, rhetorical skills) contributed to the success (or failure) of communications in this game?
Reflectivity	Generally, how well do you think the negotiations went in this game session? What was the effect of this on the final result?

At the current time, we have not had an opportunity to test this proposal with actual participants. However, it is planned to apply this approach using an adapted variant of a commercial strategy game in two different separate institutions in two countries (also with different channels / modes of play: thus separating variables such as expert / novice, online / face-to-face).

6. Conclusion

In this paper, we have set out various reasons why the analysis of spoken interactions may be relevant to the players and organisers of matrix games. The detailed analysis of lexicogrammatical features reveals broad differences in discourse strategy, which themselves correlate with variables such as the relative experience of players (but also the channel of communication). The value of linguistic analysis lies firstly in the interpretation of data: it is useful to be able to predict which phrases and terms are used in ‘successful’ as well as ‘unsuccessful’

negotiations. But linguistic analysis may also have pedagogical value: in effect, we suggest here that participants in matrix games may benefit from being able to identify, compare and label the different conversational turns and speech acts used during negotiations which they have effectively witnessed or played a part in creating.

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

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

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Augmenting Spatial Learning and Problem-Solving in Game-Based Education Through Virtual Environments

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Abstract: Rapid developments in virtual environments and their association with game-based educational processes have altered traditional learning methods. Although this study depends on how users engage with these environments on the levels of learning competence and cognitive processes, these new ways of navigating within architectural spaces focus on spatial cognition and problem-solving issues through task-based interactivity, a well-structured method in which users interact with goal-oriented assignments to fulfill the necessities of cognitive load and game-based learning efficiency. Furthermore, the study investigates spatial grounding, recollection, and cognitive processing the grade of interactive engagement. This study utilizes a task-based interactivity procedure to reveal possible outcomes of the interrelations between interactive spatial assignments and cognitive performance. With the issued VR-based spatial assignments, participants are asked to engage gradually in complex tasks, starting with passive exploration and wayfinding and navigation with simple tasks. Collected data relies on evaluating the precision of assessments, user experience questionnaires. This intake fosters insight into spatial intelligence and how it can impact the effects of structured engagement in game-based learning settings, cognitive load, and adaptability in digital learning environments. The study explores data that validates the optimization of learning efficiency regarding advanced grades of task-based interactivity through the cognitive load in game-based learning and enhanced problem-solving skills. Moreover, the study validates that interactivity in goal-driven tasks results in broader cognitive interaction and advanced spatial cognizance. These conjectures anticipate a prominent insight into VR-based practices and programs, educational game design, and learning strategies. With a focus on the contribution to the developing discourse issuing VR-based education by addressing spatial learning procedures and cognitive processes, this study reveals the potential of first-person exploration and thought processes that emerge from sensory and motor engagements within game-based learning.

Keywords: Task-Based interactivity, Spatial cognition, Cognitive load, Virtual environments, Game-Based learning

1. Introduction

This paper investigates the impact of task-oriented interaction in immersive virtual environments on spatial cognitive learning, orientation, and mental workload by illustrating an evidence-based replicable spatial cognition test based on 360° virtual environment use, Mental Rotation Tests (MRT), spatial recall training, task performance metrics, and subjective workload rating. For its applicability to situations with low technical backgrounds and time restrictions, study merges established testing instruments and embodied cognition to analyze the spatial solving consequence correlation with immersive learning. Spatial reasoning is an elementary component of human perception as well as decision-making. Spatial abilities to imagine and reconfigure spaces in the mind are highly relevant to career fields such as architecture, city planning, and engineering. With the advent of immersive technology such as virtual reality (VR), opportunities exist to take spatial learning through experiential embodied interaction to new levels. This potential is supported by meta-analytic research showing that immersive VR environments significantly improve learning outcomes across disciplines, particularly in comparison to traditional and computer-assisted methods (Coban, Bolat, and Goksu, 2022). Proposed work fills the gap in theoretical knowledge regarding spatial knowledge and empirical application of 360° virtual environments in short-term studies. by showing the formal application of a multi-method approach within reach of those with limited availability of development facilities.

Spatial learning, or the cognitive process of perceiving, structuring, and remembering information concerning spatial conditions, is a consideration across domains from architecture and design through cognitive science and schooling (Newcombe and Shipley, 2015). With increasing use coming from Immersive Technology in the form of VR, there has been increasing enthusiasm directed towards how these kinds of virtual spaces might be used in supporting spatial cognition, as well as more intuitive reasoning (Parsons et al, 2013). Spatial abilities regarding spatial memory, orientation, and spatial visualization are mentally working through spatial relationships. Shepard and Metzler (1971) demonstrated that people rotate an object in mind with some measurable speed, on which the later spatial measures, such as the MRT, were based. Their quantitative test assessed spatial ability and stressed cognitive efficiency and spatial performance relationships. The combination of theory with more recent digital tools is also supported by research in embodied cognition, where perceptual experience and body interaction have formatted cognitive mapping (Johnson-Glenberg, 2018). Based on Wilson (2002) and Slater and Sanchez-Vives (2016), studies in embodied cognition show that

body interaction with space affects cognitive processes. More than one sense is engaged through the interface provided by VR technology. Lin et al (2024) reinforce this by demonstrating that multisensory, embodied design in VR science games can meaningfully improve learning outcomes, particularly when interaction and motor engagement are emphasized. It is a concept used in developing learning spaces in which sensory and kinesthetic input triggers spatial memory and orientation. The usability and learner response to VR has also been evaluated in several design education contexts. Ozgen, Afacan, and Sürer (2021) found that VR-based design tools enhanced perceived enjoyment and usability compared to traditional paper-based design. This suggests that engaging, immersive environments can increase learners' willingness to explore and complete complex tasks, directly supporting design-based pedagogy.

On the other hand, immersive learning methods and environments engage and retain people better by simulating world complexity and scale. Learning in space is asserted to be superior by Tversky (2003) compared to navigating in an environment in the physical sense as opposed to passive viewing. In additional studies, Richardson et al (1999) confirmed navigation provides better spatial information than navigation in maps or imagery with weaker retention in memory. 360° virtual environments offer new ways to support spatial learning, especially under technical or time constraints. This study recommends a mixed-methods approach to evaluate task-based VR's impact on learning and workload without relying on intensive qualitative methods like interviews or think-aloud protocols.

This study aims to explore task-based interaction in spatial reasoning, assess spatial memory in passive and active navigation, examine cognitive workload during problem-solving, and evaluate the usability and satisfaction of 360° VR environments.

2. Methodology

The study involved five second-semester undergraduate students from Bahçeşehir University's Interior Architecture and Environmental Design department. All participants were proficient in spatial visualization, 3D composition, and orthographic drawing. This purposive sampling ensured a baseline level of spatial cognition to engage meaningfully with the MRT and VR-based environment. The aim was not to teach basic spatial reasoning but to assess whether immersive VR could enhance spatial judgment in students already trained in spatial thinking. Selecting spatially able students ensured the MRT served as a sensitive post-intervention measure rather than a basic ability test. Studies comparing VR and conventional tools for spatial learning show that immersive environments can reduce perceived workload while increasing satisfaction and engagement (Banerjee, Chowdhury, and Yein, 2023). When well-designed, VR integration in spatial education supports usability and can enhance cognitive processing. This aligns with the study's focus on enrichment rather than remediation. Participants were selected based on their technical drawing course skills, taught by the researcher, ensuring familiarity with 3D spatial tasks. Spatial visualization abilities were also informally assessed through prior coursework. While no prior VR experience or familiarity with the case study space was required, participants were asked about their familiarity, which was considered in evaluating sketch accuracy and recall. For reporting, participants were anonymized as P01–P05.

The study used an Oculus Quest 2 VR headset and 360° images of the Bahçeşehir University Material Library, captured with a 360° camera. A Google Forms-based Mental Rotation Test (MRT) pre-test and pen-and-paper drawing tasks were used for measurement. The process began with the MRT pre-test, followed by a VR session involving 360° immersive tasks, wayfinding, and object location. Post-tests included a second MRT, spatial recall sketches, the NASA Task Load Index (NASA-TLX) for workload assessment, the System Usability Scale (SUS), and the User Experience Questionnaire (UEQ) to evaluate usability. Participants completed a 10-question MRT before and after the VR task. All procedures were evaluated in detail. The test shows pairs of three-dimensional objects and asks whether they are one another's rotated version. While this test was initially developed by Shepard and Metzler (1971), it has been proven to be a valid spatial visualization test. Subsequent research focuses on individual variations in such skills as they are impacted by experience within spatial contexts (Hegarty and Waller, 2005). Participants of the study create the outline of the environment in the virtual world, and answer formally posed questions in response to object locations and paths of motion. Drawing is evaluated on a rubric based on the accuracy of object locations, directional context, and completion. Multiple-choice memory questions test memory retention in a formal style. These assessments quantify mapping and orientation skills, which are key to spatial learning (Montello et al, 2004).

Table 1 represents the primary measures utilized to quantify task performance in VR interaction for every task assigned. These measures provide objective data on spatial efficiency and environmental stimulus sensitivity. NASA-TLX focuses on the workload to measure scores in six parameters: mental, physical, and temporal

demand, performance, effort, and frustration. The NASA-TLX survey is administered to participants upon task completion. The scales are measured on a 0 to 10-point basis, instead of 0 to 100-point to ease the task, and can be normalized based on the task's perceived relevance (Hart and Staveland, 1988). UEQ assessment relies on user satisfaction and system usability, which is gauged by SUS, a five-item Likert-scale questionnaire (Brooke, 1996), UEQ, measuring attractiveness, efficiency, and reliability. These tools assessed how comfortable, easy to use, and enjoyable the VR process was. For data analysis, paired t-tests compared MRT scores before and after the VR session to identify any statistically significant improvement in spatial cognition. Spatial recall sketches were scored using a 0–10 rubric evaluating object placement, directional accuracy, and spatial coherence. Performance errors were analyzed descriptively and compared across conditions. Correlational analysis examined the relationship between task performance and NASA-TLX cognitive workload scores. SUS and UEQ were scored according to their respective standards to assess usability.

Table 1: Measurement methods

Instrument	Phase	Type	Purpose
Mental Rotation Test (MRT)	Pre + Post-Guided	Cognitive Test	Spatial visualization ability
Spatial Sketch (Unguided experience)	Post-Unguided	Visual Recall	Baseline spatial memory
Spatial Sketch (Guided experience)	Post-Guided	Visual Recall	Task-enhanced spatial memory
Spatial Memory Questions	Post-Unguided + Guided	Short Text	Location recall and sequence
NASA-TLX	Post-Unguided + Guided	Workload Rating	Subjective cognitive workload
System Usability Scale (SUS)	Post-Guided	Usability Scale	System usability perception
User Experience Questionnaire (UEQ)	Post-Guided	UX Evaluation	User experience: attractiveness, stimulation...

Virtual Reality Conditions

The VR session consisted of two phases:

- Unguided Tour: Participants viewed one sequence of 360° panoramic 13 images, but this sequence was predetermined, without tags, hotspots, or interactions. The state approximated free exploration, with both spatial encoding and attention left to the participant.
- Guided Tour: Participants experienced a VR tour with the same 360° panoramic images, but with labeled/tagged objects and hotspots. Participants clicked on the hotspots to move forward in sequence and checked the tagged objects along the way. This made participants aware of spatial relationships and salient environmental elements.

This apparent difference in exploration styles enabled measuring how task-focused interaction supports spatial knowledge, object location memory, and path recall.

3. Procedure

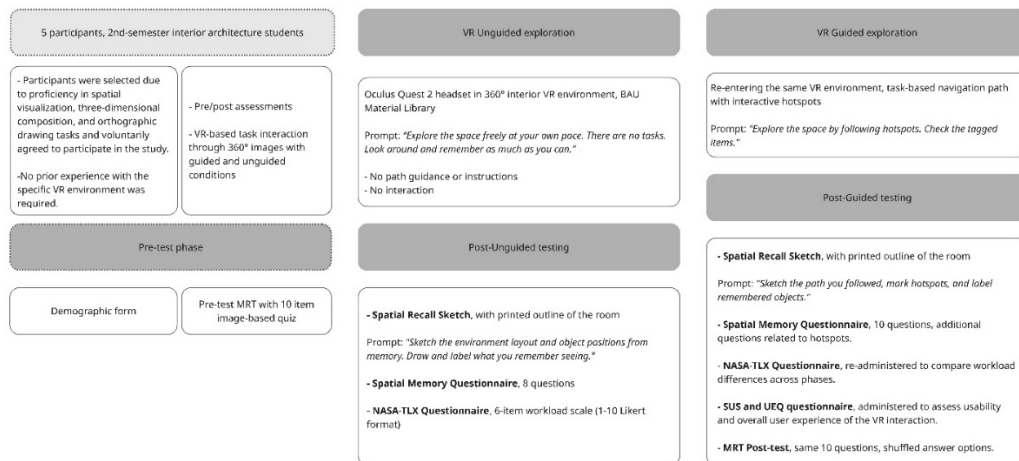


Figure 1: Workflow

Figure 1 summarizes the overall procedures for the conducted case studies.

MRT

The MRT measured spatial visualization and mental rotation ability. It included 10 items, each showing one target 3D object and four rotated options. Participants selected the correct match from a different perspective. The same items were used in pre- and post-tests, with shuffled answers to reduce memorization. Each test had a maximum score of 10, with one point per correct response. The MRT is a widely validated tool for assessing spatial reasoning, especially in design and architecture.

Spatial Recall Assessment

Participants' spatial memory was assessed using two tools:

- Sketch-Based Spatial Recall: After each VR session, participants drew a schematic floor plan from memory. Sketches were scored on a 4-criteria rubric: (1) object recall accuracy, (2) object placement, (3) overall layout, and (4) path clarity (guided phase only). Each criterion was scored from 0–2, with a maximum of 6 (unguided) or 8 (guided).
- Spatial Memory Questions: Participants answered eight open-ended questions after each session (e.g., “Which objects were closest to the entrance?”). Responses were scored 0–2, with a maximum of 16 per session. Three additional questions followed the guided session to assess route and object memory.

NASA-TLX

The NASA-TLX was used after both VR conditions to assess perceived cognitive workload across six dimensions: Mental, Physical, and Temporal Demand, Performance, Effort, and Frustration. Each was rated on a 1–10 Likert scale (1 = minimal, 10 = extreme workload). Instead of weighted scoring, unweighted averages were used. The performance dimension was reverse-interpreted, with higher scores indicating better performance and lower cognitive load.

SUS

Usability was assessed using a modified 10-item SUS, with responses on a 1–5 Likert scale. Items included both positive and negative statements (e.g., “The VR system was easy to use” and “The system was unnecessarily complex”). Scores were averaged per participant, with values above 3.0 indicating better usability. Unlike the standard 0–100 format, this study kept the 1–5 scale for simpler interpretation.

UEQ

To assess affective and interactional aspects of the VR system, participants completed 10 adjective pairs from UEQ. Items were rated on a 7-point scale (–3 to +3) across five subscales: Attractiveness, Perspicuity, Efficiency, Dependability, and Stimulation. Each subscale was averaged from two related items, with higher scores indicating a more positive experience.

4. Case Study and Findings

The findings provide insight into how immersive virtual environments affect spatial cognition, recall accuracy, and user experience. Data were collected through objective tests and subjective ratings after unguided and guided VR sessions. Results are presented across six areas: MRT, Spatial Recall Sketches, Spatial Memory Questions, NASA-TLX, SUS, UEQ, and Guided Tour Trace Recall. The case study area (Figure 2) and user experience record (Figure 3) are shown below.



Figure 2: Case study area

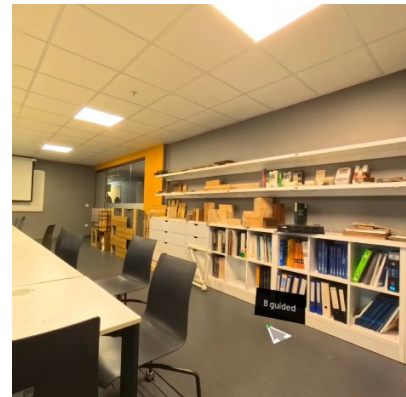
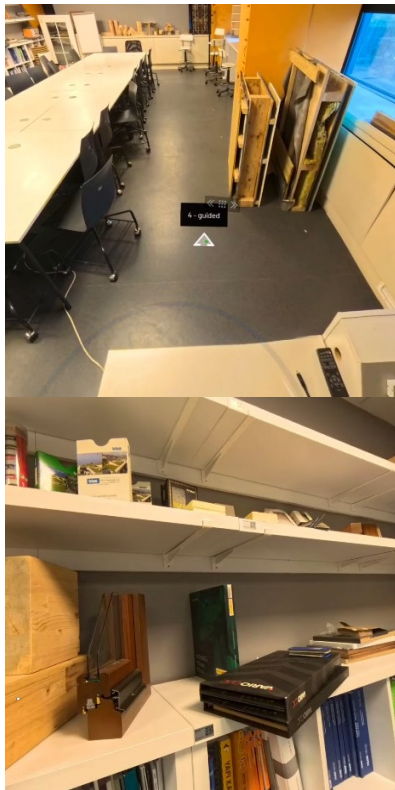
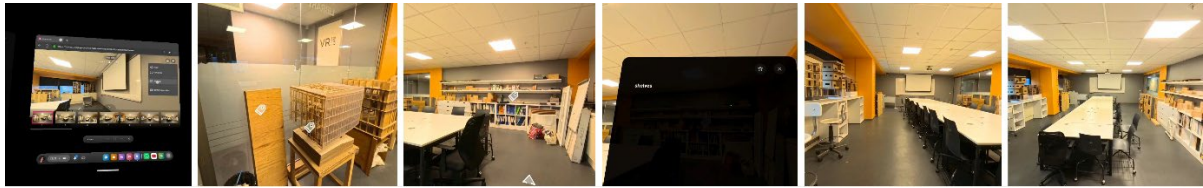


Figure 3: P02 VR guided experience record screenshots

MRT

Participants completed a 10-item MRT before and after completing the VR learning tasks (Table 2). Pre-test scores were already high, with a group mean of 9.6 out of 10. Post-test scores increased slightly to a perfect mean of 10.0. A paired-sample t-test showed that this increase was not statistically significant ($t(4) = 1.63$, $p > 0.05$), likely due to ceiling effects and the small sample size. Although the data does not have statistical

significance, using a paired t-test remains common in studies assessing short-term cognitive gains following immersive learning interventions, particularly when examining spatial reasoning and perceptual skill development (Wang and Dunston, 2013; Radianti et al, 2020). The consistently strong performance across both phases suggests that the VR experience did not hinder spatial reasoning and may have reinforced participants' mental rotation skills.

Table 2: MRT pre-and post-test results

Participant	MRT Pre-Test Score	MRT Post-Test Score	Gain
P01	9	10	1
P02	10	10	0
P03	9	10	1
P04	10	10	0
P05	10	10	0

Spatial Recall Sketch Accuracy

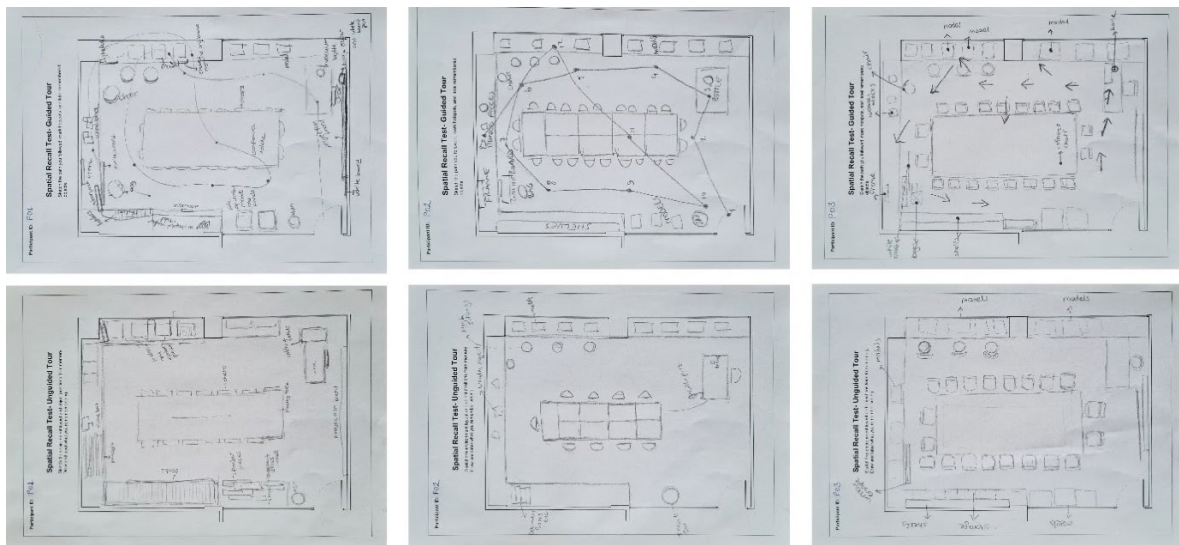


Figure 4: P01, P02, P03 (left to right) VR guided (first row) and VR unguided (second row) spatial recall sketches

Participants drew floor plan sketches after unguided and guided VR tours (Figure 4). Sketches were scored on object recall, placement accuracy, spatial layout, and path clarity (guided only). Results showed better performance in the guided condition (Table 3), where sequential navigation and tagged points supported higher scores across all categories. Participants who were less familiar with space (P01, P02, P05) showed clear improvements in recall and organization. Those familiar with the environment (P03, P04) also improved in the guided session, especially in path clarity and completeness. Guided interaction with hotspots aided spatial encoding, supporting that structured VR interaction enhances memory more than passive viewing.

Table 3: Spatial recall sketch evaluation

Scoring Scale: 0 = Absent/Incorrect, 1 = Partial, 2 = Fully Accurate

Participant	Familiarity	Phase	Object Recall	Placement	Layout	Path Clarity	Total
P01	Unfamiliar	Unguided	2	1	1	-	4/6
P01	Unfamiliar	Guided	2	2	2	1	7/8
P02	Unfamiliar	Unguided	1	1	1	-	3/6
P02	Unfamiliar	Guided	2	2	2	2	8/8
P03	Very Familiar	Unguided	1	2	2	-	5/6
P03	Very Familiar	Guided	2	2	2	1	7/8

Participant	Familiarity	Phase	Object Recall	Placement	Layout	Path Clarity	Total
P04	Very Familiar	Unguided	1	2	2	-	5/6
P04	Very Familiar	Guided	1	2	2	1	6/8
P05	Somewhat Familiar	Unguided	1	1	1		3/6
P05	Somewhat Familiar	Guided	1	2	1	2	6/8

Spatial Memory Scoring

Participants answered eight open-ended spatial memory questions after each VR session, focusing on object positions and environmental features (e.g., “Which wall had the shelves?”). Each was scored from 0–2, with a maximum of 16 per session (Table 4). Scores generally improved in the guided condition. While unguided scores ranged from 8 to 16, all participants maintained or improved after guidance. P01 improved from 9 to 15; P04 and P05 also showed gains, with P05 scoring 16/16 in both sessions. P03, already scoring 12/16, showed little change, possibly due to a ceiling effect. Overall, guided tours with hotspots and labels enhanced spatial recall, especially for those with lower initial scores, supporting the idea that structured engagement improves memory in immersive environments.

Table 4: Spatial recall results

VR Unguided experience									
Participant	Q1 (Entrance Objects)	Q2 (Window- side Objects)	Q3 (Table Items)	Q4 (Seating Count)	Q5 (Dominant Color)	Q6 (Vacuum Bottle Location)	Q7 (Shelves Location)	Q8 (Projection Screen)	Total (Max 16)
P01	1	1	1	0	2	0	2	2	9
P02	2	1	1	2	1	2	1	1	11
P03	2	2	2	1	2	0	2	1	12
P04	1	1	0	1	2	0	1	2	8
P05	2	2	2	2	2	2	2	2	16
VR Guided experience									
Participant	Q1 (Entrance Objects)	Q2 (Window- side Objects)	Q3 (Table Items)	Q4 (Seating Count)	Q5 (Dominant Color)	Q6 (Vacuum Bottle Location)	Q7 (Shelves Location)	Q8 (Projection Screen)	Total (Max 16)
P01	2	1	2	2	2	2	2	2	15
P02	2	2	2	2	1	2	2	2	15
P03	1	1	2	2	1	2	2	1	12
P04	1	1	2	1	2	2	2	2	13
P05	2	2	2	2	2	2	2	2	16

NASA-TLX Workload Ratings

Managing cognitive load is a well-documented challenge in immersive VR settings. While immersive experiences can foster a strong sense of presence, they can inadvertently increase the extraneous load and reduce learning efficiency if not properly structured (Makransky, Terkildsen, and Mayer, 2019). NASA-TLX scores were collected for unguided and guided conditions across six workload dimensions. Instructional design techniques, such as pre-training, have effectively reduced initial cognitive overload and improved knowledge retention and transfer in immersive environments (Meyer, Omdahl, and Makransky, 2019). Structured scaffolding, as used in this study, supports effective VR task design. Average workload scores remained low in both conditions (3.0–4.5 on a 10-point scale). Some participants reported slightly higher temporal demand during the guided session, likely due to sequential tasks, but overall ratings were stable or lower. This suggests that guidance did not increase cognitive load and may have improved task fluency (Table 5).

Table 5: Workload comparison

Participant	Unguided TLX Mean	Guided TLX Mean	Gain
P01	4.50	4.17	-0.33
P02	2.50	3.83	+1.33
P03	3.83	3.83	+0.00
P04	4.50	4.33	-0.17
P05	3.17	3.50	+0.33

SUS

Participants completed a 10-item SUS using a 1–5 Likert scale. Average scores ranged from 3.3 to 4.3, with all five participants rating the system above the neutral usability threshold of 3.0 (Table 6). These findings suggest that the VR interface was perceived as accessible and functionally usable, even for novice users. No participants reported usability issues significant enough to impede interaction or task completion.

Table 6: SUS averages

Participant	SUS Mean Score (1–5)
P01	3.80
P02	4.10
P03	3.30
P04	3.60
P05	4.30

UEQ

Ten adjective pairs from UEQ assessed interaction quality across five dimensions. Mean subscale scores (–3 to +3) showed high ratings for Dependability and Stimulation, with more variation in Efficiency and Attractiveness (Table 7). P02 and P05 rated the system as highly stimulating, though P05 gave a lower Efficiency score, suggesting individual differences in task ease. Overall, UEQ results reflect a positive user experience.

Table 7: UEQ results in grouped subscales

Participant	Attractiveness	Perspicuity	Efficiency	Dependability	Stimulation
P01	0.00	1.50	0.50	1.00	0.50
P02	0.50	1.00	1.00	2.50	1.50
P03	-1.00	1.00	0.50	3.00	0.50
P04	0.50	1.50	1.50	3.00	1.00
P05	1.50	1.00	-2.50	3.00	1.00

Guided Tour Spatial Trace Recall

Three final questions assessed memory of the guided tour sequence: first hotspot, path description, and last object recalled. Each was scored 0–2 (max 6) (Table 8). P02, P04, and P05 recalled the sequence with near-perfect accuracy. P01 remembered the path but only partially recalled other items, while P03 showed general partial recall with minor deviations. These results support that guided tours with visual tags enhance sequence memory and procedural recall.

Table 8: Selected questions of guided VR experience

Participant	First Hotspot	Path Sequence	Final Object Recall	Total (Max 6)
P01	1	2	1	4
P02	2	1	2	5
P03	1	1	1	3
P04	2	2	1	5
P05	2	1	2	5

5. Discussion and Conclusion

This study explored how task-based interactivity in virtual environments can improve spatial learning and cognitive performance in architectural education. It offers insights for designers, researchers, and educators developing learning technologies and educational games. The case study involved five participants (ages 20–22; three females, two males). Two had prior VR experience; three used VR for the first time. Overall, guided task-based interaction improved spatial memory, supported environmental understanding, and was perceived as manageable and user-friendly.

This paper presents a structured, usable system for assessing task-orientated interaction and spatial cognition within virtual environments while offering empirical evidence on the cognitive impact of immersive virtual learning by integrating structured VR experiences with validated assessment tools, including the MRT, spatial recall sketches, memory questions, and subjective workload and usability ratings. Findings demonstrated that guided VR experiences, enriched with labeled hotspots and interactive cues, led to higher spatial recall scores, more accurate sketch representations, and improved recollection of object locations and environmental features. This agrees with Lin et al (2024), who discovered that structured interaction and guidance in VR can support increased cognitive gain in task-based spatial thinking. Banerjee et al (2023) also proved that reduced cognitive load and increased perceptions of usability in VR tools directly impacted participants' task completion and participation. Regarding motivation, studies confirm that immersive VR experiences can significantly enhance learner satisfaction and attention. Portuguese-Castro and Santos-Garduño (2024) found that VR boosted all components of the ARCS motivation model, especially attention and satisfaction. These dimensions directly correlate with the observed improvements in task engagement and memory recall during guided sessions in our study. These outcomes were especially pronounced among participants with limited familiarity with the physical space, indicating that goal-oriented navigation supports more effective spatial encoding. While MRT scores were already high at baseline and exhibited limited gains due to ceiling effects, the retention of strong performance suggests that VR did not hinder spatial reasoning and may have reinforced pre-existing spatial abilities. Although all participants had sufficient spatial ability, individual learning differences or prior familiarity may have influenced engagement. Two participants were already taking a course in the case study area, which directly engaged with the materials and objects in space, such as timber samples in the material library. Despite this hands-on familiarity, their performance in the unguided VR tour was not distinctively better than others, and even they showed clear improvement in the guided condition. This suggests that prior exposure alone was insufficient; structured, task-based interaction in VR more effectively enhanced spatial understanding. Workload assessments validate that the structured VR experience did not increase the perceived cognitive burden, and user experience ratings indicated that the system was accessible and engaging. The integration of game-based learning principles and embodied interaction, particularly the coupling of movement, attention, and sensory input, supported deeper cognitive processing and environmental awareness.

While this study does not directly compare VR to traditional or screen-based learning, existing research and participant feedback suggest that immersive, guided interaction offers stronger engagement and spatial recall benefits than passive or 2D methods. The findings correlate with broader literature indicating that when structured with guided tasks, immersive VR can outperform traditional methods in fostering spatial understanding and user engagement.

6. Limitations and Future Studies

This project introduces an actionable test procedure to test spatial understanding through immersive technology. It provides a low-barrier approach relevant to short studies or instruction scenarios with no programming prerequisites and validated measures on cognitive, performance, and subjective instruments. Moreover, it proposes a bridge between embodied cognition theory and applied design pedagogy while addressing a gap in VR learning literature and reviewing methodological feasibility for small-scale academic settings. With the spatial content, the findings present a direction for designing educational games and virtual learning settings. Highlighting guided exploration and structured tasks can help learners develop spatial understanding more effectively. The performance gap between unguided and guided conditions highlights the value of embedded instructions and progression-based interaction in supporting engagement and retention.

This study offers meaningful findings, with opportunities for future work to enhance generalizability through larger, randomized samples. While 360° photos provided immersion, adding real-time interaction could enrich the experience. Exploring long-term learning effects and increasing task complexity through dynamic VR

environments would further strengthen future studies. In addition, long-term retention and more significant numbers of participants with diverse demographics should be arranged for testing. As shown by Makransky et al (2021), the motivational richness of VR can be a double-edged sword unless supported by generative learning strategies such as enactment or reflection. Future implementations should include cognitive scaffolds that channel learner motivation into lasting learning gains.

Ethics declaration: Confidentiality was ensured throughout data collection and storage, with all data anonymized. No identifying personal information was used. Participants received a notification form outlining the study's scope, purpose, and procedures, and provided written consent to participate.

AI declaration: In this study, AI tools were used to compile the study content and check for grammatical errors.

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A Systematic Review of Serious Games for Training Emotion Regulation Skills in Preschool Children

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Abstract: Emotion regulation (ER) is a vital skill that supports children's social, emotional, and cognitive development. Although early childhood education plays a key role in nurturing these abilities, traditional teaching strategies often lack engagement and interactivity. Serious games (SGs) have emerged as an innovative tool to promote ER by providing immersive and interactive experiences tailored to young children. This systematic review examines the current landscape of SGs aimed at enhancing ER in preschool-aged children (3-5 years), focusing on methodologies, technological strategies, and research gaps. Following PRISMA guidelines, a literature search was conducted across IEEE Xplore, ScienceDirect, and Scopus, using predefined inclusion and exclusion criteria. From an initial pool of 343 records, 37 studies met the final eligibility criteria. Findings indicate that while SGs hold promise for supporting ER, most existing solutions target clinical populations, such as children with autism spectrum disorder, rather than normative samples of preschoolers. Furthermore, few studies employ a co-design approach involving educators, psychologists, and children, despite this being crucial for creating age-appropriate and engaging interventions. The integration of these games into formal educational settings also remains limited. This review highlights the lack of SGs designed specifically for ER in preschool-aged children. By identifying key needs and best practices, the review lays the groundwork for the development of a new game, currently underway, that aims to effectively and engagingly address this gap.

Keywords: Serious games, Emotion regulation, Preschool children, Education, Systematic review

1. Introduction

Emotion regulation (ER) in early childhood plays a critical role in a child's social, academic and psychological development. Delays or difficulties in ER can lead to long-term consequences in academic achievement, peer relationships and mental health. Therefore, it is essential to provide children with tools and strategies to support the healthy development of emotional competencies from an early age.

The ability to regulate emotions is closely tied to executive functions like attention control and inhibitory control, which also undergo rapid development during these years (Zelazo, Blair and Willoughby, 2016). For example, children with well-developed ER skills at this stage are better able to cope with stress, develop healthy friendships with peers, and succeed academically (McClelland et al., 2017).

The development of ER is also supported by key theories of child development and learning. Vygotsky's sociocultural theory emphasizes the importance of social interaction and play in the development of self-regulation, as children internalize emotional and behavioral norms through guided and imaginative activities (Vygotsky, 1978). In parallel, socio-emotional learning (SEL) frameworks highlight the role of early experiences in fostering emotional awareness, empathy, and coping strategies, which are foundational for long-term well-being and academic success (CASEL, 2020). These perspectives provide a theoretical basis for using playful, interactive tools to support ER during the preschool years.

Serious games (SGs), digital games designed for educational purposes, are gaining recognition as promising tools to enhance emotional learning. They provide age-appropriate, dynamic and captivating experiences that can encourage the play-based development of ER skills. They have the capacity to captivate children in particular and offer chances for repeated practice in secure, replicated settings. But in spite of its potential, the field is still dispersed, with limited research focusing on preschool-aged children in particular.

This paper provides a systematic review of SGs designed to support ER in preschool children aged 3 to 5. It aims to explore the current landscape, analyze methodological approaches, and identify technological strategies and research gaps. By doing this, the evaluation helps provide the groundwork for the creation of more inclusive and successful teaching resources for early emotional learning in the future.

2. Methodology

Data sources

The databases IEEE Xplore, ScienceDirect and Scopus were selected for their comprehensive coverage in engineering, psychology, and educational technology. The search aimed to identify empirical studies evaluating SGs developed to improve ER in children. Additionally, the findings from the literature search and the screening and inclusion steps were reported in the flow diagram of Figure 1.

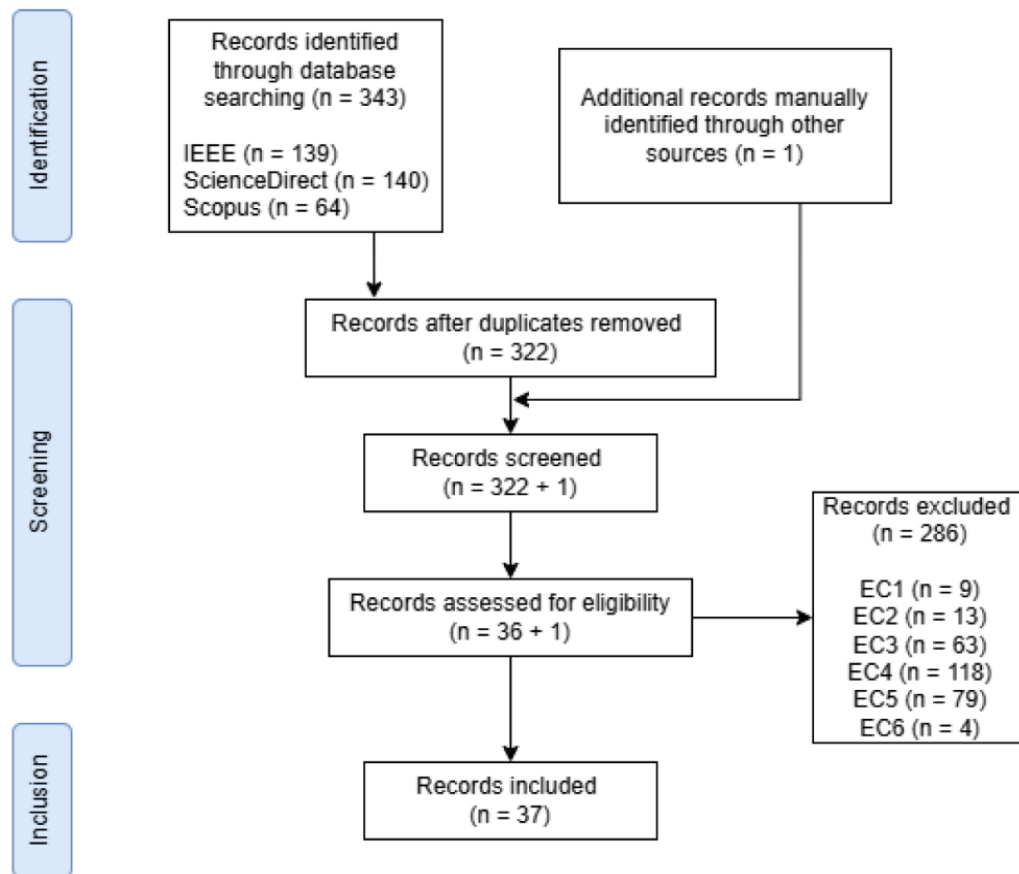


Figure 1 Prisma flow diagram

Inclusion and exclusion criteria

To ensure the relevance and quality of the research included in this review, a set of inclusion and exclusion criteria was applied. These criteria, outlined in Table 1, guided the selection process by filtering studies that aligned with the thesis objectives.

Table 1: Inclusion and exclusion criteria 1

Inclusion criteria	Exclusion criteria
IC1 Presents a game or application. IC2 Focused on emotion regulation or emotion. IC3 Includes children.	EC1 Publications not in English. EC2 Books, literature reviews, or book chapters. EC3 Studies focused on adults or adolescents. EC4 Studies that do not address emotion regulation. EC5 Studies that do not present a game or application. No full-text access available.

Search strategy

The query used: ("game" OR "platform" OR "app") AND ("emotion regulation" OR "emotional regulation" OR "emotion" OR "emotion dysregulation") AND ("children").

Screening and selection

After applying selection criteria, 37 studies were included in the final analysis.

3. Results

The majority of studies (over 70%) focused on children with Autism Spectrum Disorder (ASD) or other specific needs. Only 25% targeted typically developing children, and very few addressed preschool-aged learners explicitly. The distribution of studies, as shown in Figure 2, highlights this imbalance in the focus of the target population.

Most games were designed for computers, tablets, or web platforms. Only a minority involved co-design with educators, parents, or psychologists, which is essential for ensuring the games are developmentally appropriate and engaging.

Studies generally reported positive outcomes, such as improved emotional recognition and increased use of adaptive ER strategies. However, the evidence was often preliminary or qualitative, with limited long-term data.

An overview of these selected studies can be found in Table 2.

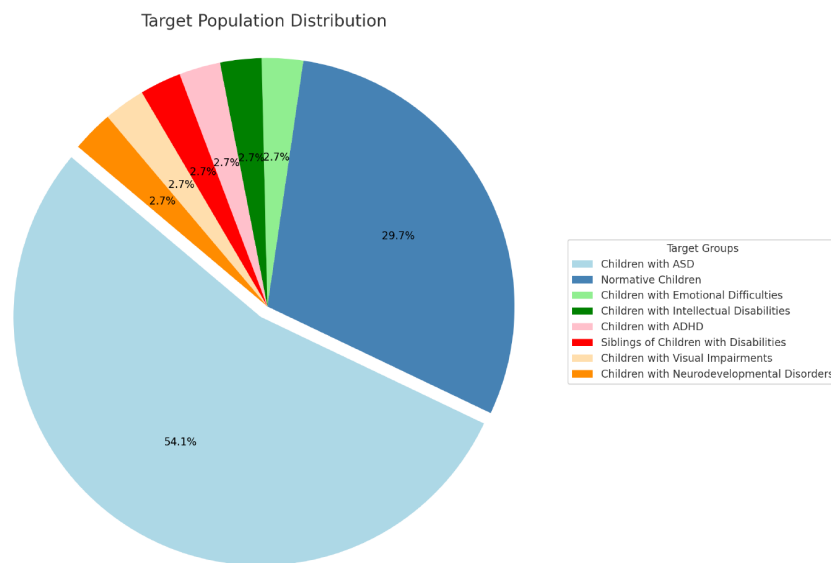


Figure 2 Distribution of studies by target population

Table 2: Overview of selected studies

Study	Game Name	Objective	Platform	Findings
Almeida et al. (2019)	ALTRIRAS	Train emotion recognition	Computer	Improved emotion recognition
Alves et al. (2013)	LIFEisGAME	Teach emotion expression	Computer	Potential improvement
Barba et al. (2022)	EMOLEARN	Emotion recognition & management	Computer	Potential support for learning
Carreño-León et al. (2021)	N/A	Emotion understanding	Computer	Positive reception
David et al. (2022)	REThink	Enhance emotion regulation	Online	Improvements linked to better mental health
DeRosier & Thomas (2018)	Zoo U	Assess social-emotional skills	N/A	Higher competence linked to school behavior
Elhaddadi et al. (2021)	JeStiMulE	Improve facial emotion recognition	N/A	Significant improvement
Fridenson-Hayo et al. (2017)	Emotiplay	Teach emotion recognition	Internet	Significant improvements

Study	Game Name	Objective	Platform	Findings
Fuentes García et al. (2015)	N/A	Teaching emotions	N/A	N/A
Gray et al. (2019)	BrainQuest	Enhance executive functions	Mobile	Qualitative improvements
Humphries & McDonald (2011)	Emotion Faces	Enhance emotion recognition	Touchscreen	Effective engagement
Lievense et al. (2021)	See	Improve self-concept	Computer	Significant improvements
Liu et al. (2021)	N/A	Improve social communication	N/A	N/A
Löytömäki et al. (2024)	Emotion Detectives	Teach emotion discrimination	Web	Significant improvements
Marchi et al. (2019)	ASC-Inclusion	Teach emotion recognition & expression	Internet	N/A
Moltrecht et al. (2021)	N/A	Support emotion regulation	Web	App perceived as helpful
Pacella & López-Pérez (2018)	Emodiscovery	Evaluate regulation strategies	Web	Adaptive strategies preferred
Papoutsis et al. (2024)	The Park of Emotions	Improve emotional intelligence	Web	Significant improvement
Ravale et al. (2023)	N/A	Improve learning/social skills	N/A	N/A
Vázquez-Reyes et al. (2023)	TEA Learning	Improve learning/social skills	N/A	N/A
Sandoval-Bringas et al. (2021)	N/A	Teach emotional/social skills	N/A	N/A
Shams et al. (2020)	EmoGalaxy	Compare emotion regulation tools	N/A	N/A
Sturm et al. (2016)	eMot-iCan	Improve emotion recognition	N/A	N/A
Veerman et al. (2024)	Broodles	Support siblings' emotions	Digital	Culturally acceptable
Wang et al. (2021)	N/A	Develop educational intervention	N/A	N/A
Weilun et al. (2011)	N/A	Rehabilitate socio-emotional skills	N/A	N/A
Wiguna et al. (2021)	N/A	Support ADHD symptoms	N/A	Improvements observed
Wintner et al. (2022)	Mightier	Improve emotion regulation	Online	Positive outcomes
Finkelstein et al. (2009)	cMotion	Teach emotion recognition	N/A	N/A
Dizicheh et al. (2021)	EmoAnim	Screen emotions	N/A	N/A
Heni & Hamam (2016)	N/A	Design emotion games	Mobile	N/A
Speer et al. (2021)	MindfulNest	Support emotion regulation	Tablet	Needed teacher guidance
Kashani-Vahid & Mohajeri (2018)	N/A	Enhance emotion regulation	N/A	Significant improvement

Study	Game Name	Objective	Platform	Findings
Piazzalunga et al. (2023)	N/A	Track emotion & attention	Tablet	Significant improvement
Stankova et al. (2021)	N/A	Train emotional understanding	N/A	Need for frequent training
Sudarmilah et al. (2015)	N/A	Identify game preferences	N/A	Preferred animal characters
Zoerner et al. (2016)	Zirkus Empathico	Train socio-emotional skills	Mobile	Showed potential

4. Conclusion

This systematic review reveals a significant gap in the current landscape of SGs for ER: there is a notable lack of interventions specifically designed for preschool-aged children. Most existing games are developed for older children or for those with developmental conditions, particularly ASD, leaving the needs of typically developing preschoolers largely unmet. This limited scope raises important considerations for researchers and game designers.

Many existing serious games lack core design features essential for this age group. For instance, few incorporate intuitive, non-verbal interaction methods (e.g., touch-based navigation, visual cues), or narrative frameworks that support emotional understanding through relatable characters and scenarios. Moreover, the absence of co-design with key stakeholders, particularly educators, psychologists, and the children themselves, often results in games that are misaligned with real-world educational contexts, cultural relevance, or user engagement needs. Co-design can ensure that emotional challenges, vocabulary, and gameplay mechanics are developmentally appropriate, and practically implementable in classroom or home settings. Another critical issue is the predominance of qualitative or exploratory findings in the current literature. While many studies suggest positive outcomes in terms of emotional recognition or regulation, the lack of rigorous methodologies, such as randomized controlled trials, longitudinal designs, and comparative analyses, limits the generalizability and scalability of these results. Without stronger empirical evidence, integrating SGs into formal curricula or therapeutic programs remains a challenge.

In conclusion, addressing these gaps is crucial for developing effective tools that foster ER skills during a foundational period of emotional development. Future game designers should prioritize features such as: multimodal interaction, emotionally intelligent characters and storylines, and a strong grounding in participatory design with early childhood experts and end-users.

This review lays the foundation for the development of a new serious game currently in progress, designed collaboratively with stakeholders and tailored to the needs of typically developing preschoolers. Moving forward, interdisciplinary and participatory research will be essential to ensure that digital interventions are not only evidence-based but also developmentally appropriate, engaging, and contextually relevant.

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Enhancing Learning Through VR Game Design in Higher Education

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Abstract: This study examines the integration of Virtual Reality (VR) as a development platform within a university-level Software Construction course, specifically in a video game design module for Computer Science students. Traditionally centered around 2D game development, the course introduced a VR-based project to modernize the learning experience and increase student motivation. Students were paired based on similar academic performance and provided with Meta Quest headsets. Each team was assigned a random thematic prompt—such as magic, city, forest, retro, or miniature world—and tasked with creating a fully interactive 3D environment in Unity. Within this space, they developed a mini game featuring essential mechanics, including objectives, rules, timers, and win/loss conditions. The activity emphasized both creative design and technical implementation within an immersive gameplay context. In addition to its immersive qualities, the activity incorporated gamification strategies, including random challenge constraints, milestone-based progression, peer feedback, and a final showcase that simulated real-world presentation scenarios. These elements were designed to enhance motivation and engagement through a structured, game-like learning journey. The primary aim of this pedagogical intervention was to assess whether the interactive and immersive nature of VR, augmented by gamified instructional design, could enhance student engagement, motivation, and the perceived relevance of course content. A post-activity survey gathered students' perceptions, focusing on engagement levels and the comparative educational value of the platform relative to traditional ones. Findings reveal that students considered the VR activity significantly more engaging and professionally relevant. They reported increased motivation, greater satisfaction with the creative process, and a stronger connection to real-world software development practices. These outcomes suggest that integrating virtual reality (VR) and gamification can promote deeper involvement and a more meaningful learning experience in software engineering education. In this undergraduate-level course, the baseline requirement is to develop a video game and briefly explore the topic of haptics in gaming. Nevertheless, this VR-based activity offers students an added value by enabling them to fully design and implement a video game deployed on the Meta Quest platform. The technical knowledge and practical experience gained through this process go beyond the standard curriculum and are exclusive to the groups that engage in the VR implementation. This not only deepens their understanding of immersive technologies but also equips them with skills rarely acquired at this stage of their academic training. However, it is important to recognize that the study relies mainly on self-reported data. While such perceptions provide valuable insight, they are inherently subjective and may reflect novelty effects or social desirability bias. Future research should incorporate additional data sources such as more performance metrics, code quality analysis, or instructor evaluations to assess actual learning and skill acquisition. Additionally, learning in this context is understood as the development of both technical competencies – such as Unity programming and VR interaction design – and transversal skills including teamwork, adaptability, and creative problem-solving. These skills, while difficult to quantify, are essential for software development careers. This paper details the instructional design, implementation strategies, technical considerations, and student feedback associated with the activity. While the results offer compelling evidence for the value of VR and gamification, it is equally critical to consider challenges and limitations, including technical accessibility, student discomfort, and the risk of overestimating the pedagogical value of immersive novelty. Moreover, critiques of gamification as a concept – such as those by Fuchs (2014) and Bogost (2011), who question its alignment with neoliberal educational logics – remind us of the importance of applying such strategies thoughtfully, ensuring that they support rather than trivialize the learning experience.

Keywords: Virtual reality, Gamification, Student engagement, Computer science education, Educational innovation, Higher education

1. Introduction

Immersive technologies, particularly Virtual Reality (VR), are transforming the landscape of digital interaction and are beginning to shape pedagogical approaches in higher education. As a channel capable of fostering presence, immersion, and interactivity, VR has demonstrated significant potential in promoting experiential and student-centered learning (Freina and Ott, 2015; Radianti et al., 2020). However, it is important to consider the limitations of this technology, including issues of accessibility, physical discomfort, and uneven student engagement, as well as the possibility that novelty may temporarily inflate perceptions of effectiveness.

In the context of computer science education, VR is increasingly being adopted to simulate realistic development environments, offer dynamic user experiences, and facilitate the acquisition of complex technical skills in engaging and meaningful ways. Despite its growing commercial availability and usability, the integration of VR into core academic curricula remains relatively limited. Most university-level software development courses continue to rely on conventional platforms and tools that, while foundational, may not

fully align with the current technological landscape or the demands of the software industry. Traditional instructional approaches often focus on 2D application or game development environments, which can constrain the creative possibilities and immersive potential of student projects. Furthermore, such tools may fall short in sustaining learner motivation and in cultivating the diverse skill sets required for the development of modern interactive systems.

The Software Construction and Decision-Making course serves as a cornerstone within undergraduate computer science programmes, providing foundational training in areas such as web development, database management, and video game creation. However, while these topics are essential, the course's approach to game development typically emphasizes 2D projects. While these offer value in terms of logic, structure, and coding practice, they may not adequately prepare students for contemporary development environments that increasingly rely on 3D engines, real-time rendering, and immersive interactivity. There is thus an opportunity to explore how emerging technologies—specifically virtual reality (VR)—can be strategically integrated into this course to enrich the learning experience, stimulate student engagement, and more authentically reflect industry practices.

This study introduces a VR-based pedagogical intervention within the Software Construction and Decision-Making course to examine its impact on student engagement, motivation, and the perceived relevance of course content.

In this activity, the technique of peer programming (Williams and Kessler, 2002) was employed by pairing students with similar academic performance. This strategic pairing allowed both members to collaborate more effectively, as they felt equally capable and supported. Working in pairs helped reduce the anxiety typically associated with learning and applying new technologies, such as virtual reality, fostering a more confident and balanced environment for exploration and problem-solving.

The intervention also required students using VR headsets to design interactive 3D environments and implement themed mini-games in Unity. This cross-platform game engine enables developers to create interactive 2D and 3D content, widely used for game development, simulations, and immersive experiences (Unity Technologies, 2023).

Each pair was assigned a random creative prompt (e.g., magic, city, retro), challenging them to balance technical implementation, imaginative storytelling, and user experience within the constraints of an immersive development framework. The project aimed to bridge theoretical learning with applied software construction practices, offering a holistic approach to skill development.

By analysing post-activity student feedback, the study assesses not only how students perceive the educational value of VR in comparison with traditional tools but also how immersive development influences their motivation and perceived alignment with real-world software engineering workflows. These findings contribute to the broader discourse on immersive learning environments in computer science education, offering empirical evidence that supports VR as a viable instructional platform. At the same time, we acknowledge the need to interpret such data with caution and to pursue further research using triangulated methods to verify learning outcomes and address potential limitations in accessibility and effectiveness. Ultimately, the research underscores the potential of VR to serve as both a content delivery medium and a development context that reinforces software engineering concepts, stimulates creativity, and enhances student engagement in technical disciplines.

2. Methodology

2.1 Course Context and Participants

This study was conducted as part of the Software Construction and Decision-Making course in the undergraduate Computer Science curriculum. Most students take it in their fourth semester and study fundamental topics like web development, database administration, and video game design. It also teaches software engineering principles and collaborative development practices.

The study involved 28 students in 14 pairs. To ensure equity in collaboration and reduce variance due to prior academic performance, participants were paired based on their cumulative Grade Point Average (GPA). Stratified pairings were used to distribute technical skills fairly and encourage fair teamwork across teams.

2.2 Intervention Design

An alternative to the 2D game development module was presented to explore the possibilities of applying immersive technologies to software development education. This intervention involved students applying technical knowledge in an emerging domain of real-time 3D interactive systems.

Each student team received a Meta Quest headset. In the Meta Quest series, developed by Meta, standalone VR headsets can execute virtual experiences without the need for external computing devices (Meta, 2023). These devices are designed with portability, ease of use, and compatibility in mind, catering to the most popular development platforms.



Figure 1: Meta Quest 3 mixed reality headset featuring controllers and spatial awareness capabilities

The primary development environment was chosen because Unity supports VR integration via the XR Interaction Toolkit. This platform enables cross-platform development, rapid prototyping, and real-time deployment to VR headsets, allowing students to iterate between development and testing. The asset pipeline and documentation of Unity also made it a very accessible but powerful tool for undergraduate implementation.

Randomly assigned game development themes stimulated creative thinking and thematic diversity. Themes included futuristic, retro, magic, forest, city, miniature worlds, beach, and space. Those creative constraints framed narrative design and aesthetic choices, while allowing students considerable latitude to interpret this material in the immersive format.

2.3 Implementation and Development Process

This intervention lasted two weeks and was implemented in the second half of the semester, following instructional modules on 2D game design, object-oriented programming, and agile workflows. The timing was deliberate, allowing students to possess the fundamentals necessary for transitioning into virtual reality development.

2.3.1 Two-Week In-Class and independent work plan

During these two weeks, students worked on their VR video game projects following a blended schedule. Some sessions were conducted in class, focusing on collaborative tasks, feedback, and technical support, while other sessions were completed independently, allowing students to make progress at their own pace. This approach provided flexibility, encouraged responsibility, and enabled students to manage better the challenges of developing with new technologies.

This was the blended schedule for the first week of the assignment:

- Week 1. In-Class Session: Implementation began with a technical onboarding session that taught students the key concepts of virtual reality (VR) development. That meant learning about Unity's XR interaction Toolkit, headset setup, spatial Interaction paradigms, and VR-specific UI elements in a hands-on workshop. Students learned locomotion (teleportation and smooth movement), object interaction (grabbing and throwing), and environmental issues such as scale, comfort, and accessibility.
- Week 1. Independent Work: To enable couples to work independently during the first week, students received asynchronous learning materials, including video tutorials, curated documentation, and

sample Unity projects that demonstrate best practices in immersive development. These resources facilitated the continuation of learning and self-paced exploration.

For version control and collaborative development, each team was assigned a private Git repository. Teams were encouraged to simulate game behaviour within the Unity Editor and to deploy builds regularly for testing on the Meta Quest headset. This approach enabled the iterative fine-tuning of game mechanics, player experience, and interface design.

To guide the structure of their games, all teams were required to implement the following core gameplay features:

- Clearly defined objectives and rule sets
- Real-time feedback mechanisms (e.g., score counters, timers)
- Win and loss conditions
- VR-appropriate navigation and interaction techniques

Such criteria should have guaranteed pedagogical consistency while allowing for variation in technical ambition and creative vision.

The blended schedule for the second week of the assignment was as follows:

- Week 2. In-Class Session: At the beginning of the second week, a checkpoint was established to track progress and adherence to project goals. In this session, instructors provided formative feedback, addressed technical issues, and conducted mini-peer review sessions. The latter involved teams presenting playable prototypes and classmates providing feedback, thereby creating a community of practice that reflected real software development environments.
- Week 2. Independent Work: The teams refined details and made modifications based on the feedback received after presenting their progress.

The intervention concluded with a showcase, during which all teams presented their completed virtual reality (VR) games. Students pitched their project to peers and instructors, followed by live playthroughs with the VR headsets. This event had two purposes: it was both an informal summative assessment of students' technical and creative achievements and a celebration of their immersive learning.

To further illustrate the outcomes of the final design challenge, the following images showcase a selection of student-developed virtual reality (VR) games. These screenshots highlight the diversity of creative approaches, technical implementations, and thematic interpretations that emerged during the project. Each game reflects a unique combination of narrative design, user interaction, and immersive world-building, demonstrating students' ability to apply core software engineering principles in a novel and engaging medium. The visuals not only exemplify the level of innovation and polish achieved but also underscore the pedagogical potential of open-ended, project-based learning in virtual reality environments.



Figure 2: Screenshots of student-developed virtual reality games

2.4 Immersive and Gamification Learning

Although the VR intervention focused primarily on novel and immersive development, this activity is also part of a gamified course. Gamification refers to the application of game-design elements in non-game contexts to increase engagement, motivation, and learning outcomes (Deterding et al., 2011). Each pair of students had the opportunity to implement extra functionalities to earn "diamonds," the virtual currency used throughout the gamified course.

Having the optional possibility of developing additional functionality validated and approved by the teacher to obtain "diamonds" within the gamified environment, without affecting the grade within the final mark, generates a greater sense of autonomy and feedback, elements that the literature on gamification identifies as key to immersive interaction (Hamari, Koivisto, and Sarsa, 2014). The combination of immersive interaction with a gamified experience component thus allowed for a two-layered interaction strategy: one cognitive and the other experiential.

However, we also recognize that gamification as a pedagogical strategy is not without critique. Scholars such as Fuchs (2014) and Bogost (2011) have questioned whether gamification risks reducing complex educational goals to simplified reward systems or reinforcing neoliberal ideologies that emphasize productivity and control. In our implementation, we tried to avoid these dilemmas by framing game elements as voluntary, creative extensions that encouraged intrinsic motivation rather than compliance.

The VR format further amplified these effects by offering a heightened sense of presence, agency, and feedback—elements that gamification literature identifies as key to immersive engagement (Hamari, Koivisto, and Sarsa, 2014). The combination of immersive interaction with a gamified structure thus enabled a dual-layered engagement strategy: one cognitive and one experiential.

Embedding gamification within VR-based learning extends beyond mere novelty, functioning instead as a pedagogical catalyst for sustained motivation and meaningful learning. Nonetheless, thoughtful and critical application is essential to ensure that gamification strategies enhance rather than trivialize the learning experience. These findings support the increasing alignment between gamification theory and emerging educational technologies.

3. Discussion

The success of the final design challenge highlights several key insights regarding how undergraduate software engineering students respond to open-ended, creative, and collaborative learning environments. Most notably, the high levels of engagement, autonomy, and technical rigor demonstrated in the final prototypes suggest that students can thrive when given freedom to explore their ideas while still being guided by well-defined constraints and checkpoints. Although the quantitative data presented reflects mainly students' perceived levels of engagement, as shown in Figure 6, the actual execution of the activity led to the natural development of technical skills in an additional and innovative topic for this course. Through the process of designing, developing, and deploying VR-based video games on the Meta Quest platform, students were exposed to real-world immersive technologies that are not typically covered in standard course sections. This outcome provides tangible curricular enrichment beyond what is captured through self-reported perceptions.

While the previous paragraph highlights that the findings are primarily based on self-reported perceptions, it is also important to recognize that each student pair successfully designed and developed a fully functional VR game. These tangible and deployable products provide concrete evidence of technical achievement and creative engagement. Still, we urge caution in interpreting these responses as direct evidence of learning gains, as further evaluation would be needed to objectively assess the depth and retention of the acquired skills.

3.1 Balancing Structure and Creativity

A critical balance between structure and freedom is central to the success of this activity. The imposed thematic constraint—designing inclusive IoT solutions for underrepresented groups—gave students a focused problem space, which prevented idea overload and encouraged empathy-driven innovation. Simultaneously, allowing students to choose their user group and technical approach promoted autonomy, which has been shown to correlate with higher motivation and learning outcomes in constructivist learning environments (Ryan and Deci, 2000).

The incorporation of weekly deliverables, including the ideation canvas, midterm prototype, and final presentation, created a rhythm and accountability throughout the project. These progressive checkpoints provided students with the opportunity to refine their designs iteratively, receive meaningful feedback, and integrate new knowledge, whether technical, design-related, or user-centered, into their solutions.

The final showcase functioned as a motivational anchor, yet future iterations should consider integrating more robust assessments to evaluate students' actual skill development. These may include rubrics for technical quality, instructor evaluations, or peer code reviews.

3.2 Pedagogical Implications of Gamification

Although the course did not adopt a fully gamified structure, several embedded elements intentionally paralleled game dynamics to promote engagement and motivation. The design challenge was framed with mechanics akin to those found in game-based learning environments:

- A thematic constraint functioned like a narrative quest, encouraging students to design within specific moral and social boundaries.
- Progressive milestones, such as the canvas, prototype, and final presentation, mirrored the structure of game levels, providing regular feedback and escalating challenges to maintain momentum.
- The final showcase functioned as a culminating "boss battle," where students presented their work publicly and received feedback from peers and instructors, fostering a sense of closure and recognition.

These elements were informed by Self-Determination Theory (Deci and Ryan, 2000), which emphasizes autonomy, competence, and relatedness as foundational to intrinsic motivation. Still, critical perspectives on gamification – such as Fuchs (2014), who argues it can reinforce managerial control, and Bogost (2011), who critiques it as exploitative – highlight the importance of applying game elements in ways that genuinely empower students rather than manipulate behavior.

In our course design, we aimed to avoid shallow reward systems by focusing on voluntary, creative extensions and meaningful feedback. Nevertheless, further research is needed to explore whether students interpret these elements as playful or performative – and how that perception influences learning outcomes.

3.3 Data Collection

The pedagogical impact of the VR-based intervention was evaluated through a structured post-activity survey administered to all 28 students. This survey captured students' perceptions across three dimensions: Engagement, motivation, and perceived relevance to academic and professional preparation. However, the lack of a more robust evaluation and assessment methods limits our ability to substantiate the efficacy of the intervention in terms of actual individual skill acquisition.

Moving forward, we recommend a mixed-methods approach that combines self-reports with direct measures of code quality, participation logs, and perhaps even biometric or behavioral engagement data to provide a more comprehensive understanding.

3.4 Data Analysis

Quantitative responses were analysed using descriptive statistics to identify trends in engagement, motivation, and perceived educational value. Open-ended responses were examined through thematic analysis to extract recurring themes related to student experiences, perceived challenges, and reflections on learning outcomes. The mixed-methods approach was selected to ensure a comprehensive understanding of the intervention's impact (Creswell & Plano Clark, 2011).

4. Results

A total of 20 students participated in the post-activity survey, which assessed their experience with the Virtual Reality (VR) based game development project. The survey included five Likert-scale questions and two open-ended questions to gather both quantitative and qualitative insights regarding motivation, engagement, technical challenges, and perceived learning outcomes.

4.1 Quantitative Findings

Students responded positively overall to the VR activity, with strong agreement on increased motivation, engagement, effort, and enjoyment compared to traditional software development projects.

- Motivation and Interest: For the statement *“During the VR development activity, I felt more motivated than during other software development activities”*, 75% of students rated 4 or 5, indicating elevated motivation. Similarly, 75% rated 4 or 5 for *“The experience of working in Virtual Reality increased my interest in learning new technologies.”*

Motivation and Interest Questions

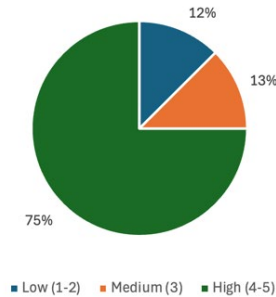


Figure 3: Results of questions related to motivation and interest

- Engagement and Effort: Responses to *“I felt more engaged with the project because of the immersive nature of Virtual Reality”* were predominantly positive, with 75% of students rating 4 or 5. Likewise, 75% agreed or strongly agreed that their *level of effort was higher than usual* in this VR activity.

Engagement and Effort Questions

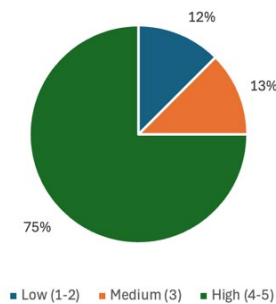


Figure 4: Results of questions related to engagement and effort

- Enjoyment: The statement *“Developing a video game in VR was more fun than developing on traditional platforms”* received somewhat more varied responses, yet 75% still rated it favorably (4 or 5). A small minority expressed lower satisfaction.

Enjoyment Question

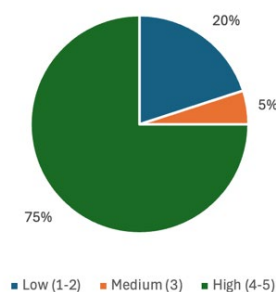


Figure 5: Results of the question related to enjoyment

- Grade distribution: All 14 student pairs successfully completed the activity and deployed their projects to the Meta Quest headsets. Each team achieved a final grade above 90 out of 100, demonstrating a high level of engagement and mastery of the required skills. A graph illustrating the grade distribution is included to provide a visual representation of the consistently strong performance across all teams.

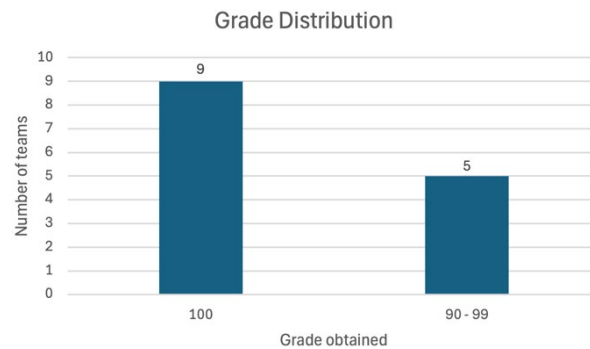


Figure 6: Grade distribution for each one of the 14 student pairs

These results highlight the overall success of the activity and confirm that every student was able to meet the objectives and deliver a functional deployment. They also demonstrate that the immersive VR environment, combined with gamified instructional elements, effectively increased students' motivation, engagement, and enjoyment in the software development process.

4.2 Qualitative Findings

Open-ended responses provided rich insights into students' experiences and the educational value of the VR activity.

- **Overall Experience:** Students described the VR development as fun, exciting, and enriching, particularly appreciating the immersive interaction with their creations. Many noted the novelty of working with VR technology, which is seldom integrated into their curriculum. However, technical challenges were frequently mentioned, including difficulties with headset setup, limited access time, hardware compatibility issues, and the complexity of Unity's 3D environment. A minority felt the activity was rushed or experienced physical discomfort, such as motion sickness. (Fig. 6)



Figure 7: Word Cloud of the overall experience of students

- **Learning Outcomes Relevant to Future Development Careers:** Analysis of the second open-ended question revealed four main themes:
- **Technical Skills and Challenges:** Students learned to navigate the complexities of 3D VR development, including Unity 3D and Meta Quest controls, and gained awareness of the importance of compatibility testing.
- **Problem-Solving and Adaptability:** The activity highlighted the need for methodical debugging, patience, and flexibility when working with new technologies.
- **Teamwork and Collaboration:** Collaborative problem-solving and mutual support were seen as critical for successfully navigating the challenges of VR projects.

- *Personal Reflection and Attitude: While many found the experience rewarding, some expressed frustration or hesitation about similar future projects, reflecting diverse attitudes toward emerging technologies.*
- *Overall, the VR-based project not only enhanced technical competencies but also fostered critical soft skills, such as adaptability, collaboration, and resilience, that are essential for professional growth in software development.*

5. Conclusions

The implementation of this two-week VR video game development activity, using the peer programming technique, proved to be an effective strategy for guiding students through the creation of a novel and entertaining VR video game product.

Working collaboratively allowed them to tackle the technological challenges of virtual reality with greater confidence, while continuous guidance and feedback from the professor ensured that learning goals were met. The peer programming dynamic encouraged shared problem-solving and more profound understanding, which were crucial for engaging with such an advanced and demanding technology.

Moreover, by integrating this project into the course's overarching gamified experience, students were further motivated to go beyond the basic requirements. The opportunity to earn "diamonds" for adding extra functionality not only sparked creativity and initiative but also reinforced their sense of progression within the course.

Nonetheless, the reliance on student perceptions as the main evaluative metric limits the ability to draw definitive conclusions about learning. Additionally, the VR format may not be equally accessible or effective for all learners.

We recommend future studies incorporate triangulated assessments, longitudinal tracking, and engagement with critical scholarship to ensure that immersive and gamified educational experiences fulfill their pedagogical potential without becoming tools of superficial engagement or technocentric hype.

This alignment between cutting-edge tools and playful learning design significantly enriched the students' educational journey, making the use of relevant and current technology both meaningful and enjoyable.

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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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Teaching Industrial Engineering Through Simulators Based on Gamification and XR Reality

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Abstract: The effective integration of gamification in industrial engineering education is increasingly gaining attention for its potential to enhance student engagement and learning outcomes. At Tecnológico de Monterrey, we seek new and innovative activities to improve the learning process. This research shows the results in three years of teaching with the MxREP ERP, Quality, Statistics, Project Management, and Data Science, implementing gamified classroom activities within the Industrial Engineering Department, focusing on using Enterprise Resource Planning (ERP) system simulators. These simulators are complemented by data visualization tools, project evaluation software, and lessons incorporating augmented and virtual reality (AR/VR) technologies. The primary objective is to assess how these tools influence students' learning experience and academic performance. The simulators utilized in the program replicate real-world ERP systems, providing a hands-on approach to understanding complex business processes and decision-making scenarios. Through interactive simulations, students can apply theoretical knowledge in controlled, risk-free environments, thereby reinforcing their comprehension of ERP systems' functionalities and interdependencies. Data visualization tools further supplement this learning by enabling students to analyze and interpret large datasets, fostering critical thinking and analytical skills essential for industrial engineers. Project evaluation tools embedded within the curriculum offer students the opportunity to manage and assess the progress of simulated projects. These tools are designed to mimic the project management challenges faced in the industry, encouraging students to develop strategic planning and resource management skills. The incorporation of AR/VR lessons Berglund (2023) adds an immersive dimension to the learning experience, allowing students to explore virtual factories, conduct virtual inspections, and interact with digital twins of industrial systems. This technology enhances engagement and provides deeper insights into system operations and problem-solving techniques.

Keywords: Higher education, Educational innovation, Gamification, MIX reality

1. Introduction

In 2019, prior to the COVID-19 lockdowns, a need was identified to create learning experiences more closely aligned with the realities of daily operations in a manufacturing company. This was to enhance the impact of learning on students, ensuring it extended beyond purely theoretical knowledge. The TEC20 academic model was designed to transition from a project-based and knowledge-assessment model to a competency-development model. At the core of this new model was the development of challenges, defined as problem-based scenarios designed by a "partnering stakeholder" (an external agent from outside the university). These stakeholders, in collaboration with professors, establish the framework for competency development that enables students to solve the challenges.

2. Development

In 2019, engaging with companies for facility visits, process analysis, or securing real-world or realistic projects was challenging. Limitations included space constraints (visits capped at 15 students for groups of 35) and process confidentiality. Consequently, professors often resorted to adapting cases for instructional purposes. Industrial Engineering, a field integrating techniques and methodologies from mathematics and statistics, equips students to identify, modify, and manage parameters for operational excellence in manufacturing. However, some Industrial Engineering topics become theoretical and lack practical application due to the absence of real-world problems or lab-based experiential learning. This can lead to student disengagement, distraction, and loss of interest, necessitating a blend of active, realistic, and captivating exercises. The Department of Industrial Engineering and Systems at Tecnológico Campus Querétaro initiated two key strategies. First, an "Integrative Workshop" was implemented at the end of each semester, involving multiple departmental classes in a day-long project. Second, a board game was developed to simulate processes within an assembly company, from customer order placement to final product delivery. The game, designed to be flexible and adaptable to

individual professor's classes, centered on assembling a Meccano car within fifteen minutes to allow for sufficient learning iterations. Gonzalez et al (2022)

2.1 Impact of Confinement

The COVID-19 confinement accelerated the need for virtual assembly and manufacturing labs and plants. However, the initial months revealed a noticeable decline in learning outcomes across both educational models. Previously undetected restrictions emerged, including student isolation, stress from lack of social interaction, boredom, excessive screen time, and workload. Summer 2020 saw a hybrid development combining the Tec21 car assembly with a digital environment using augmented reality (AR) on the EON XR platform. However, material explosions, line capacity calculations, and statistical process control/forecasting were conducted in Excel and Minitab. While providing a robust learning platform, this approach overwhelmed students, leading to negative perceptions of the lesson. Learning occurred, and the AR platform was accessible; however, student confinement hindered teamwork, transforming multidisciplinary projects into aggregated individual efforts with fragmented learning. This context led to the development of the Tec21 virtual car assembly plant: an online computer game simulating professor-designed scenarios using a Meccano car assembly. This platform integrates AR and virtual reality (VR) practices for the modeled assemblies, incorporating gamification for individual or team-based problem-solving. Prior to the summer, the R&EIT educational innovation research team employed undergraduate research fellows. Despite their talent, these students exhibited a tendency for distraction through mobile phone use. Some professors perceived technology as a distraction rather than a learning tool. A survey in Summer 2021 assessed students' weekly gaming hours and classroom gamification activities. Recognizing the emotional impact of student confinement and the potential of gamification in simulators and virtual plants, R&EIT explored readily available AR lessons. EON XR lessons were adapted to the board game models. Concurrently, projects were launched to create proprietary VR/AR lessons based on the physical Meccano car models, which were being 3D-modeled in Autodesk's Fusion 360 platform.

2.2 Theoretical Framework

According to Alex Games (2014), play is the primary mode of learning, involving experimentation, iteration, and pattern recognition within a trial-and-error loop to develop winning strategies. Addressing concerns about student emotional well-being, academic quality, and competency development (transversal and disciplinary), a methodology was implemented. This methodology proposed by Gonzalez et al (2021) combined design of experiments and design thinking to identify a "success zone" in design, defined by the intersection of three key variables: engagement, competency development, and learning. Abstract concepts were mathematically represented as measurable variables to pinpoint the optimal learning environment. Designs were then focused on achieving results within this zone, ensuring gamification success (Figure 1).

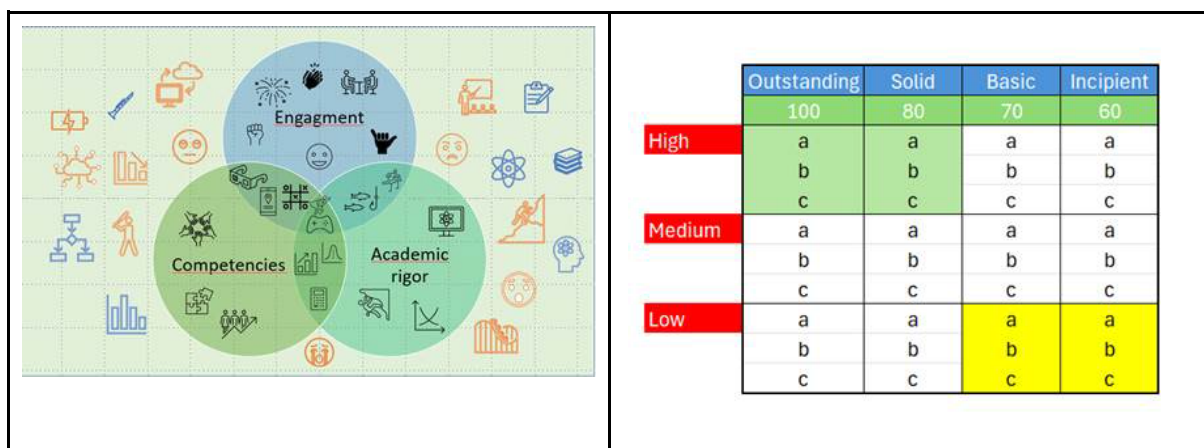


Figure 1: Design Thinking and Design of Experiments Methodology for academic lessons

Education often conflates gamification, serious games, and game-based learning. This confusion stems from serious games and game-based learning utilizing games as a foundation for motivating learning. Gamification in education strategically incorporates game design elements to enhance learning within a specific discipline. Key elements include immediate feedback, points systems, motivation to win, recognition, and the freedom to make mistakes and retry. (Deterding 2011) (Kim 2015) Serious games are technology-driven designs with a defined learning purpose beyond mere entertainment. They are intentionally designed for educational objectives, encompassing our simulators and VR/AR practices for modular learning in Industrial Engineering (Figure 2).

Serious games can be described as purposeful games aimed at addressing real-world problems in controlled, life-emulating environments. While they can be enjoyable to boost engagement, entertainment is not their primary goal. (Wouters et al 2013). Game-based learning uses games as instructional/learning tools, representing learning through games within a professor-designed educational context. These are typically existing games with defined rules, designed to balance entertainment and player skill in retaining concepts. (EdTec Review 2013)



Figure 2: Game elements used in the MxREP Simulator

3. The MxREP Simulator Development Process

The MxREP simulator facilitates learning across Industrial Engineering disciplines using a Meccano car assembly plant that replicates ERP system processes. It leverages a robot ("Chencho") to optimize variables across departments for maximum company profits. The simulation is accessible online and supports teamwork. Existing manufacturing process simulators often lack product visualization. Emulating SAP processes is easier with products using three or four row materials, which doesn't expose students to the complexities of real-world bill of materials management in car manufacturing. VR/AR lessons bridge this gap, providing students with the experience of visualizing car assembly component by component.

3.1 XR Technologies

Augmented reality (AR) overlays digital information onto physical environments, using devices like smartphones. Given the widespread smartphone ownership among engineering students, AR is a democratizing technology for delivering educational content. Virtual reality (VR) immerses users in digital simulations where they can manipulate objects and interact with the environment. VR's educational limitations include the need for specialized equipment (VR labs) and a focus on collaborative rather than individual work due to time/space constraints. Mixed reality (MR) combines AR and VR, projecting digital environments onto the user's real-world surroundings via devices like headsets. A PwC study, "What does virtual reality and the metaverse mean for training?", investigated post-COVID-19 employee training and learning challenges. The study highlights the dilemma of remote and hybrid work's impact on upskilling: "Employers are facing a dilemma: Their workforce often needs to learn new skills, upgrade existing capabilities or complete compliance training. Yet the new reality of remote and hybrid work has made traditional, in-person upskilling more challenging. Online and app-based courses can fill in some gaps

but not all. So how can employers deal with this challenge?" The PwC study indicates that VR training enables employees to learn four times faster, feel 275% more confident in applying their knowledge, and experience 3.75 times greater emotional connection to the learning process.

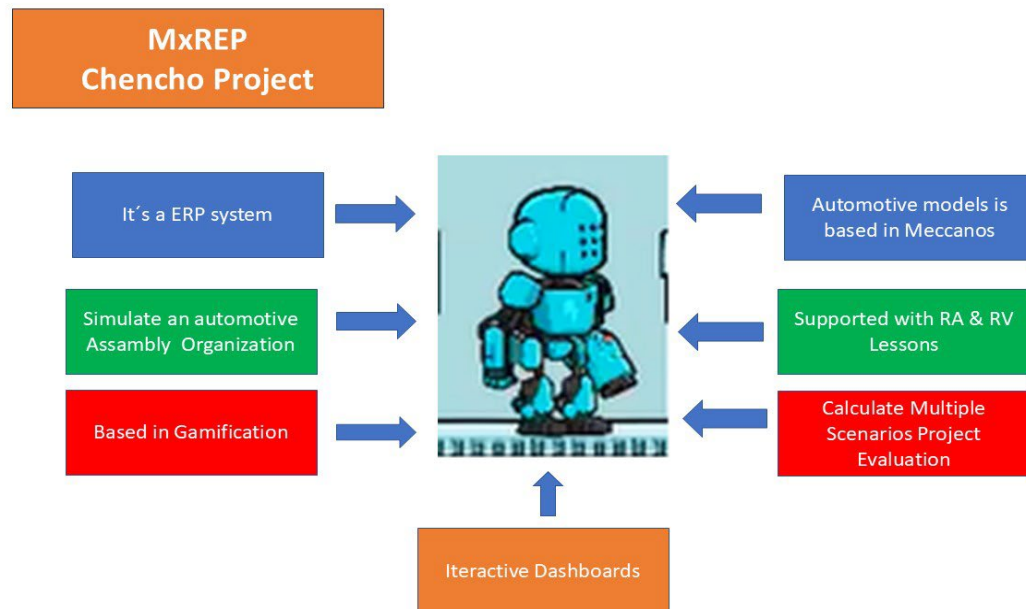


Figure 3: The MxREP Futures deployment in the simulator rounds

3.2 How MxREP Works in the Industrial Engineering Learning Process

The MR REP simulator (Figure 3) aims to accelerate the learning of complex engineering topics through lessons designed for three learning domains:

- In-depth product knowledge (geometry, bill of materials, mechanical interactions)
- Layout design, material flow definition, assembly strategies
- Quality principles through problem-solving lessons using the 7 quality tools or DMAIC.

The simulation lets the users manage and control a virtual manufacturing company, being in control of the different inventory, processes, employees and orders. Taking a hands on approach to optimizing the construction and completion of the orders in a safe and test-focus environment.

Starting with the simulation the users can find themselves in the first area where they can manage the raw materials used for the construction and assembly of the vehicles.

3.2.1 Raw material

Users will be able to manage their resources, order materials from different suppliers and manage their inventory. This will enforce the strategizing abilities and their organization; maintaining the necessary logistics of all the materials needed for the production of different products. With this, the users can plan the logistics of the different orders, maintaining the necessary stock and reducing costs or having excess inventory.

3.2.2 Employees

To create all the necessary products, the user can't do it on their own, so getting some help is essential to finish all orders in time. To do that there is a panel to hire and manage employees, assigning them to different areas or phases in the production line. This generates a cost, time implication and essential workers that needs to be taken into account when planning orders and managing production.

3.2.3 Fixed assets

The last panel is for managing fixed assets. These will help the user acquire certain tools that will help them improve productivity, quality or increase production. Creating a goal for the user to grow and increase the efficiency of the company as much as possible and be able to generate lots of money while cutting costs.

3.2.4 Production flow

The simulation gives the opportunity to manage orders for different products with an expected delivery date. For that reason the player should be ready with all the materials necessary prior assembly, or order them as

soon as possible to avoid delaying the delivery (Figure 4). Followed by the activation of the production lines necessary to process the raw materials into the finished product and get a return of investment with profit. This will conform the basic flow of actions a player must follow on an everyday basis analogy, but progress is key to maintain entertainment and investment of users, so the fixed assets available for purchase and the always improving efficiency of the factory will be making the player come back into the simulation and use the topics learned in class to optimize the production and increase earnings as much as possible.

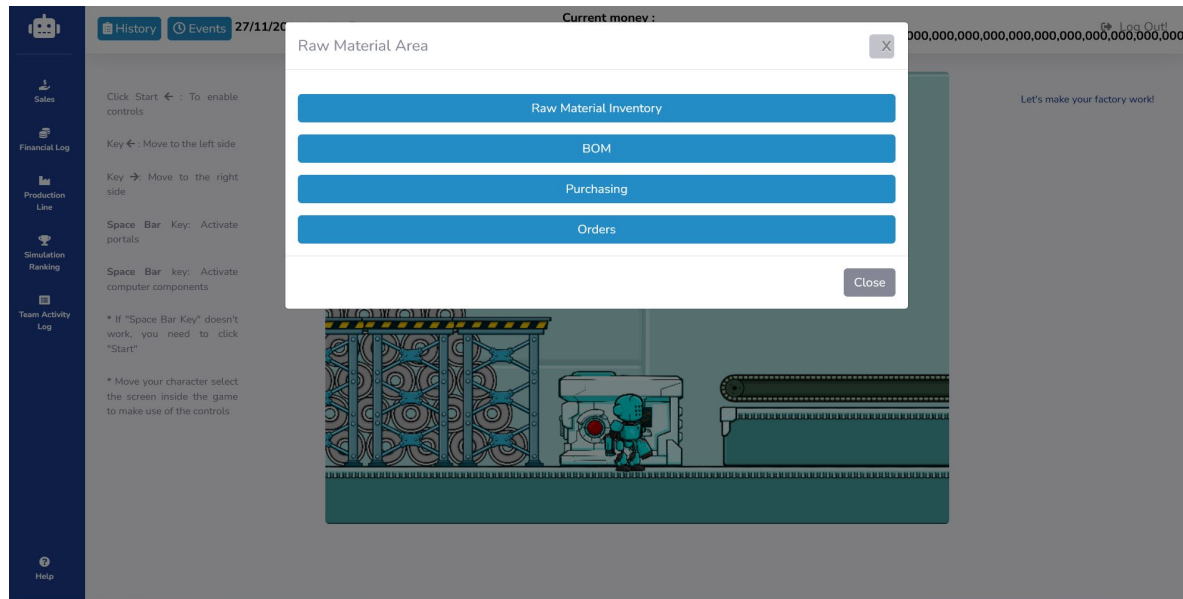


Figure 4: Raw Material Area menu with inventory management options

3.2.5 Sales

In this tab, users are able to view and manage their product sales data. The interface will show a table with various entries, which include data such as the product name, cost, and the final price, allowing the student teams to monitor their revenue performance and make strategic business decisions based on product profitability. Just as in real life scena.

3.2.6 Financial Log

The Financial Log tab gives the user detailed visibility into their organization's cash flow activities. The user is presented a structured data table with filtering capabilities that allow users to segment financial records by transaction type (Expense) and status (Purchasing Raw Material), alongside a date range selector (November 1-30, 2024) for temporal analysis. The main data display is designed to present transaction details across multiple dimensions, including Type, Status, Date, Before Amount, Amount Expense/Income, and After Amount, effectively tracking the financial impact of each operation within the simulation. The user can also toggle between a data table view and a graphical representation, supporting both detailed transaction analysis and trend visualization to help student teams make informed financial decisions and manage their simulation budget effectively (Figure 5).

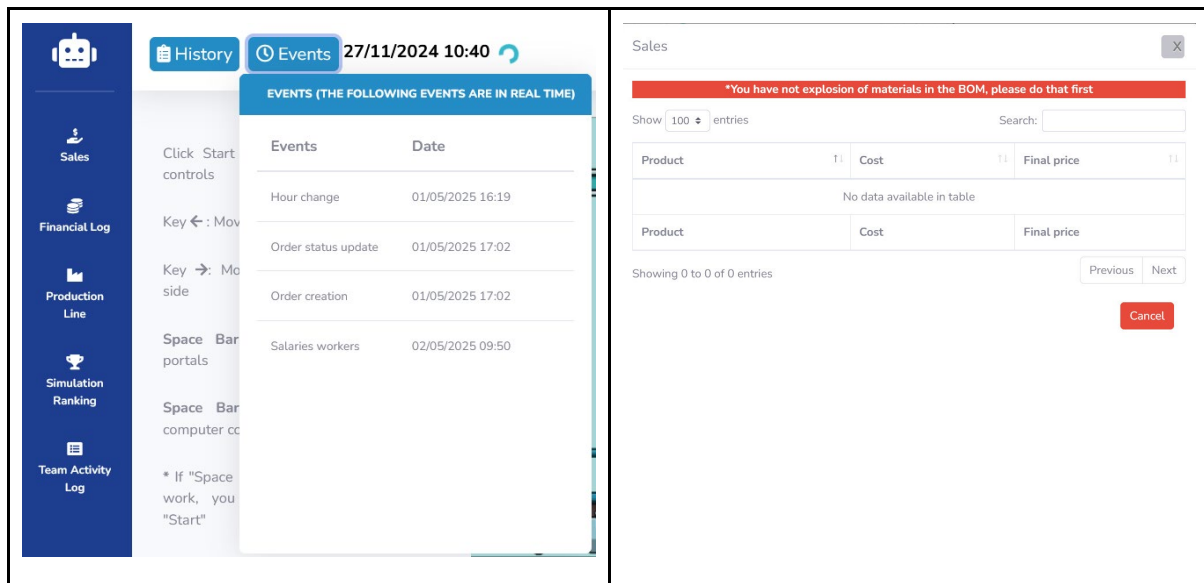


Figure 5: a) and b) Real time events calendar with upcoming factory operations and sales tables awaiting BOM

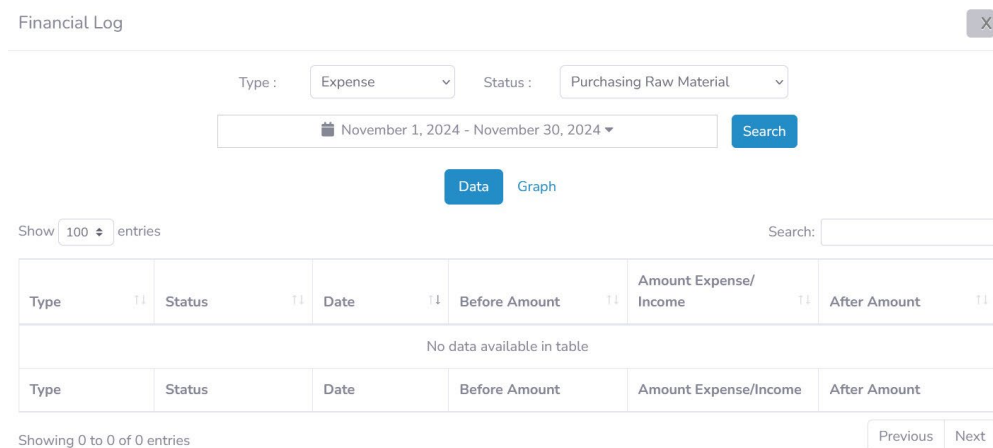


Figure 6: Production Line Tab, Six-step F1 manufacturing workflow interface

3.2.7 Production line

The production line tab (Figure 6) allows users to configure and activate different production workflows. The interface displays available production line templates (in this case F1, Buggy, and DRON) on the left, while the main section shows detailed configuration options for the selected template. For the F1 production line, the system has a six-step manufacturing process representing a complete vehicle assembly workflow. Users can specify resource allocation by defining quantities of both fixed assets (specialized control and marking machines) and human resources (employees) required for production operations. This production line tab helps student teams to make strategic decisions about production capacity, resource utilization, and manufacturing processes.

3.2.8 Simulation ranking

The simulation ranking tab is meant to increase competitiveness inside the simulation, improving the engagement the students have with this application. It provides users with a clear visualization of their team's standing relative to other participants. This is an important gamification element added to the learning experience.

3.2.9 Team activity log

The team activity log tab serves as a monitor system for the students, users can filter activity by the type (Simulation, Finance, BOM, Purchasing, Raw Material, Employees, Production Line, Sales, Ranking, and Orders) inside the left panel, select specific team members for a focused analysis in the center panel, and also view

detailed timestamped activities on the right panel. This tab serves as both an accountability tool and a historical record of team operations (Figure 7). This collaborative transparency enables teams to coordinate their efforts, maintain awareness of actions taken by teammates, identify potential workflow bottlenecks, and analyze patterns in team member engagement.

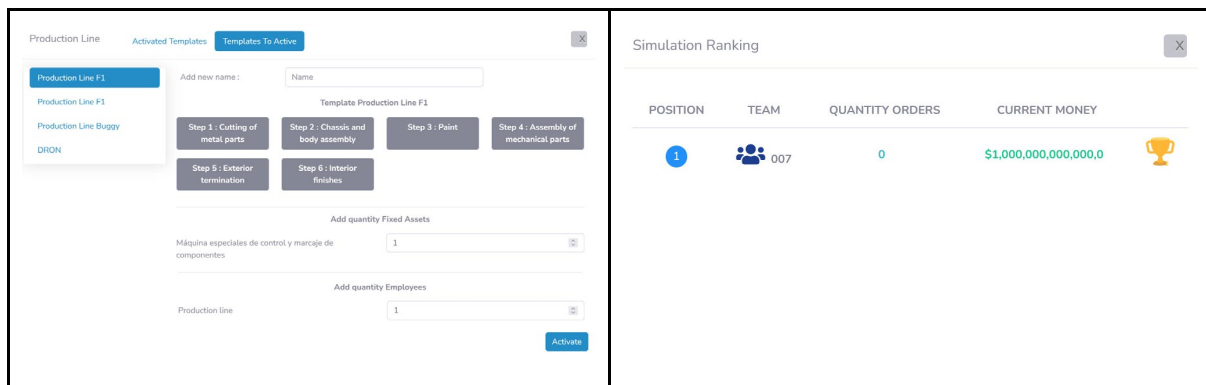


Figure 7: a) and b) Financial Log Tab, financial transaction tracker with type/status filters. Simulation Ranking Tab, team leaderboard showing position and assets

3.2.10 Collaboration

This simulation allows and promotes team building and collaboration of different users to complete all tasks in the factory, allowing for specialization in certain areas, community and a common goal that can bring people together, or allow for friendly competition amongst a classroom. This is not only to improve social and communication skills, but to create a share experience environment, letting the students help each other on different topics.

4. Results

Over the past 5 years, we have implemented the virtual plant an average of 9 times per year in different learning units (UF) within Tecnológico de Monterrey, every UF has two groups, every group average 31 students. In the last 3 years, we have introduced various improvements, such as distribution centers for the logistics module and more products that can be assembled (e.g., drones), which has increased our capacity to impact a larger number of students. For this research, we present the results implemented in the latest learning unit for the Industrial and Systems Engineering program, involving two groups of 26 and 29 students. Both groups had to solve a problem-based scenario focused on designing a drone manufacturing plant, requiring them to learn how to calculate line capacity and design the plant layout with the total number of machines and employees.

A pre-test was developed, consisting of 20 questions randomly selected from a pool of 50. Subsequently, the students completed the entire exercise, which included hands-on practice with physical drones, followed by using the simulator and accessing the virtual and augmented reality lessons. The results are presented below Figures 8 and 9.

Statistics

Variable	Total Count	Mean	StDev	Minimum	Q1	Median	Q3	Maximum	Range	Mode
Pre Test	25	67.60	16.78	45.00	50.00	70.00	80.00	95.00	50.00	45, 50
Post Test	25	92.20	9.58	65.00	85.00	95.00	100.00	100.00	35.00	100

Variable	N for Mode
Pre Test	4
Post Test	12

Figure 8: Descriptive statistics of the Pre Test y Post Test escenarios

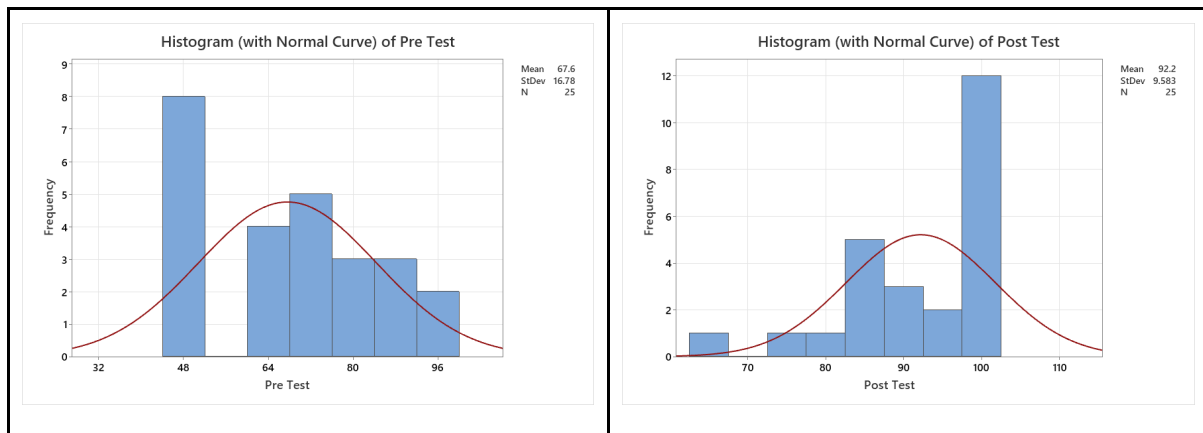


Figure 9: Distribution comparison between Pre y Post Test

The statistical results are shown by applying a pre-test on knowledge of line capacity analysis to students from the G1 of the UF IN3001B Design of a Smart Organization. As seen in Figure 8a, most of the data are skewed to the left with a low average; 8 out of 25 students scored 45 out of 100. The exam consists of 20 items generated from a database of 50 questions, aiming to minimize the risk of copying or having identical exams. After conducting the Simulation Session, it can be observed in Figure 5b that the vast majority of students, 12, achieved a maximum score of 100 on an exam consisting of 20 questions using the same database of 50 as in the pre-test. The paired t-test shows that the hypothesis that traditional learning and learning based on immersive technologies with an ERP component are the same in students is rejected. A t-value of -9.78 indicates sufficient evidence that immersive learning based on the MxREP simulator, combined with XR technologies in a stressful environment generates better knowledge among students.

5. Conclusion

The theoretical model underpinning the MxREP simulator and the augmented and virtual reality lessons allows us to highlight the robust design of this learning ecosystem. Its primary focus is on developing disciplinary and transversal competencies, but it has the potential to be scaled to industrial applications, transitioning from a serious game to an exclusive ERP platform. The experience gained in the initial years of implementation enabled a redesign of the simulator towards gamified learning. This shift facilitated a rapid acquisition of industrial engineering concepts and, crucially, enhanced the retention of key concepts. It also motivated students to engage in competition through immersive learning, compelling them to refine game strategies based on operational excellence in the car assembly process.

Having a digital twin of the product, encompassing the various car models, provided students with a comprehensive experience akin to being in a manufacturing plant. This approach not only fostered disciplinary learning but also cultivated essential life skills, such as problem-solving, analysis under pressure, teamwork, critical thinking, and, above all, confidence in their acquired knowledge. From a design perspective, incorporating students from computer technology programs allowed for a balance between learning objectives and optimal learning methodologies. This resulted in heightened student engagement with the simulator and the lessons developed within it, as well as in the virtual and augmented reality lessons. Budgetary constraints were addressed through a modular design approach, similar to assembling Lego bricks, where components were connected as soon as they were ready to form the simulator's core, utilizing interfaces. This aspect of project management is noteworthy, as it required implementing the four types of thinking for educational innovation projects—systemic, concurrent, prospective, and resilient—for each team member.

Across these five years, more than 25 research protocols applied during the use of the MxREP simulator have consistently demonstrated a significant improvement in learning outcomes when comparing traditional instruction of industrial engineering concepts with lessons based on emerging technologies like AR, VR, and process simulators. Future work will focus on compiling the data generated from the various simulations to derive knowledge using artificial intelligence. This will enable us to identify patterns and obtain results that enhance the quality of demand forecasts, for example, or suggest workstations and/or parts where errors causing low organizational productivity may be located. And these concepts, which can be complex, are learned in an immersive and enjoyable way through the design of serious gamification.

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Teacher Positions and Play Qualities in Esports at Specially Planned Youth Education Programmes

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Abstract: This paper examines how teacher roles influence gaming activities within esports programmes offered at Specially Planned Youth Education (STU) in Denmark. The STU programmes cater to young people with developmental, cognitive, and psychosocial challenges, who are unable to participate in mainstream education. This paper introduces play theory as a valuable framework for understanding how teachers facilitate gaming, especially in the context of structured esports programmes. Traditional approaches to game-based learning often focus on goals, achievement, and knowledge transfer. In contrast, this study emphasizes the affective and sensory dimensions of gameplay using concepts from play theory. Our study is based on two years of fieldwork at three different institutions. We collected data through observations, interviews, and video recordings. The empirical data is based on observations and presented in the form of three detailed narrative vignettes, each illustrating a specific teacher-student dynamic while playing either *League of Legends* or *Counter-Strike*. These narratives demonstrate how changes in teacher positioning influence the emotional flow of the gaming environment, with shifts between moods such as devotion, intensity, tension, and euphoria. In the context of STU institutions, we find that teacher presence plays a crucial role in helping students regulate emotions, stay engaged, and connect socially. A teacher can help calm a high-intensity situation or raise the energy and focus of a group through timely intervention. These dynamics are especially significant for students with special needs, who may rely more on adult cues and support to navigate social situations. Our findings highlight that successful facilitation of esports in special education settings depends on teachers' ability to read and respond to the emotional and sensory dynamics of play. Teachers who can shift roles fluidly not only affect game-related performance but also contribute significantly to the social and affective experience of the students. This paper provides new insights into the potential of esports as an educational tool and proposes that play theory offers a valuable framework for understanding game-based learning beyond a narrow focus on learning outcomes.

Keywords: Play, Gaming, Esports, Special education, Teacher roles, Vulnerable youth

1. Introduction

The use of commercial games as part of special education curricula have become increasingly common in Denmark in recent years. In particular at the Specially Planned Youth Education for young people aged 16-25 called STU. Here, we focus on Esports programmes at STU, which are offered as specialised tracks or elective programmes at nearly 20 STU programmes nationwide (stuguiden.dk). The young people who enroll in esports tracks often do so in consultation with their municipal youth guidance counsellors (KUI-vejledere), based on their interest in gaming.

A previous study has focused on how game-based teaching can be divided into different phases of planning, orientation, playing, and elaboration (Kangas et al 2017). These phases call for different demands and competencies for the teachers. However, little emphasis within research on game-based teaching has been put on understanding educational gaming as a playful and situated activity. In fact, earlier research on games and learning tend to background playful aspects of games and instead emphasize games as more or less instrumental tools that can ensure specific learning outcomes (Nolan & McBride, 2014)

Following this, we argue that game-based teaching in the context of special education should be conceptualised as a playful activity, which we can understand by drawing on insights from play theory. In this paper, we unfold two aspects that can help enrich our understanding of gaming as a playful activity. The first is the feel and rhythm of playing videogames. It is an aspect that builds on phenomenological understandings of how players experience gaming activities and how games and players are connected (Keogh 2018, Vahlo, 2017). What we pursue here is a deeper understanding of what it feels like to be engaged in gaming activities primarily from a student perspective in the particular setting of the STU? Second, play theory is introduced to focus on how teachers position themselves in and around gaming. Our interest here is what kind of change shifts in adult positions have on students' game experience, feel and rhythm?

To answer these questions, we start by introducing the context of gaming activities at the STUs. Then, we introduce our theoretical perspectives, which are a blend of game and play theory connected by key concepts

of rhythm and feel. Before we present our empirical data, we account for our phenomenological perspective on gaming and the impact this has on how we present the data. Lastly, we discuss the implications of the roles of teachers when facilitating social gaming activities and possible potentials moving forward.

2. Context: Esports at STU

The STU is an upper secondary education programme for young people with special needs who, for various reasons, are unable to complete regular forms of youth education. The target group includes a wide range of young people with diverse physical and mental challenges. Approximately half of the young people referred to STU are due to general learning difficulties, and about one-third are referred due to developmental disorders such as autism or ADHD (Danish Ministry of Education, 2017). There are around 250 different STUs across Denmark (stuguiden.dk), offered by both private and public institutions.

For more than two years, our research team has followed esports teaching at three different STUs. The primary objective of esports education at the three STU institutions participating in our project is twofold: to develop the students' gaming skills and to enhance their opportunities to be part of a physical community. It also aims to promote personal and social competences that are relevant beyond the esports setting. The esports programmes primarily targets male students. Only one female and two non-binary students were active in the period of our field work. Also all teachers teaching the programmes were male.

The two games we have observed in this study are the competitive multiplayer games *League of Legends* and *Counter-Strike*. In both games, two teams of five members compete against each other. While *League of Legends* is a fantasy-based strategy game focused on controlling characters, called champions, with unique abilities in a dynamic, top-down battlefield, *Counter-Strike* is a tactical first-person shooter rooted in realistic settings and precise gunplay. Both games emphasize teamwork, communication, and strategic coordination, making them well-suited educational environments for working with social skills among the STU-students.

3. Method

The empirical data in this paper stem from the project "Esport as a Learning Space and Bridge Builder for Vulnerable Youth at STU" (2023-2026), in which a research team of five has collected data through field observations, video recordings and interviews with the students, teachers and youth guidance counsellors.

The data for this study is mainly based on observations and field notes and is presented in the form of vignettes (Stevens et al., 2008) drawn from the above material. Our vignettes are condensed narratives based on recurring patterns of social interaction in our empirical data. Based on a phenomenological perspective, the aim is to depict how students at the STU are not simply acting in a virtual world, but that playing a videogame must be understood as a cybernetic circuit (Keogh 2018). Through their social gaming activities, students incorporate technologies and audiovisual-haptic feedback that extend, restrict, and ultimately augment their embodied experience into complex assemblages of capacities and processes (Ash 2013, p. 34). In a cybernetic understanding of videogame play, the player's body is not left behind in the actual world while we focus on the action taking place in the virtual world. It is a meshing of the different bodies where the players both produce and perceive the play experience that our empirical vignettes try to capture. Therefore, action in and across both worlds will be presented in our vignettes. Additionally, the vignettes attempt to capture aesthetic elements of videogame play such as the feel (Swink 2009), the rhythm (Jayemanne 2017), the timbre (Kanaga 2011), the attunement (Ash 2013) and the mood (Skovbjerg 2021). Lastly, all vignettes portray the interaction of the teachers and the students in the room, the positions they take, and how they affect the rhythm of play. Ultimately, because esports programmes at the STUs are in such a specific setting, what we try to accomplish with the vignettes is to give coherent, easily understandable, yet sensitive depictions of our data.

Before we turn to our vignettes, let us first explore the aesthetic dimensions of gaming and consider how play theory can enrich this perspective. We will also outline the positions teachers can take when facilitating play, as proposed by play theorists, and discuss how these roles can inform practices in social gaming contexts.

4. Theory

Videogames possess an embodied textuality making what the game is about inseparable from what it feels like to play. Several game theorists have through various concepts attempted to describe the aesthetic aspects of videogame play. For instance, Swink (2009) has explored what it feels like playing a videogame. What makes a car heavy, a rifle meaty or the controls of a game tight? Specifically, with regards to game controls, Kanaga (2011) has introduced the music term timbre, which is a particular rhythm of movement. In this view, playing a

set of chords on a guitar gives the same feeling as doing a triple jump in SuperMario. On a macrolevel of overall game pace, Jayemanne (2017) points toward diachronic and synchronic elements of play as fundamental to understanding videogame time. When playing a videogame, interconnected, overlapping, and differently paced temporalities are at play. The muddle of performances of players at different stages of the game is what constitutes the fabric of a video game.

At the STUs we see differences in rhythm through the two games played at the STUs. Playing *League of Legends*, each game can easily extend over 30 minutes of playing time, including different stages in which divergent strategies for obtaining key objectives can take place. This facilitates a slow rhythmic build-up across early-, mid- and end-game phases. Conversely, a round of *Counter-Strike* only last around two minutes, in which several player characters may have been killed, and a bomb has either gone off or been infused. As a full *Counter-Strike* match comprises a maximum of 24 rounds, the gameplay of planting and defusing explosives is as much about repetition as it is about progression. Failure (i.e. getting killed) and repetition (i.e. trying again next round) becomes a vital component of progression and help players become more attuned to the rhythms of the game. Ash (2013) defines attuning oneself to a game as the self-management of an assemblage of bodily capacities and cognitive processes, which together comprise a specific affective state.

From a play theoretical perspective, it is exactly the shift in rhythm between repetition and change that makes up the theoretical framework of play moods developed by Skovbjerg (2021). In her work, Skovbjerg identifies four different moods that range from highly structured to ambiguous and fluid, depending on how repetition and variation unfold in practice. Moods are associated with core actions that involve building, fiddling, balancing, jumping, performing, pretending, smashing, and yelling among others. The mood of devotion is defined by a sense of flow, lightness, and calmness, with the body engaging in soft, fluid movements. Play in this mood is quiet, repetitive and demands precision and concentration. The mood of intensity is characterized by bodily sensations such as tingling excitement, butterflies in the stomach, and the anticipation of holding one's breath. It includes strong feelings of joy, excitement and frustration. Intense play is loud, fast and emotional. The mood of tension occurs as participants experience a sense of connection with the social environment, reinforcing the shared nature of the play experience. During play in this state there is a feeling of balancing a fine line between success and failure. Something is at stake here, often times you are being watched while performing. And lastly, the mood of euphoria brings about an intense and heightened emotional state, that is only fleeting and cannot be sustained indefinitely. The mood of euphoria is about ecstatic happiness and a sense of freedom. Rules and norms are sometimes broken, and a spontaneous outbreak of euphoria has a tendency to spread to other participants in play. The moods of play are not meant to be understood as static. Moods can change during play and there are no clear-cut boundaries between the four listed moods. In our vignettes we see how moods change, and our interest lies in pointing out the potential of adults being aware of different moods and how their interaction around play can sway the mood of play in different directions.

Several studies show that the participation of pedagogues in children's play activities, can support children in recognizing each other as potential playmates and strengthen social interaction (Ludvigsen et al., 2005; Skovbjerg & Henningsen, 2017). Pedagogical staff are, however, only to a limited extent successful in creating equal opportunities for participation in children's play communities (Danish Evaluation Institute, 2020). This is especially worrying for children in vulnerable positions as studies show that they are more frequently excluded from peer communities and find it more difficult to participate in the play communities within early childhood settings than other children (Stanton-Chapman, Walker, & Jamison, 2014). The risk of exclusion follows through when children reach school age and beyond (Hansen et al., 2018, Hansen et al. 2020). This group tends to direct their attention less towards others of their own age and more towards the educational staff (Kuutti et al., 2021; Harper & McCluskey, 2003) and therefore rely on professionals to keep them engaged in play communities.

Bork (2023) has provided the following map of different positions professionals can take when interacting with play communities.



Figure 1: Play model for choice of positions in communities of play (Bork 2023, p. 4)

As illustrated, adults can either position themselves inside or outside the context of play. Similarly, the teachers at the STUs can actively participate in gaming contexts either as co-players or playing coaches. Conversely, they can also withdraw themselves from the actual gameplay and position themselves either as an observer or instructor of play. Focusing on the other axis, adults can seek initiative by instructing the gameplay from either inside or outside the game, or they can opt to follow the initiative of students by either observing them play or by playing along with them. In relation to the positioning of adults in and around play, research has shown that there are several barriers among professionals to engage in play activities, as participating wholeheartedly in play can lead to a feeling of embarrassment and insecurity. Furthermore, there is a fear among pedagogues and educators that engaging fully in play will lead to a loss in recognition among parents and peers, because while playing it is easy to let go of the controlling aspects of childcare. Therefore, it is vital for the management to facilitate a strategy to effectively grow a culture where play is seen as important and where it is appreciated that the individual employee shows capacity for play courage (Winther-Lindqvist, 2023).

With these lenses in mind, we present three vignettes, one from each STU, illustrating the embodied interaction between the students and the games, the positions of the teachers, and the shifts in rhythm and mood during gameplay.

5. Analysis

In the following three sections, we present a vignette based on field work from each of the participating STUs. Before each narrative, we give a short introduction to the teacher and the surroundings. The vignettes are coupled with a short analysis of the teachers' change in position. In the discussion following the vignettes, we discuss the change in play moods and the impact the teachers have as they occupy roles of observer, instructor, playing coach and co-player.

5.1 From observer of Play to Instructor of Play

At the first STU, the vignette shows a tiny group of young adults and a single teacher. Usually no more than seven students are present, and they are situated in gaming chairs with individual PCs. Rules are strict in terms of keeping each station clean, and the small room is organised in such a way that the teacher freely can move about behind the chairs and observe the gameplay on the screens. At other times, a whiteboard at one end of the room is used by the teacher to help facilitate discussions on key aspects of the only game they play during

his sessions: League of Legends. In this first vignette, the group is in the midst of a competitive game against a team of online opponents. The vignette highlights a situation where the teacher changes position from observer of play to instructor of play, thereby influencing the play mood of the situation.

5.1.1 VIGNETTE #1

A champion emerges from the inner turret zone at a measured pace, armored from crown to heel in polished Demacian steel. The blue and gold of his standard-issue cape is dulled by trail dust, but the lion crest on his shoulder remains clearly visible. The central path is a quilt of worn stone slabs, many of which are cracked or partially overtaken by creeping vegetation. Flanking the lane are retaining walls, blackened with fire damage and overgrown in places.

There is a magical resonance in the air and in the distance wildlife and distant combat indicators suggest action elsewhere. As he passes, the nearby turret's crystalline core pulses once then fade back into dormancy.

Controlling the action is a student in a black hoodie. His left hand hovers lightly over the keyboard—fingers curled, resting on WASD—while his right hand glides the mouse with fluid, practiced precision. His eyes flick between the mini-map and the center screen, scanning terrain, cooldown timers, movement patterns.

Behind the student, the teacher passes through the rows, the way he always does—half patrol, half ritual. He stops behind the student's chair, gaze narrowing. His arms remain crossed, but there's a weight to his stance now.

From the river bend near the champion, two hostile signatures emerge from the brush. The first one bursts forth in a lunge, his blade cleaving outward in a wide, red-streaked arc as sand trails behind him. The champion turns quickly. A golden shimmer pulses around him as he charges forward for a single, stunning strike. Sparks fly on impact and the foe recoils. No time to react, an axe drops with a blunt, crushing weight. The champion flinches, knees bending slightly from the force.

The champions form hardens momentarily, coated in a brief golden aura. Then, with a sudden shift, he pivots and spins—his sword flashing in a continuous circle, blurring into a whirlwind. Dust kicks up. The second enemy stumbles back, his form flickering red and drops in a burst of light.

The teacher nods once. "There it is," he says, voice low but clear. "You timed the damage reduction perfectly—took the hit, didn't panic. That spin? Clean execution. You held the pivot just long enough to catch both of them on the edge. That's new. You weren't doing that last week."

Then, without pause, he adds, "Next time, watch your position near the brush. You gave up angle before you knew who was missing." A pat on the back. Then he moves on. Smiling, just a little bit.

The vignette illustrates a recurring pattern of the teacher's way of engaging with his students during matches. He walks around the room, quietly observing the action, while occasionally shifting position to instructor giving very precise gameplay related praise or pieces of advice. From the student's perspective, we first get a glimpse of the immersive feeling of entering a fantasy world as a badass armored knight. Looking at the narrative from a theoretical point of view, we observe the timbre (Kanaga 2011) of gameplay as the student, while playing, is aware of the rhythmic clicking of the mouse to make the champion progress forward, as well as the constant checking of map position, accumulation of resources and demands of teammates. It takes a certain level of experience and mastery to execute what might be described as a stroll in armor through a magical world, but once obtained there is an almost meditative flow to it all. The small precise movements of the hands and the concentrated awareness of all the parameters makes for a play mood akin to much creative and construction play, which again aligns with the play mood of devotion (Skovbjerg 2021). The calmness and routine feeling of the play is shattered once the champion player is catapulted into combat. While the intensity of the battle does not involve the controlling player jumping or running in or around his chair, the heightened feeling of excitement and the increase in speed of action is clearly visible as he controls the champion.

What the teacher does to the mood as he steps in is a reinstalment of the previous calmness. He breaks down the motions in easy digestible steps and points out the progression of the student, thereby placing what might appear to be a chaotic battle on a progression journey the student is on and has been on for quite some time. In game theoretical terms we might say that the teacher translates an intensely frantic moment of play into a technical exercise of a specific timbre related to a champion's special abilities. The vignette shows a situation of

play where the mood changes from devotion to intensity and back again, partly due to the active interference of the teacher.

5.2 From Observer of Play to Playing Coach

At the second STU, the esports programme takes place in a larger setting. Two rooms are connected via an open double door, and the capacities make room for approximately fifteen people playing at the same time. There is also a large meeting table in the biggest room and a TV screen often used to showcase highlights from games or to exemplify exercises the teachers wish to drill. Two teachers share this programme while one of them is mostly in charge of media training and the other of gaming activities. The teacher responsible for the gaming part is a former coach at a local *Counter-Strike* club and is an elite level player himself. In this vignette we see him situated in the meeting room, watching the action while the students are in the parallel room playing a competitive online game of *Counter-Strike*, before he decides to actively engage in gameplay to facilitate a change in play mood.

5.2.1 VIGNETTE #2

The teacher sits by a table watching a big screen while taking notes with pen and paper. A steady noise from a group of students sitting in the nearby room joined through an open double door fills the otherwise quiet room. They banter enthusiastically amongst each other using loud voices and frequent grins. The screen portrays an armed man running through a series of hangar corridors. From his perspective we can see an automatic rifle swaying in front of him as his gaze darts back and forth apparently in search of potential enemies lurking round the corner. In a short frantic moment, a soldier appears and fires several shots leaving the man dead on the ground. The teacher in the room looks down to scratch down a few notes while the action on the screen continues.

In the other room, the group of students is growing increasingly frustrated. The room is almost completely occupied by a long table packed with computer screens. The students are placed on either side of the table as they fiddle with electronic mice and tilted keyboards. They all wear headsets by which a strange mix of instructions, bits of information and insults create their shared dialogue. "Damn Russian hackers with their aim bots!" a sturdy young member of the group shouts as he sits back tapping the keyboard in a seemingly meaningless manner.

They are having a rough time, and the mood is growing sour. Time and time again, we see cameras falling dramatically to the ground and a pair of camouflage clad legs run by indicating that one of the student-characters have been killed. A digital overlay indicates a score of 6-0 to the opponents.

The teacher at the desk gets up and signals one of the students to get up as he takes over his seat. He puts on the headset and quickly adjusts the microphone. In ten seconds, he tells the group what to buy, which route to take, and where to place the bomb. It's the first time he has spoken since the match began. A short time later, the bomb goes off accompanied by the loud cheers of the students. The teacher wastes no time as he gives another series of instructions.

The team goes on to win the next three rounds.

As in the previous vignette, the teacher starts in the position of the observer. He does not participate in the game and to begin with he makes no effort to engage with the players. What he observes is a group of young people that is more occupied with internal banter and slating off opponents than focusing on in-game strategy and performance. Seen from a play perspective, the mood is joyous to begin with, and the teacher might have seen social benefits to letting the playful interaction continue in the pursuit of strengthening relations between the students. However, as the team continues to lose and the joy dissipates, the euphoric mood turns destructive as keyboards get hammered, and banter turns to inappropriate accusations. When the teacher steps in and changes his role from observer to playing coach, he changes the mood dramatically. The student-players must perform to follow the instructions given by the coach. They now act as a team and the social aspect of the situation changes from freewheeling to tense and performative. In our data, we observe how this particular teacher has a capacity to steer his students away from and unfocused play mood to a highly performative one either by entering the play as a playing coach or at other times by giving precise instructions without actively engaging in the gameplay.

5.3 Adults as Co-Players

At the third STU, only four students are present at the time of the last vignette. Three students have been playing competitive League of Legends matches alongside two teammates who are attending class online via Discord.

One last student sits by himself playing Roblox. One of the two teachers present explains that the student is still new and is being carefully eased in. Him playing in the same room as the others is the latest progress. The room has plenty of space, the equipment is of a high standard, and all the students and teachers wear headphones. The vignette illustrates the casual mood of an “all random game” (ARAM) with no external participants, and how the active in-game participation of a teacher can heighten the stakes and the mood.

5.3.1 VIGNETTE #3

“We don’t have time for a full game, so let’s just do an ARAM”. The two teachers in the room are discussing what to do with the last half hour before lunch.

“Yeah, but we’re only five. I guess one of us has to join in.”

“Well, my baby girl’s got chickenpox. I only slept like an hour and a half.”

A pause. Then a shrug. “Guess it’s me, then.”

Moments later, six champions face off on Butcher’s Bridge. The structure, once a weather-worn stone causeway leading to a forgotten temple, now serves mostly as a worn-through thoroughfare between Bilgewater’s slaughter docks and its low-end slums. The three champions crossing from one side show no interest in architectural history.

“How much did it cost to get your girl vaccinated?”, a student asks via the voice chat, addressing the teacher observing the game. The student does not remove his gaze from the screen as he casually controls a red-haired woman wearing tight black clothes and a pair of serrated daggers. The champion is Katarina, a Noxian assassin of the highest caliber and the eldest daughter to the legendary General Du Couteau. The conversation continues casually as Katarina and her two allies advance along the bridge. Then, the rhythm breaks.

“My mouse keeps bugging. It’s been doing it all day!” interrupts a student tagged “The Lobster Splitter” on Discord.

“I’ll grab a new one,” the teacher outside the game replies calmly, already standing. “Just do the best you can.” But as he gets up, the first clash erupts.

“I hope you take a bungee jump without a rope, man!”. A student yells as his champion Annie, the fiery child prodigy wearing teddy bear ears, falls dramatically to the ground screaming as the screen turns black and white. “Haha, happy respawning”, the participating teacher replies, as he darts out of reach of an area attack. “I’m on a roll today! This is just too easy”. From the shadows, Katarina flickers forward in a blur of steel. Her blade catches the teacher’s champion mid-step, striking clean as her daggers vanish and reappear like red-tinted lightning. “Wait, what! You were out of reach!” The teacher squeaks. “Too slow, old man”, the student controlling Katarina replies with a smirk, his cheeks flush with the thrill, a mix of adrenaline and the risk of teasing a teacher. “Oh, I will get my revenge”, the teacher swears with a grin, as he waits for the death timer to hit zero. The room, moments ago filled with low chatter and yawns, now echoes with laughter, taunts, and frantic key tapping. Lunch can wait.

In this vignette, one of the teachers takes an active and participating role in the gameplay activities. He makes no effort to instruct any of the students, nor does he impose any social roles or mark the boundaries of play. Instead, he seems just as engaged in participating with the game as his students do. Following Bork (2023), his position is that of an adult co-player. In terms of play moods, it is difficult to pin down the mood at the beginning of the vignette. The game is a casual game and to start with all participating actors treat it as such. While there is a lightness and calmness around the non-game related small talk, there is not the high amount of concentration present that is required for the interaction to be devoted play. Neither are the stakes high enough to build a real feeling of tension. This changes when the teacher heightens the mood by breaking the expected character of a teacher and openly mocks the student he has successfully slain in game. The change inspires another play participant to engage in a daring move, where he dashes forward and performs a kill move on the teacher’s character. The subsequent banter-like dialogue shows how the euphoric mood has the tendency to spread among the play participants. In the vignette, the co-playing teacher shows a degree of play courage. Not only does he participate on equal terms as his students, but he also dares to raise the stakes by taunting his adversaries, setting himself up for possible failure. Even when taken down, he continues to sustain the heightened emotional state by promising to get revenge. The vignette showcases a brief moment of euphoric

play, partly initiated by a participating co-playing teacher, who possesses play courage and competencies to heighten the mood of play.

6. Conclusion

The three vignettes show how gaming activities can be seen through the lens of play moods and how the participation and shift in positioning of the adults can influence the mood. In the first vignette, the mood changes from devotion to intensity and back again, as the teacher steps in from his observing role to give clear instructions of what just happened in an intense moment of play. In the second vignette, the teacher also starts in the observing position. Here, however, he decides to engage actively in the gameplay, as he takes on the role of playing coach to steer the mood from euphoric to a performative mood full of tension. In the third and last vignette, one teacher is fully engaged in gameplay activities to begin with. He heightens the mood by breaking character and inspires both the in-game actions of his students and also the dialogue surrounding the play situation.

Our data shows the importance of being able to change positions as a teacher during esports teaching. While there is no evidence to support that specific shifts from particular positions automatically changes the play mood in a certain direction, being aware of the possible positions and having the competencies to step in and permeate the play mood is a pivotal skill of the competent esports teacher.

Further research on the relation between gaming activities and play moods is required to make further claims of how to understand co-located cooperative gaming as a play phenomenon.

Ethics declaration: The research has clearance from the Aalborg University research ethics committee.

AI declaration: AI have been used for proofreading and as thesaurus.

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Tiers of Engagement II: Profiling the Characteristics of User Engagement and Motivational Tiers in Business Simulators

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Abstract: This study investigates student engagement and motivation in the use of a business simulation game in the context of a fully online economics course. Building on our prior research, we refined our data collection instrument to include self-reported measures of engagement, intrinsic motivation, perceived learning outcomes and reflections on learning from 388 BA students. Based on this data, we updated and expanded our Tiers of Engagement framework, identifying 15 different engagement tiers. By analyzing 1552 qualitative comments on our respondents' reflections on their learning, we provide characteristics describing these tiers. The tiers show a correlation between higher engagement and intrinsic motivation on perceived learning outcomes and depth of reflection on learning. We also examined the impact of narrative tasks added to the simulator, which were designed to bridge theoretical concepts with practical application. Our findings highlight the simulator's effectiveness in fostering engagement and learning, particularly for highly motivated students, while also identifying areas for improvement in facilitating engagement (and potentially learning) for lower tiers. This research contributes to understanding how game-based learning can enhance educational outcomes in higher education.

Keywords: Game-Based learning, Engagement and motivation, Online education, Business economics education, Business simulators, Self-Determination theory.

1. Introduction

We present an updated and detailed framework for student tiers of engagement in game-based learning activities. Our study aims to further identify and describe specific characteristics of the different tiers of engagement. Through targeted queries, we have expanded our tier framework with a higher granularity, regarding both engagement level (low to high) and intrinsic motivation level (presence of intrinsic motivational factors). This has enabled us to further study the differences both between and within the different tiers.

We also investigate the impact of a supplemental intervention, narrative tasks framed as requests from the business' board of directors. The purpose was to tie the simulator's practical perspectives on business closer to the curriculum's theoretical perspectives, aiming to strengthen student achievement of learning outcomes tied to the link between theory and practice.

We consider whether changes in results from the previous study can be ascribed to changes made in the onboarding and debriefing process of the simulator, as well as improvements in the narrative tasks. These changes were based on the good practice recommendations in our previous article. The main research question for this article is: "What characterizes students on different tiers of engagement in the use of business simulators".

2. Theoretical Background

2.1 Foundation of the Tiers of Engagement

In our previous article (Guttormsen and Weines, 2024) we gave an overview of the theoretical background for our approach to organizing our respondents into different tiers of engagement. To operationalize "engagement" in the context of a business simulator game, we drew on various perspectives from the game-based learning field, and strongly inspired by Schwartz and Plass (2019), settled on considering "engagement to be the active effort, and quality of this effort, students have put into making meaning out of, and making use of the business simulator in their learning processes" as our working definition. Our perspective on motivation was mainly inspired by Deci and Ryan's (2000) self-determination theory (SDT), focusing on extrinsic and intrinsic motivation, and how the business simulator can facilitate students' expression of intrinsic motivation. We furthermore used Miele and Scholer's (2018) concept of metamotivational processes to define our criteria for assessing the level of reflection on learning in the responses and reflection of motivational fit (or quality of effort – that the students are motivated "enough" and/or "in the right way"). By building on literature on engagement,

motivation and self-regulated learning, we aimed for an appropriate and relevant framework for the context of higher education business programs.

Our framework also built on previous studies of the same business simulator we use. Baksaas and Nygård (2019) saw that the simulator could facilitate deep learning. Hovland Honerud et al (2023) found students reporting positive motivation and increased learning in relation to terms and methods, but no cognitive effects on grades and knowledge tests. Skjelbred and Daus (2022) did not find evidence that high satisfaction increased game effectiveness. Our results mirrored the positive results in these studies, and while we did not measure the effectiveness of the simulator, we found that high engagement and intrinsic motivation corresponded with deeper reflections on learning and perceived utility for learning outcomes. In Platz' (2022) systematic review on games in economics education, she highlighted that while motivation is central in the GBL literature (and support for motivation being a factor for learning), the effects of GBL on motivation are unclear. Our data indicated that complexity, challenge and realism could be drivers for engagement, but we did not consider our findings to be strong.

2.2 Further Perspectives on Business Simulators in Higher Education

In revising our framework, we have explored more literature that specifically deals with simulators in higher education business programs. Barker and Warner (2023) provide a thorough overview of how business simulators can provide opportunities for experiential learning tied to difficulties in managing businesses, such as analysis of options for enhancing decision making skills and making strategic decisions in the context of time and resource constraints. From their own evaluations, they point to the importance of practice runs for building students' confidence in using simulators in their learning. Ahuja (2024) also reviews studies on the use of simulators in business education, pointing out that scholars have highlighted several areas where they are useful. These include the practical application of theoretical knowledge, development of critical thinking skills, adaptability, simulated realistic experience, enhanced retention, engagement, as well as enhancing students' confidence in their own abilities. Ahuja notes the opportunities of simulations to not just enhance subject-specific knowledge but also foster development of broader skills. Butler et al (2025) presents a study of factors that impact individual students' performance in business simulators. They found that students with quantitative majors did not, as hypothesized, perform better than students from other majors. Instead, they found that gender had an impact, with women performing worse than men, but suggest further research to clarify this. As expected, they found that grades and time spent in the simulation correlated with better performance.

3. Methodological Design

Like our previous article, our study uses a concurrent triangulation design, where we combine quantitative and qualitative data to explore our research question (Almeida, 2018). Through an online survey framed as a post-simulator reflection assignment we gathered responses from 423 respondents, of which 388 gave consent for their responses to be used for research. We asked the students to report their effort in completing the simulator (i.e. engagement) and to indicate their interest/enjoyment in the simulator (i.e. presence of intrinsic motivation) by choosing the relevant statement on a closed scale.

Students were also asked to report the simulator's impact on their perceived achievement of four learning outcomes on a closed scale. There were four open-ended questions where students were asked to reflect on their experience with the simulator, potential collaboration with other students, the practical relevance of the simulator, and the impact of the narrative tasks (assignment from the board of directors) added by the course instructor. For these open questions, the respondents were given prompts for what they could elaborate on.

As with our previous study, we rely on self-reported data. Relying on established criteria for validity of self-reported data (Gonyea, 2005), we consider our data to be valid in the context of our study. We refer to our discussion of validity in our previous article, and we further discuss potential limitations for our current study later in this article.

Table 1: Open questions in reflection assignment

Category	Query
Reflection on your experience with the simulator	Write what you liked/disliked with the simulator, or any other experiences. Please also answer: Do you think you learned anything from the simulator? If so, what did you learn from the simulator? How did you learn this through the simulator?
Use of the simulator in collaboration with others	Did you discuss the simulator with other students? If so, what use do you think it had for your learning?
Practical relevance	1) How has the simulator impacted your understanding of how theory and practice are connected in business economic analysis? Did you experience the simulator as realistic? 2) How could the simulator be improved in this regard?
How did the assignments from "the board" impact your achieved learning outcomes?	How did you experience the assignments from the board?
Other feedback	If you have other feedback you want to add you can add it here (not mandatory)

We used the same criteria for assessing the depth of reflection on learning as in our previous study, reported in Table 2. However, we note that we prompted the students to reflect on if, what and how they learned through use of the simulator (see Table 1). As the survey was primarily a post-simulator reflection task, we offered the students these questions to strengthen their reflections on their learning.

4. Empirical Findings and Analysis

4.1 Analysis

After collecting the data, some of it had to be coded into more useful parameters for our analysis.

This coding is covered briefly in the tables below before we move on to the data analysis.

Table 2: Criteria for coding reflection on learning

Level of reflection on learning indicators:	How the students describe their experience with the simulator, their perceived learning from it, and insight regarding their learning process. We differentiate between how detailed and deep their thoughts about the simulator and their own learning are as described below.
High (3):	Reflects on what they have learned, but also how they learned, and what could facilitate more learning. Relating their learning to larger contexts.
Medium (2):	Reflects on what they have learned.
Low: (1)	Reflects on what tasks they have done and if they have learned/not learned (e.g. answering "yes" or "no" without further specifications).

Table 3: Criteria for coding level of intrinsic motivation for the simulator.

Level of intrinsic motivation indicators:	How the students describe their experience with the simulator with regards to their feelings of joy and interest towards working with the simulator.
High (H):	Answered "I thought the simulator was very fun and interesting".
Medium (M):	Answered "I thought the simulator was somewhat fun and interesting".
Low: (L)	Answered "I thought the simulator was a neither fun nor interesting", "I thought the simulator was a little boring/not interesting" or "I thought the simulator was very boring/uninteresting"

Table 4: Criteria for coding learning from narrative assignments.

Level of learning from narrative assignments indicators:	How the students describe their perceived learning or usefulness of the narrative assignments put in by the course instructor.
High (3):	Comments indicating great learning value, such as: "Very helpful or very educational", etc.
Medium (2):	Comments indicating some learning value, such as: "Ok", "a bit helpful", etc.
Low: (1):	Comments indicating no or negative learning value, such as: "disruptive", "confusing", "bad" etc.

4.2 Analytical Framework

The tiers were constructed based on the data collected on the students' self-reported effort (engagement) on a Likert scale from 1 to 5, and on the students' perceived level of intrinsic motivation towards the simulator from high to medium to low as shown in Table 3 above. The result was a framework consisting of 15 different tiers, presented in Table 5 below. The tiers with few respondents are marked with *.

Table 5: Tiers of Engagement analytical framework

Tiers of Engagement	Distribution of students	Mean reported level of reflection	SD Reflection	Mean reported achievement of learning outcomes	SD Learning Outcomes	Mean usefulness of narrative assignments	Mean age	SD age	% Men (tier)	% Women (tier)	% Men (total)	% Women (total)
H5	19,1%	1,79	0,67	4,40	0,52	2,34	32,33	7,54	42 %	58 %	17 %	21 %
*M5	1,3%	1,40	0,55	4,25	0,56	2,00	29,40	12,24	20,0%	80,0%	0,5%	2,0%
*L5	0,3%	1,00	0,67	4,25	0,51	2,00	28,00	7,87	0,0%	100,0%	0,0%	0,5%
H4	33,9%	1,75	0,72	4,08	0,48	2,31	28,65	6,74	55 %	45 %	39 %	29 %
M4	13,3%	1,63	0,63	3,71	0,57	2,24	28,37	6,94	33,3%	66,7%	9,1%	16,9%
*L4	1,3%	1,80	0,69	3,25	0,58	1,75	28,60	6,86	60,0%	40,0%	1,6%	1,0%
H3	9,9%	1,79	0,62	3,88	0,61	2,30	27,95	6,25	61 %	39 %	12 %	7 %
M3	11,2%	1,62	0,76	3,40	0,52	2,11	28,84	7,04	62,8%	37,2%	14,4%	8,0%
*L3	3,9%	1,20	0,70	2,63	0,70	1,50	30,40	7,04	33,3%	66,7%	2,7%	5,0%
*H2	1,3%	1,40	0,55	3,60	0,38	2,00	25,40	1,52	40 %	60 %	1 %	1 %
*M2	2,3%	1,33	0,71	2,86	0,72	1,63	29,33	5,57	22,2%	77,8%	1,1%	3,5%
*L2	1,3%	1,20	0,58	2,60	0,73	1,75	29,40	6,88	20,0%	80,0%	0,5%	2,0%
*H1	0,0%											
*M1	0,3%	1,00	#DIV/0!	1,00	#DIV/0!	1,00	27,00	#DIV/0!	100,0%	0,0%	0,5%	0,0%
*L1	0,5%	1,00	0,00	2,00	0,58	2,00	25,00	1,15	0,0%	100,0%	0,0%	1,0%

4.3 Quantitative Analysis

The distribution of students in each tier was calculated by taking the total number of students that reported a level of intrinsic motivation given by the letters (H=high, M=medium, L=Low/none), and the reported effort put into the simulator given by the numbers (1-5) that corresponded with the tier. This was divided by the total number of students in the study.

The same criteria used in the distribution were also used when performing the quantitative analysis to group the data into tiers. This allowed us to calculate the mean, standard deviation and percentage measurements for each tier. The objects of these measurements were the students' tier specific level of reflection, reported achievement of learning outcomes, age, gender distribution, and perceived learning value from the narrative assignments. The characteristics will be covered in the qualitative analysis. The measurements were then analyzed for identifying patterns. They were then visualized in diagrams and compared to corresponding diagrams from our previous study.

4.4 Qualitative Analysis

The focus of the qualitative analysis is on the text comments answered by the students regarding their reflections on the simulator as a learning activity, potential learning through cooperation, practical relevance to real world business, their experience with the narrative assignments from the "board", and other open-ended comments. In total, 1552 text comments were analyzed, ranging from one word to several paragraphs.

To analyze this rich data, we manually went through all the comments and coded the level of reflection and reported utility from the narrative tasks, using the criteria in the tables above. We also utilized a Large Language Model (LLM) in order to make short descriptions of each tier's characteristics. Based on our own analysis of the text comments, the summaries fit the "essence" of each tier. Still, it should be interpreted with caution as it is an AI generated summary. The AI that was used was ChatUit 4o. This is an internally hosted and secure AI chatbot/LLM within our university (UiT). The chat history can be provided, if necessary, but it is written in Norwegian language.

5. Findings

The findings from the analysis are visualized in the figures below. The distribution of students into the tier corresponding with their engagement and intrinsic motivational level resulted in the tier specific population shown in Figure 1.

About 19.1% were placed in the highest tier, **H5**. This indicates that a significant number of the participants were highly engaged and intrinsically motivated towards the simulator. We also see that for those who reported the highest level of engagement (5), only 1.6 % of the entire population in the study reported medium or low intrinsic motivation. This indicates that high intrinsic motivation towards the simulator might be key for putting in the highest effort and fully engaging with the simulator.

On engagement level 4 we see the highest distribution of students. A total of 48.6% of the respondents were placed here. Of these, 33.9% reported a high level of intrinsic motivation, while 13.3% reported medium intrinsic motivation. The remaining 1.3% reported low levels of intrinsic motivation. This indicates that intrinsic motivation was an important factor for reaching this level of engagement.

On engagement level 3, high or medium levels of intrinsic motivation seem to play a weaker role for becoming engaged, with 9.9% high intrinsic motivation, 11.2% medium intrinsic motivation and 3.9% low intrinsic motivation. But from engagement 3 and down, the role of intrinsic motivation for becoming engaged seems to be less as the distribution of motivational factors evens out. We note that the engagement 2 and 1 tiers in total consists of only 5.7% of the respondents.

This distribution seems to be fairly similar to the corresponding distribution from our earlier work. This indicates that the simulator used in these two studies produces similar engagement and motivation corresponding to our figure for a previous cohort of the same business analysis course.

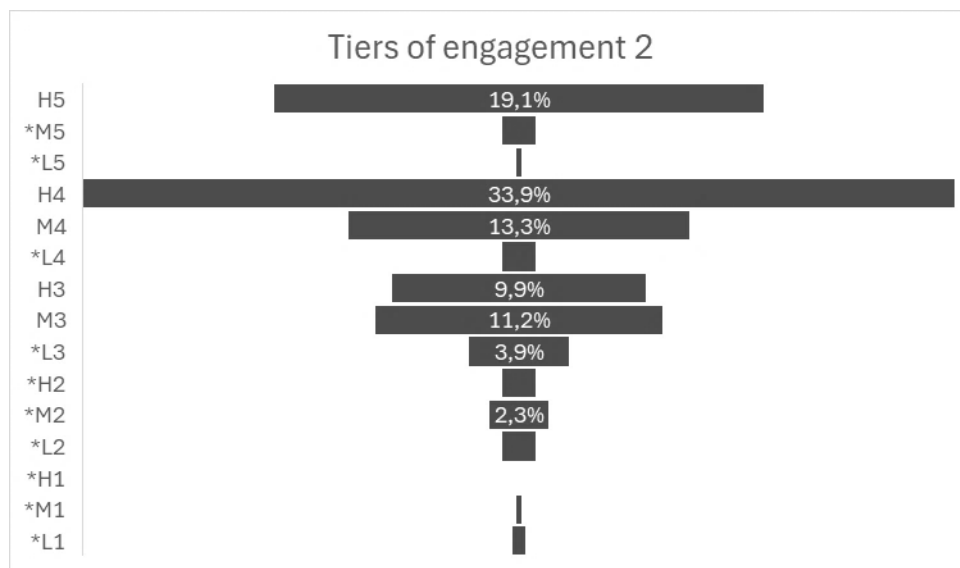


Figure 1: Tiers of engagement distribution of students

With regard to gender differences, and how they are engaged and motivated by the simulator, we analyzed the relative distribution of men and women in each tier. The relative gender distribution for each tier is presented in Figure 2.

We did not find any significant differences between genders with regards to motivation and engagement. Some tiers have more men and some have more women. However there seem to be a slight difference, with two of the three highest significantly populated tiers having a greater distribution of women, while two of the significantly populated lower tiers had a greater distribution of men. This difference is slight, and not significant enough to give any indication with regards to gender differences in the simulator.

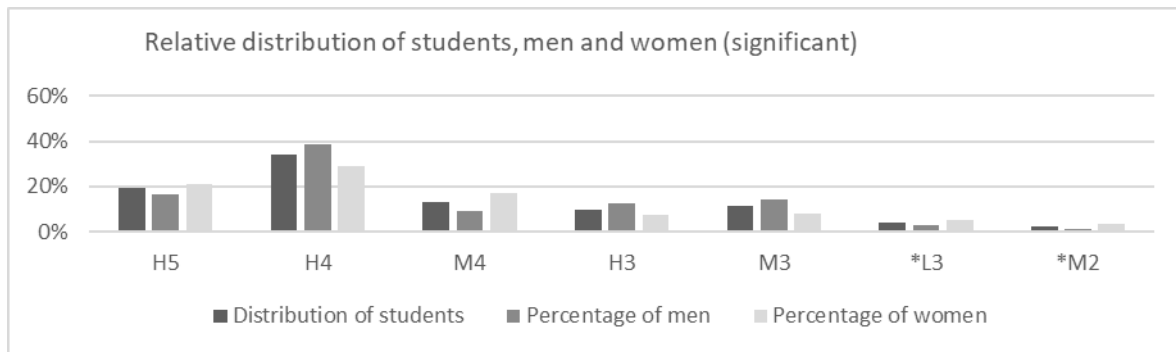


Figure 2: Gender distribution in tiers

So, we can tell that the simulator in our context seems to be an effective method of facilitating high engagement and intrinsic motivation for learning business analytics through simulators. Does this mean that the students that are engaged and motivated report a higher level of learning? And do they offer deeper reflections? To answer this, we turn to our findings on learning effectiveness. Specifically, level of reflection, achievement of learning outcomes, and learning from narrative assignment, as shown in Figure 3. We limit this to the tiers with a significant population. We also comment on the variance (standard deviation) in these tiers.

Looking at the figure and the data, we can see that higher engagement corresponds with a higher mean of reported learning outcomes. We also see an impact from motivation type. **H3** has a slightly higher reported learning outcome than **M4**. This forms a declining wave pattern through the tiers, showing how both engagement and intrinsic motivation impacts reported perceived learning and reflection on learning.

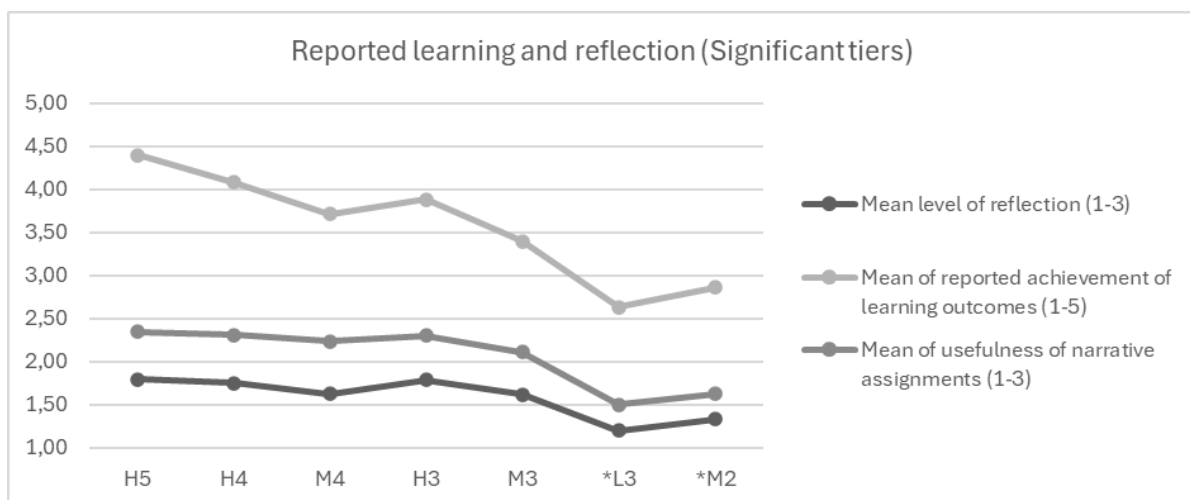


Figure 3: Means of learning and reflection from this study

With regards to the mean level of reflection and mean learning value from the narrative assignments we can see the same type of wave pattern, although not as pronounced as in mean of reported perceived learning outcomes.

This does not mean that every individual student in a tier experiences the same results on reflection and achievement of learning outcomes. Looking at the standard deviations presented in Figure 5, we see that every tier has a variance in answers that can be considered medium-to-high. This is especially prevalent for reflection, where the standard deviation on average is 0.69 on a 1-3 scale. This means that within each tier, the individual variance between the students' reflection scores is moderate-to-high and can vary greatly from the mean.

The standard deviations for achievement of learning outcomes are on average 0.57. With a scale that goes from 1-5, this standard deviation can be considered low. This means that for achievement of learning outcomes, the individual students in each tier report scores that are relatively close to the mean. Therefore, the mean level of reflection can only describe the tiers as a whole, and not the individual students. There is still some variance in the mean level of achieved perceived learning outcomes as well, but this can to a certain degree also be used to describe the individuals.

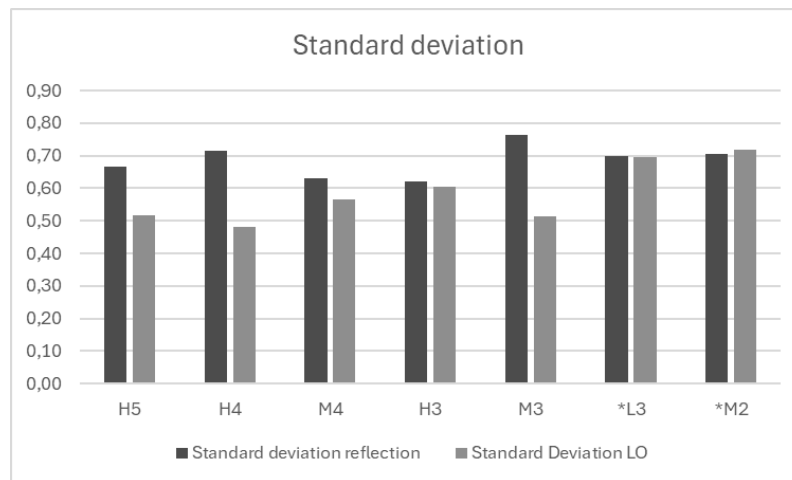


Figure 4: Standard deviations on learning and reflection

The final quantitative findings are the age distribution among the tiers, presented in Table 5. We see that the tier with the highest mean age is **H5**, with a mean age of 32.33 years. This indicates that **H5** is on average populated by students of a higher age than the other tiers. For the middle tiers, the mean ages are relatively alike with a mean age of around 28.5 years. The mean age for the lower tiers increases slightly to about 29.5 years. The standard deviation of age is on average about 6.87 across all tiers, the only outliers are **M5**, **H2**, **H1**, **M1**, and **L1** which are insignificant because of their low population.

This indicates that the simulator either motivates and engages, or does not engage and motivate, older students. Younger students tend to spread evenly among the tiers. We cannot say for sure why this is, but leaning on insight from the qualitative data, it could be that older students have more practical business or life experience and could either see the simulator as very relevant and realistic, increasing motivation and engagement, or not relevant and realistic, decreasing motivation and engagement.

The characteristics of each tier, based on AI-assisted analysis of the qualitative data is reported in Table 6 below.

Table 6: Characteristics of the Tiers of Engagement

Tier of Engagement	Characteristics
H5 (19,1%)	Highly Engaged and motivated students. Immersed in the simulator. Reflects on strategic choices. Prefer learning through practical assignments.
*M5	Highly Engaged and result-oriented students. Find the simulator helpful but wants more interactivity.
*L5	Highly Engaged and diligent students. Not motivated. Finds the simulator boring / irrelevant. Not enthusiastic
H4 (33,9%)	Engaged and motivated students that put in fair effort.
M4 (13,3%)	Engaged students. Moderately motivated. Finds the simulator helpful, but not too exciting.
*L4	Engaged but not motivated students that do the work to pass. Not enthusiastic. Finds the simulator to be repetitive and sometimes irrelevant.
H3 (9,9%)	Moderately engaged and motivated. Finds the simulator fun.
M3 (11,2%)	Moderately engaged. Does the work to pass.
*L3	Moderately engaged, not motivated, finds the simulator to be repetitive, irrelevant and boring. Does the work to pass.
*H2	Low engagement and motivation. Finds the simulator fun.
*M2	Low engagement, moderately motivated
*L2	Low engagement. Not motivated. Does the work to pass. Finds the simulator boring and irrelevant.
*H1	
*M1	Not engaged. Moderately motivated.
*L1	Not engaged and not motivated. Does the work to pass. Finds the simulator boring and irrelevant.

6. Limitations and discussion

6.1 Limitations

Our study is based on self-reported data from students who have consented to their reflection assignment being used for research. While we consider our data to satisfy Gonyea's (2005) suggested criteria for validity, we acknowledge that the data could be skewed due to being self-reported. Rating of engagement and motivation

is not based on analysis of qualitative data but on direct queries of the respondents' experience on a closed scale.

As the survey was a mandatory part of completing the simulator coursework, this may have impacted the effort spent on answering it. The respondents were asked to consent in order for their surveys to be used in our study, and informed that their data would be anonymous and not traceable. The survey was primarily a reflection assignment intended to provide an individual post-simulator debriefing that actively prompted for reflections on learning, and secondarily a data collection for research. We therefore point out potential bias in the questions reported in Table 1. However, despite the prompting, the mean level of reflection does not indicate any large positive bias towards deeper reflection.

As the student population we have studied is heterogeneous, with a high mean age and many who are studying in combination with full-time employment, the respondents could potentially be highly motivated and more prone to putting effort into their studies. We see fewer negative responses regarding the time and effort required for the simulator compared to the last study. This could be because of the increased timespan the simulator was open, and the increased emphasis on the trial runs.

6.2 Differences From Previous Study

Due to the changes in the survey and expansion of the tier framework, direct comparison with the previous study is difficult. By asking the respondents to directly report their effort in completing the simulator and their experience of interest and enjoyment, the tiers are not based on our own application of the criteria to assess engagement and motivation. This also means that the engagement and motivation levels are not derived from analysis of the same set of qualitative data. In addition, the use of a five-point scale increases the granularity of the framework. The integration and facilitation of the simulator by the course instructor was also modified based on our recommendation in the previous study. This can also have implications for how the respondents have answered the survey. Our focus is therefore not on comparison between the current and previous study, but to analyze the differences between the different tiers in the most recent dataset.

6.3 Discussion

The analytical framework and resulting findings show that engagement is a clear driver for perceived achievement of learning outcomes, and that high levels of intrinsic motivation towards the simulator can improve existing engagement and compensate for lower engagement. We mainly discuss the findings from the tiers with a significant population. Deci and Ryan's (2000) self-determination continuum show motivational types from non-self-determined to self-determined on a spectrum from amotivation, via external motivations and internalized motivations, to intrinsic motivation. Depending on motivation type, different regulatory styles and practices are employed. Our tiers do not correspond directly with the continuum, and it is possible to have several motivational types at the same time, but we find it useful in explaining the differences between our tiers.

In characterizing the **H5** tier (19.1%), we found that they in general report a deeper immersion in the simulator. They are also on average older than in the other tiers, and think deeply about strategic choices. The immersion and strategic thinking might come from their experience, which allows them to visualize the simulators' context more clearly and therefore tie the curriculum to the practical context. They enjoy working with practical assignments which bolster their motivation and engagement. This kind of simulator might be an ideal fit for these students (i.e. they are both motivated "enough" and "in the right way", ref. Miele and Scholer, 2018). They are able to reflect on a deeper level about the simulator and its content, as well as bolstering their theoretical knowledge through immersion and application in the practical context.

For the **H4** tier (33.9%) these students are also intrinsically motivated and engaged in the simulator, but they lack the immersion seen in **H5**, perhaps because they are on average younger and have less experience. This leads them to reflect and think about their choices on a surface level rather than on a deeper level. Still, they find the simulator fun and see it as a useful learning tool.

For **M4** (13.3%) we found that they have lower intrinsic motivation but put in a lot of effort into the simulator. They do not find it as fun as the higher tiers, but view it as a helpful tool for their learning. For students in this tier, it could be helpful to make the simulator more fun and intrinsically motivating in order to lift them to a higher tier. A potential way to achieve this could be to enhance the narrative tasks by making them feel more realistic and relevant, with enhanced feedback in order to drive the students' sense of autonomy and mastery.

In addition to the level of intrinsic motivation, the higher tiers of our framework (**H5**, **H4**, **M4**) exhibit a varying degree of characteristics that are similar to the 'somewhat internal' to 'internally' motivated sections of the SDT-

continuum. They see the value and relevance of the learning activity beyond being a requirement to pass the course, some even expressing interest, joy and satisfaction from their engagement with the simulator.

H3 (9.9%) finds the simulator fun but only puts in moderate effort. **M3** (11.2%) put in a moderate amount of effort but mainly express that they complete the simulator in order to pass the course. These tiers might compare to the ‘external’ to ‘somewhat external’ sections of the SDT-continuum. They comply with the course requirement, and some might experience an internal reward for completing it, but do not see the value for learning. There could be potential in further refining the facilitation to make the usefulness and value of the simulator as a learning tool more visible.

Even though the lower tiers represent a small part of the total population, their comments might shed some light on what could be done to assist them in climbing to higher tiers. Looking at the lower tiers of the framework (***M2**, ***M1**, ***L3**, ***L2**, ***L1**), we see that they find the simulator repetitive, boring or irrelevant, wanting more interactivity and excitement. A common characteristic shared by these tiers is that students state that they completed the simulator in order to pass the course. Similar comments are also found in the ***L4** tier. These tiers make out 9.7% of the total population. The comments and characteristics of the lower tiers are similar to the ‘non-self-determined’ and ‘externally motivated’ sections of the SDT-continuum. They do not see the value of the learning activity, they comply and complete it in order to pass the course (i.e. avoid the punishment of not being able to take the exam), and do not seem to see any internal reward in their own performance in the simulator.

As discussed above, direct comparison with the previous study is difficult. The lowest tiers then represented 15% of the population. The instructor made changes to how the simulator was integrated and introduced in the course, aiming to reduce the frustration reported by some students and facilitate understanding of how the simulator could be useful for learning. It is not possible to conclude if the reduction of the lowest tiers by a third is due to the changes in facilitation, or the changes in data collection. However, there might still be potential in refining how the simulator is facilitated, making the relevance clearer in order to help externally motivated students see the potential benefits of engaging with the simulator.

Our data shows that higher engagement corresponds with a higher mean of reported learning outcomes, with motivation type also having an impact. With a mean of 4.40, **H5** has the highest reported perceived achievement of learning outcomes, with a drop to 4.08 for **H4**. **M4** reports a mean of 3.71, with **H3** having a small increase to 3.88. **M3** reports a mean of 3.40. We see a declining wave pattern down through the tiers, which illustrates the impact of engagement and intrinsic motivation. We see similar patterns for reflection on learning and the usefulness of the narrative tasks.

In the qualitative data, we find several instances of students finding the simulator to be useful for improving practical skills (such as reading budget reports, making budgets, etc.) and strategic thinking (seeing the effect of their choices, trial and error, planning ahead, making use of the information in the market reports). These reported outcomes match the potential learning benefits of business simulators as reported by Ahuja (2024). Recurring comments include better understanding of price elasticity, perceived realism, and the opportunity to apply the curriculum in a practical context. Drawing on these reflections on learning from students, it might be possible to better prime the students in how they can use the simulator as a tool for learning, potentially boosting the benefit for students across the tiers. However, we see that while the higher tiers (**H5** and **H4**) express experiencing benefit from the added narrative tasks for application of theoretical concepts in a practical setting, the lower tiers often express the tasks as disruptive or disconnected from the simulator. This should be kept in mind so that opportunities for increased learning for the higher tiers do not come at the expense of the lower tiers.

We used the same criteria as in the last study to code the depth of reflection on learning, but as described above we also prompted for reflections on *if*, *what* and *how* they learned. We were therefore unsure if we would see an increase in the level of reflection. We found, however, that compared with our previous study, the highest tier (**H5**) sees a drop in the level of reflection on learning, from 2.5 to 1.79. In tiers **H4** and **M4**, the level of reflection is similar to the equivalent tiers in the previous study (1.63-1.79 vs 1.68-1.75). Because of the high standard deviation on reflection, it is hard to say anything about individual reflections.

One of the changes in facilitation was a higher emphasis on the trial run of the simulator. Barker and Warner (2023) highlight the importance of such trial runs for enabling students to get the most out of simulators in their learning. In the qualitative comments, several students made positive comments about the trial runs. As we

have analyzed the data, we have considered if the trial runs also contribute to the high levels of effort students report. As a large share of the students in the course are working full-time, both the trial- and full runs of the simulator were open for a longer period of time in order to not cause stress.

In the **H5** tier, the majority are women (58%). In the **M4** tier, there are slightly more men (55%). These are the tiers that also report the highest perceived impact on learning outcomes (means 4.40 and 4.08). Due to time constraints, we have not run separate analyses on gender. 11.5% of the total women in the study are found in the ***M2**, ***L3**, ***L2** and ***L1** tiers, and they make out a clear majority in each of these tiers. However, these tiers do not have a significant population. Butler et al (2025) found that women performed worse in business simulators, but that high performance correlated with time spent. Our data might indicate that the level of effort and intrinsic motivation outweighs the effect of gender, but we do not consider our data to strongly support this.

7. Conclusion and Future Work

The main research question for this article is: "What characterizes students on different tiers of engagement in the use of business simulators". Through refining our data collection, our tiers of engagement framework has a higher granularity, enabling us to look closer at different segments. While it relies on self-reported data, we think that this rich data offers opportunities to closely examine how students experience business simulators.

Our study shows that the higher tiers of engagement express a higher perceived learning outcome, higher level of reflection on learning, and higher utility from the added narrative tasks. They exhibit a clear view of how the simulator provides opportunities to connect theoretical curriculum with practice. They also find the simulator to be interesting and enjoyable. One can say that the simulator as a learning activity is a good fit for their motivation.

The middle tiers expend effort to complete the simulator, but while some find it interesting, they do not necessarily see the value of the simulator as a learning experience. The lower tiers make out a small share of the total population and are characterized by finding the simulator to be boring, repetitive or irrelevant.

While our study shows that in our context, the use of the simulator is to a large extent seen as a meaningful and useful learning activity, we have identified some potential venues to further improve the facilitation and integration of the simulator in our course. These include improving the introduction of the simulator by making the potential for learning and value as a learning tool more visible and making the added narrative tasks feel more realistic and relevant, improving feedback in order to drive the students' sense of autonomy and mastery. However, the reflections from the lower tiers indicate that they experience the added tasks as confusing or disrupting, which makes it important to make sure that further development is made in ways that facilitate engagement not only for the students who are already moderately or highly motivated.

A potential for further development is to more precisely examine different motivational types, further refining the characteristics of the tiers in order to more clearly differentiate between external and internal factors, as well as the self-regulating processes employed by students when engaging in this type of learning activity.

Ethics Declaration: The data was collected with informed consent and anonymously.

AI Declaration: We made use of a LLM in the analysis of the data, as described in the analysis section.

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Beyond Traditional Teaching: Games and Origami as Tools for Mathematics Learning

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Abstract: The use of innovative and engaging teaching methodologies is crucial in the education of future teachers, as it improves their current learning experiences and provides valuable teaching resources for their future classrooms. This paper presents a study which explores the integration of games and origami as educational tools in a math course for pre-service teachers. The implementation of playful challenges in mathematics education encourages students to apply mathematical concepts in a practical and interactive manner, thereby enhancing their engagement and comprehension. Furthermore, these strategies extend beyond reinforcing curricular content. They help foster a more positive attitude towards the subject matter. The activities were carefully designed to address specific mathematics topics identified as either the most relevant or those where students revealed more difficulties. At the end of the semester, a survey was conducted to evaluate students' perceptions towards the use of games and origami in the mathematics teaching-learning process. In this paper we describe some of the activities designed for this study and analyse the results of the survey. Previous studies reveal that students generally welcome the incorporation of games and origami, perceiving them as effective tools for enhancing motivation and promoting positive learning outcomes. Our findings corroborate these studies.

Keywords: Educational non-digital games, Game based learning, Mathematics education, Origami, Pedagogical innovation

1. Introduction

Mathematics is present in almost every aspect of our every-day life. Although not everyone is constantly aware of it, the reality is that the world we inhabit has always relied on mathematics and will continue to do so with increasing significance (Pais and Hall, 2021; Yadav, 2019). Unfortunately, the learning environment in most mathematics classrooms in Portugal is not particularly stimulating. The mathematics experienced by students is often perceived as painful and monotonous (Alien-Fuller, Robinson, and Robinson, 2010; Grootenboer and Marshman, 2016). In an era of rapid transformation, changes are also required in the teaching and learning processes, particularly in mathematics. It is essential to develop “powerful and challenging” mathematical tasks “to captivate students and enhance their learning” (ME, 2021).

In recent years, there has been a growing interest in innovative teaching and learning methodologies, particularly those that foster engagement and motivation among students. In this context, gamification and origami have emerged as powerful pedagogical strategies, leveraging game elements to create dynamic and interactive learning environments (Goland and Jackson, 2009; Kapp, 2012; Morando and Turconi, 2022; Pais and Hall, 2024).

Gamification involves the application of game mechanics, such as points, badges, leaderboards, and challenges, to non-game contexts (Kapp, 2012), with the aim of increasing motivation and engagement (Morando and Turconi, 2022; Pais and Hall, 2024, Ryan and Deci, 2017). The underlying principle is that by integrating elements typically found in games, learners can experience a sense of accomplishment, competition, and enjoyment, which, in turn, enhances their learning process (Hall et al, 2024; González-Cutre et al, 2016). This approach has been widely adopted in various educational settings, demonstrating its potential to improve students' participation, knowledge retention, and overall learning experience.

2. Gamification

Gamification has emerged as a promising pedagogical strategy to increase learner motivation and engagement by integrating game design elements into educational settings. Unlike traditional instruction, gamified experiences often leverage mechanisms such as point systems, badges, leaderboards, challenges, and narrative

contexts to sustain students' interest and foster active participation (Dinata, 2021; Kapp, 2012; Hamari, Koivisto and Sarsa, 2014). These elements can promote both intrinsic and extrinsic motivation, supporting goal-setting, and feedback loops.

Research shows that the effectiveness of gamification depends not only on the mechanics used but also on how well these are aligned with learning objectives, the learners' characteristics, and the broader learning context (Seaborn & Fels, 2015; Toda et al., 2019). For example, meaningful gamification, where game elements are intentionally connected to pedagogical outcomes, has been found to yield more sustainable engagement and deeper learning (Landers, 2014).

The effectiveness of gamification is influenced by various factors, including the design of the gamified experience, the context in which it is implemented, and the individual preferences of learners. Several studies highlight the positive impact of gamification on motivation and learning outcomes (McGonigal, 2011; Kapp, 2012; Hamari, Koivisto and Sarsa, 2014). However, as pointed out by Hall et al. (2024), the success of gamified activities relies on thoughtful instructional design that integrates game-based principles without compromising mathematical rigour.

3. Educational Games and Origami Activities for Mathematics Classes

Educational games can transform the mathematics classroom into an environment where students learn through exploration, experimentation, and play. When designed with pedagogical intention, these games contribute to the development of mathematical fluency, procedural understanding, and conceptual insight (Perrotta et al., 2013; Plass, Homer and Kinzer, 2015). Essential design principles for effective mathematics games include (Kapp, 2012; Hall et al, 2024):

- *Curriculum Alignment:* Games should target curricular goals and address common misconceptions.
- *Skill Development:* Varied exercises build fluency and reinforce math skills.
- *Engagement:* Game elements make learning interactive and fun.
- *Inclusivity:* Random elements allow all students to participate, promoting collaboration and resilience.
- *Full Participation:* All students stay involved, even when not actively playing.
- *Clear and Challenging:* Simple rules and balanced difficulty keep students interested.
- *Good Pacing:* Steady pacing maintains motivation.
- *Smart Incentives:* Small rewards and gentle penalties encourage strategic thinking.

The last two authors of this paper have a long experience in designing didactical games, targeting a wide range of educational levels (from primary school to university), in a diversified range of educational contexts (formal such as schools and prisons, and informal such as museums and botanical gardens) and, in some cases, taking into account students with special needs (La Fortuna, Morando and Spreafico, 2022; Morando and Turconi, 2022; Morando and Spreafico, 2023; Hall et al., 2024)

In parallel, origami-based activities offer a tactile and visual approach to mathematics education. Beyond their aesthetic appeal, they facilitate deep conceptual understanding by linking abstract mathematical ideas to concrete, hands-on experiences (Golan and Jackson, 2009; Hull, 2013; Wares and Valori, 2020). They can be designed to address a wide range of topics throughout the folding process—not only in geometry but also in areas such as arithmetic and fractions (Frigerio and Spreafico, 2018). Furthermore, the use of origami in an educational context “enhance self-esteem and a sense of accomplishment, while developing learning skills such as motor skills, spatial perception, logical and sequential thinking, hand-eye coordination, focusing and concentration, aesthetics, 3D perception, and principles of basic geometry” (Goland and Jackson, 2009, p. 1). Other studies reach similar conclusions, also referring an increase in the perseverance in problem-solving tasks (Higginson and Colgan, 2001; Cipoletti and Wilson, 2004; Tubis and Mills, 2006).

The fourth author of this paper has developed several origami-based activities covering diverse mathematical topics and educational levels. For example, Spreafico (2023) presents an origami activity for practising multiplication, while Magrone, Morando and Spreafico (2025) propose an activity addressing the concept of domain of a function and its behaviour at the boundary of the domain alongside two optimisation problems, emphasising real-world applications and creative problem-solving.

4. Methodology

4.1 Methodological Options

The research question underlying this study is how the incorporation of non-digital educational games and origami activities in maths classes can enhance student motivation and engagement in learning mathematics.

In this perspective, a mixed case study was developed (quantitative and qualitative, based on a logic of complementarity), grounded on a pragmatic paradigm and case study design (Yin, 1994; Ponte, 2006). The teacher responsible for the course in question is simultaneously one of the researchers of this study.

In order to develop this experience, the techniques of inquiry, direct observation and analysis of documents were applied, and the following instruments were used: field notes and final questionnaire.

The main objective of the questionnaire was to assess students' perceptions regarding the use of educational games and origami in the classroom. The questionnaire was created using Google forms and answered online by 27 students. This was a convenience sample, as participants were easily accessible to researchers. Statistical analysis of the data, specifically descriptive statistics, was performed using Excel.

4.2 Description of the Study

This case study was conducted during the first semester of the academic year 2024-2025 and involved the 1st year students enrolled in the course "Complementary Mathematics I" (Matemática Complementar I) of the masters' program "Master in Teacher Education - Pre-school education and 1st cycle of basic schooling" (Mestrado em Educação Pré-Escolar e Ensino no 1º Ciclo do Ensino Básico) at the University of Aveiro, Portugal. This two-year program prepares pre-service teachers for pre- and primary school levels.

The course consisted of a weekly three-hour face-to-face class, totalling 14 sessions. Of the 45 students enrolled, 41 attended the classes (one dropped out, and three only took the exams).

The course focused on two main topics: geometry and problem solving. The first part of the course explored geometry problems involving perimeter, area, and volume, beginning with a review of fundamental concepts such as segments, lines, and angles. The second part of the course addressed geometric transformations, with a strong emphasis on plane isometries. This was followed by an exploration of planar symmetry, concentrating on the symmetry groups of rosettes, friezes, and wallpaper patterns, using classification flowcharts by Washburn and Crowe (1988). The final part of the course was dedicated to problem solving through various approaches, with particular emphasis on the use of diagrams, following the bar model methodology from Singapore mathematics (Forsten, 2010).

Recognizing the benefits of game-based learning and other hands-on activities as pedagogical strategies, the first author of this study integrated non-digital games and origami activities throughout the semester. Students engaged in four games and completed three origami activities.

5. The Games Played

All the games in this study have been designed by the authors of this paper, in accordance with the principles described in Section 3. The authors chose to use only non-digital games for two key reasons. Firstly, the course itself is designed with a paper-and-pencil focus, aligning with the educational environment these pre-service teachers will likely encounter (pre-school and primary school levels). Secondly, the teacher identified a need to address basic maths skills in many students and felt this could be best achieved without resorting to digital tools.

This section describes the four games played.

5.1 Euclid's Regatta

Euclid's Regatta is an educational game designed to help students understand and apply concepts from plane geometry and point location through playful, hands-on interaction. The game is intended for two teams of 3–4 players each and involves physical materials including:

- A small origami boat for each team
- Cotton thread to represent lines or segments
- Buttons to represent points
- Adhesive (Patafix) for fixing elements on the game board (table)
- A timer to track performance

- A table for registration of times per team/challenge.

The game is structured into five challenges, each set up on table and involving a specific geometric task. Teams take turns trying to position their boat according to the challenge instructions.

Gameplay Mechanics

All boats start from the same position on the table. To decide who begins the first challenge, both teams roll dice – the highest result starts. In subsequent rounds, the losing team begins. If there is a tie, dice are rolled again. During a turn, a player must blow on the boat to guide it into the correct position – touching it by hand is not allowed. The timer starts at the beginning of the attempt. If the boat falls off the table, 30 seconds are added and the boat restarts from its original position. Once the team believes the boat is correctly positioned, they call out, and the opposing team stops the timer and verifies the placement. Incorrect placement results in a 30-second penalty. The team then registers the time needed to complete the task.

The second team then takes their turn following the same procedure. After completing the five tasks, The team with the shortest cumulative time wins.

The types of challenges in this game can be quite varied. For example, one challenge in this version required positioning the boat on the line perpendicular to line r (represented by a piece of string) and passing through point P (represented by a button), as illustrated in Figure 1 (left).

5.2 Isometries in the Square

"Isometries in the Square" is an educational board game designed to help students explore and apply concepts related to plane isometries, specifically translations, reflections, and 180° rotations. The game is intended for three teams of 2–3 players each and promotes spatial reasoning, mathematical thinking, and teamwork through playful interaction.

Game Components

- A 10x10 square grid game board with three coloured lines all meeting at the central point. Two of the lines represent the coordinate axis and the third one is the bisector of the first and third quadrants quadrant.
- A deck of 60 action cards
- 120 coloured buttons (40 of each of three colours)

Gameplay description

- Each team receives 40 buttons of a specific colour and places three buttons of their choice anywhere on the grid as an initial configuration. The action card deck is shuffled and placed face down.
- The aim of the game is for teams to place the largest number of connected (adjacent by side or vertex) buttons of their colour on the board by performing geometric transformations indicated by the action cards.
- Teams take turns drawing one action card from the deck. Depending on the card drawn, teams must place new buttons on the board by performing a specified isometry (translation, reflection, or rotation) using one (or two) of their existing buttons as a reference point.
- If the card has no special symbol, the team places one button. For example: A card stating "Reflection across the green line" allows a team to place a button in the square that is symmetric (by reflection) to one of their own buttons across the green line.
- If the card displays a double-heart symbol, the team must use a pair of adjacent buttons (sharing an edge or vertex) and place two new buttons, each following the transformation specified.

Rules

- Buttons may not be placed in occupied squares.
- For double-hearted cards two adjacent squares must be used.
- If there are no empty squares satisfying the card condition the player must pass his turn.

The game ends when the action deck is exhausted.

At the end of the game, teams score one point for each button that is adjacent (by side or vertex) to at least one other button of the same colour. The team with the highest score wins. Figure 1 (right) shows the board of one of the playing groups close to the end of the game.

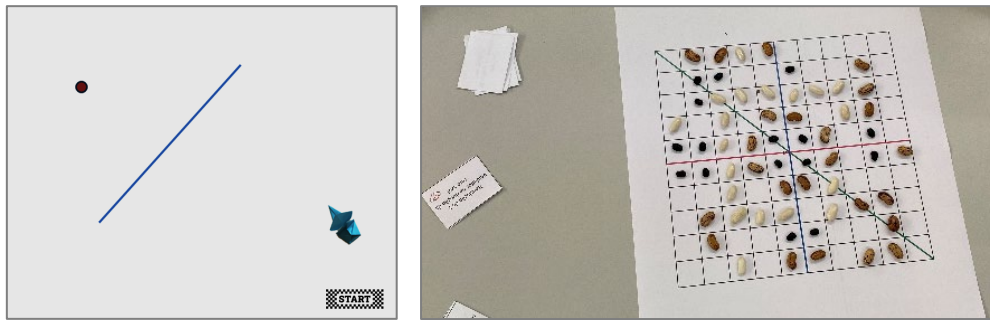


Figure 1: Illustration of “Euclids’ Regatta” (left) and photo of “Isometries in the Square” (right).

5.3 Symmetry in Action

"Symmetry in Action" is an educational game for two teams of two students each, designed to promote geometric reasoning and spatial awareness by challenging students to construct figures that exhibit specific symmetrical properties.

Unlike traditional exercises that require identifying symmetries in pre-drawn shapes, this game reverses the process: students are asked to create figures that satisfy given symmetry conditions. This inversion enhances understanding by actively engaging learners in the construction of symmetry. However, it increases the level of difficulty of the game.

Game Components

- Two decks of 12 identical tiles. (the decks are different from each other but with similar symmetry characteristics; we used two tiles designed by the Portuguese artist Eduardo Nery (1938-2013) shown in Figure 3)
- A deck of 36 condition cards specifying symmetry requirements (for rosettes and friezes)

Game objective and instructions

- The objective is for teams to construct geometric figures that fulfill the symmetry conditions specified on the cards, using their set of tiles.
- Each round begins with the teacher drawing a card from the condition deck and reading it aloud (alternatively, teams may take turns drawing and reading cards themselves). Each card presents a specific condition—for example, “build a 2x2 square rosette with only rotational symmetry of order 2 (C_2),” or “build a frieze with a 2x2 unit cell featuring only translational symmetry ($p111$)”
- Teams then use their tiles to construct a figure that satisfies the condition described on the card.
- Once a team believes their configuration meets the requirement, they declare it.
- If the proposed figure is correct, the team earns one point.
- If it is incorrect, they receive one penalty point, and the other team may attempt the challenge. If the second team’s figure is correct, they earn one point.
- After points are awarded, a new card is drawn, and the next round begins. The game continues for a fixed number of rounds or within a predetermined time limit.
- The team with the highest number of points at the end of the game is declared the winner.

Figure 3 shows the tiles used in this game and two examples of challenge solutions: “build a 2x2 square rosette with exactly two axis of symmetry (D_2)” (left); “Build a 2x2 square rosette with rotational symmetry of order 4 and no reflection symmetry (C_4)” (right) .



Figure 2: Symmetry in Action: The two tiles by Eduardo Nery and examples of challenge solutions

5.4 Problem Basket

This game is a treasure hunt-style game that challenges teams to solve a series of problems. The solutions to these problems lead to the discovery of a magic word. The game aims to develop problem-solving skills.

The game was played within the topic of problem solving and addressed different mathematical topics. Several problems involved doing measurements in the classroom or the building. The game can be adapted to any mathematical context and it is described in Pais and Hall (2024).

6. The Origami Activities

In this section we describe the three origami activities performed during the semester.

6.1 Euclid's Boat

Euclid's Boat is an origami model required for playing Euclid's Regatta. While folding the boat, students follow step-by-step instructions designed to explore fundamental geometric concepts through hands-on practice. Along the way, they are prompted to analyse each step from a mathematical perspective, identifying the geometric construction involved and the corresponding Huzita–Hatori axiom applied.

This system of axioms formalises the geometry of paper folding and includes operations such as folding a line through two given points (Axiom 1), creating the perpendicular bisector of a segment by folding one point onto another (Axiom 2), and constructing the angle bisector formed by two intersecting lines (Axiom 3). The folds involved in constructing the boat encompass all three axioms. Figure 3 (left) shows the resulting origami boat.

6.2 Greenhouses

This activity has been proposed by Morando and Spreafico (2023) within the context of an outreach mathematical activity in a botanical garden. In this activity, students are challenged to build paper greenhouses using a simple origami model that results in a pentagonal prism shape (see Figure 3, centre, for the resulting models). As they progress, they are encouraged to analyse the 2D and 3D geometric forms involved, culminating in exercises focused on calculating perimeter, area, lateral surface, and volume based on the cross-sections of the models.

To deepen understanding, students compare different greenhouse configurations by modifying roof angles and base dimensions. These variations lead to meaningful discussions on how structural changes affect geometric properties, supported by calculations and percentage comparisons. An extension of the activity introduces the concept of scale, prompting students to determine whether a full-size greenhouse, proportionally scaled from the origami model (e.g., 1:90), could accommodate a 5-meter-tall tree.

Through these tasks, the activity integrates geometry, real-world problem solving, and proportional reasoning, while also allowing for creativity through optional model decoration.

6.3 The Fraction Fish

The third origami activity, known as The Fraction Fish, is designed to support the exploration of fractions through a progressive paper-folding process. This activity has been proposed by Frigerio and Spreafico (2018, pp. 153–160) as a way to integrate mathematical reasoning into hands-on learning. Using a square sheet of paper (15×15 cm), students follow guided folding steps to create a stylised fish, pausing at key stages to analyse and quantify the relationship between the coloured and white regions of the model.

At each stage, students are prompted to identify a suitable unit of measure—such as a rectangle, square, or triangle—and to express the parts of the model as fractions of the whole. This approach enables discussions on a range of fractional concepts, including complementary fractions (e.g., $\frac{1}{3} + \frac{2}{3} = 1$) and equivalent fractions (e.g., $\frac{1}{3} = \frac{4}{12}$ or $\frac{2}{30} = \frac{1}{15}$). By changing the reference unit throughout the activity, students develop a flexible understanding of how fractional values can vary depending on the unit chosen.

As the model evolves, increasingly complex comparisons are introduced, involving fractions with denominators such as 8, 14, and 30. The activity concludes with the completed fish model (see Figure 3, right), after engaging students in repeated reasoning with fractional decomposition, equivalence, and unit-based comparisons, all within a visual and hands-on learning experience.



Figure 3: Photos of the origami models: Euclid's Boat (left), Greenhouses (centre) and Fraction Fish (right)

7. Survey Results

At the end of the semester, students completed a five-part questionnaire. The first section focused on participant demographics, the second on the use of games in class, and the third on the use of origami. The fourth and fifth sections (not analysed here) concerned assessment methods and general course evaluation.

Regarding participant characterization, student ages ranged from 19 to 33 years old. The majority (70%) were between 19 and 22 years of age, with only one student (4%) over 26. Most were full-time students (96%), and only one (4%) reported working while studying. The gender distribution was highly skewed toward female students (85%), which aligns with trends in pre-service education programs for pre- and primary school teaching.

7.1 Use of Games in Class

Students were first asked to express their overall appreciation for playing educational games in class using a five-point Likert scale (1 – disliked very much; 5 – liked very much). As shown in Figure 4, all responses were positive, with no students selecting neutral or negative options.

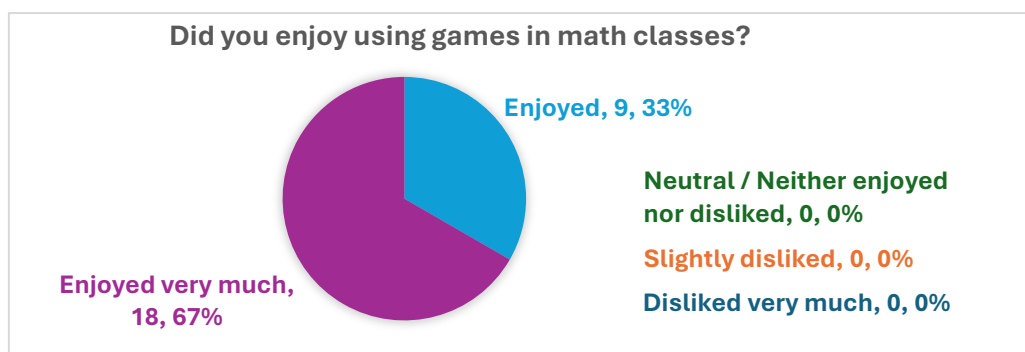


Figure 4: Pie chart of responses for the question “Did you enjoy playing educational games in class?”

Next, students were asked whether they considered the use of games to be relevant in the teaching and learning of Mathematics. All respondents answered “Yes,” indicating a unanimous perception of games as valuable pedagogical tools. When asked if they would recommend using games in math classes, 93% of students responded affirmatively, while one student (4%) selected “Indifferent”; no one answered “No.”

Students were also asked to rate their level of agreement with a series of statements about the impact of educational games in the classroom, using a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree). The heatmap in Figure 5 summarizes the responses, including mean and standard deviation (SD).

The results indicate a clear consensus on the positive impact of games in class. The highest frequency of responses was “5 – Strongly Agree” for all statements, with mean values above 4 and relatively low standard deviations. These findings suggest that the use of educational games contributed to making learning more interactive, stimulating, and motivating for students.

The use of educational games in maths classes contributed to:	1	2	3	4	5	Mean	SD
making learning more interactive.	0	2	6	2	17	4,3	1,1
making classes more stimulating.	0	1	6	4	16	4,3	1,0
increasing student motivation.	0	2	5	4	16	4,3	1,0

Figure 5: Heatmap of responses related to the impact of games on the teaching and learning process.

To assess preferences, students rated their appreciation for each game on a five-point Likert scale (1 – disliked very much; 5 – liked very much). Results are presented in Figure 6.

Appreciation for each game	1	2	3	4	5	Mean	SD
Euclid's Regatta	0	0	3	12	12	4,3	0,7
Isometries in the Square	0	1	4	9	11	4,2	0,9
Mysterious symmetry	3	3	9	7	5	3,3	1,2
Problem Basket	0	1	4	10	12	4,2	0,8

Figure 6: Heatmap showing students' appreciation levels for each game.

"Euclid's Regatta" received the highest average score, followed closely by "Isometries in the Square" and "Problem Basket." In contrast, "Mysterious Symmetry" received more mixed feedback, reflected in its lower average score and higher standard deviation, suggesting a more divided reception among students. According to field notes taken by the teacher, several students found the challenges in this game too difficult, which discouraged their participation. These results indicate a general appreciation for the games overall, while also highlighting that certain formats or levels of complexity may resonate more effectively with students than others.

7.2 Use of Origami in Class

The third section of the questionnaire explored the use of origami activities. Students again expressed high levels of appreciation, as shown in Figure 7, with no negative responses.

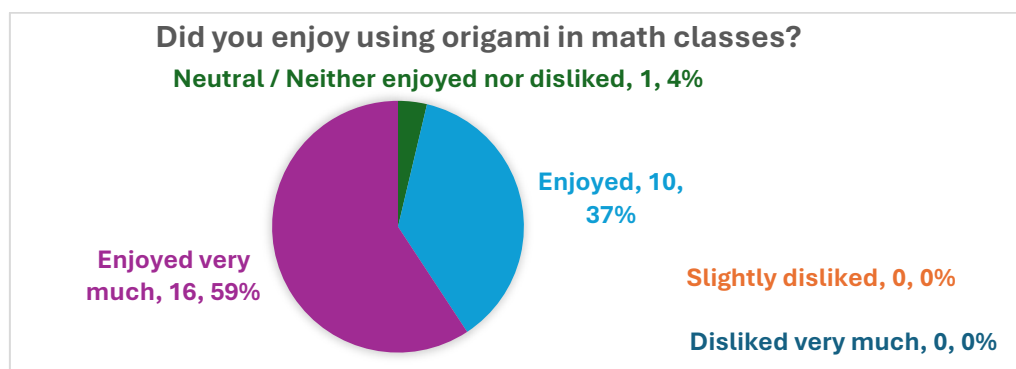


Figure 7: Pie chart of responses for the question "Did you enjoy using origami in math class?"

Next, students were asked whether they considered the use of origami to be relevant in the teaching and learning of Mathematics. Most students (93%) responded affirmatively, while one student (4%) selected "Indifferent" and another answered "No." When asked whether they would recommend using origami in math classes, 96% of students responded affirmatively, and only one student (4%) answered "No."

Students rated their agreement with statements regarding the impact of origami activities using the same five-point Likert scale. Results are presented in Figure 8. As with the games, students agreed that origami helped make learning more interactive and engaging. Although the average scores were slightly lower than for games, all means were still above 4, indicating overall positive experiences.

The use of origami in maths classes contributed to:	1	2	3	4	5	Mean	SD
making learning more interactive.	0	2	6	6	13	4,1	1,0
making classes more stimulating.	0	2	5	7	13	4,1	1,0
increasing student motivation.	0	2	7	6	12	4,0	1,0

Figure 8: Heatmap of responses related to the use of origami in maths classes.

Students also rated their appreciation for each origami activity (see Figure 9).

Appreciation for each origami activity	1	2	3	4	5	Mean	SD
Euclid's boat	0	0	2	8	16	4,5	0,6
Greenhouses	0	1	4	10	11	4,2	0,8
The Fraction fish	0	0	3	10	13	4,4	0,7

Figure 9: Heatmap showing students' appreciation levels for each origami activity.

Among the three origami tasks, “Euclid’s Boat” was the most appreciated, followed closely by “Fractions Fish” and “Greenhouse.” All activities received high ratings with low standard deviations, indicating widespread approval.

8. Conclusions

This study investigated how educational non-digital games and origami activities in maths classes can contribute to increased student motivation and engagement in mathematics learning. The results demonstrated that students not only enjoyed playing the games and engaging with origami, but also reported feeling more involved in class and motivated to learn. These findings were supported by both questionnaire responses and field notes taken by the teacher during class observations.

The activities allowed students to interact with mathematical concepts in a meaningful, playful, and collaborative way. Furthermore, as future teachers, participants recognised the pedagogical potential of these strategies, both for reinforcing their own learning and for enriching their future classroom practices.

Overall, the integration of games and origami into mathematics education proved to be an effective and well-received approach to promoting active learning and conceptual understanding.

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Ethics declaration: The paper contains the result of a non-interventional study, i.e. a survey (qualitative questionnaires), which does not need ethical approval. The completion of the questionnaire was voluntary and anonymous; moreover university (school) is the guarantor of data processing and privacy for activities performed in the curricular framework.

AI declaration: Use of generative AI in some paragraphs to improve the language, as English is not the authors' first language. Specifically used the question ‘Check grammar and coherence without adding new sentences’. This prompt provides minimal suggestions for grammar, clarity and coherence in sentences, does not reorganise the sentences in the paragraph and does not add new sentences.

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Social Inclusion of Vulnerable Youth Through Esports Education

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Abstract: In Denmark, there are increasing problems with school refusal and marginalization of vulnerable youth. At the same time, joint gaming activities may have a positive influence on young people's social relationships and experience of being part of communities. In this article, we focus on how esports education with games such as *Counter-Strike* and *League of Legends* can contribute to engaging vulnerable and isolated young people (age 16-25) at Specially Planned Youth Education (STU). Specifically, we look at how esports teachers and municipal educational guidance counsellors experience the isolated young people's participation in gaming activities as a process of social inclusion that helps young people to cross boundaries between different domains - e.g. leisure, education and/or internship. Our analyses are based on interviews with teachers and guidance counsellors affiliated with three STUs, who are participating in the research project "Esports as a learning space and bridge builder for vulnerable young people at STU". We understand the young people's participation in esports education as a process of social inclusion, which involves bridging of experiences across different domains that have specific knowledge practices and social norms for what counts and does not count as legitimate participation. More precisely, we understand esports education at STU as social inclusion through an interplay of four domains: 1) the young people's gaming domain in their leisure time, 2) the STU as an educational domain, 3) the young people's adult domain, as well as a 4) guidance domain. Based on thematic analysis of the interview data, we identify three themes: 1. Esports education as an introduction to STU, 2. Esports education as a safe and structured framework, and 3. Esports education as a springboard to participation in new communities. Lastly, we discuss the potentials and challenges of social inclusion of vulnerable youth through esports education.

Keywords: esports, Vulnerable youth, Special education, Social inclusion, Autism

1. Introduction

Although many young Danes today are objectively thriving and doing well, current research shows trends that point to a decrease in young people's well-being (Katznelson et al. 2021; Ottosen et al., 2022). This can also be seen in an increasing tendency for school refusal, which can lead to lower academic performance, as well as a lower likelihood of completing later education and getting a job (Knage & Kousholt, 2023). This increase can partially be explained by a rise in the number of children, who are diagnosed with autism and/or ADHD (Nordin et al., 2024).

In connection with the political objective that 90 percent of a youth cohort should complete a youth education before they turn 25 (Ministry of Children and Education, 2017), there has been extra focus on the so-called 'NEET youth', i.e. vulnerable young people who are neither in education nor employment (Not in Employment, Education or Training), and who typically have a background characterized by significant primary school absence and psychological distress in adolescence (Bolvig et al., 2019; Ottosen et al., 2022). Educational activity and work experience throughout the teenage years and up to the young people's 20s are considered crucial here to ensure that these young people do not end up in permanent vulnerability.

Among vulnerable young people, there are also significant challenges with loneliness, which is particularly prevalent among vulnerable young people with special needs, especially including young people with autism, ADHD or mental challenges (Ministry of Education, 2017). Socially vulnerable young people with special needs are thus lonelier than young people in the general population. While many vulnerable young people experience marginalization, several studies show that young people can gain positive social benefits from participating in gaming activities by, for example, strengthening relationships or making new friends (Eklund & Roman, 2017).

The positive experiences are often linked to online multiplayer games such as *Minecraft*, *World of Warcraft* or *Counter-Strike*, where players have to cooperate and communicate to achieve jointly defined goals. In continuation of this, studies have shown how the use of multiplayer games in schools can contribute to strengthening academic and social inclusion in the classroom (Hanghøj et al., 2018a). Similarly, multiplayer gaming can be used as a conversational framework to create better relationships between citizens and therapists in forensic psychiatry, when the therapist, for example, plays together with the citizen as part of a course (Terkildsen et al., 2022). Other studies show that vulnerable young people from the NEET group can benefit from

their gaming experiences in relation to seeking education or employment (Væksthusets Forskningscenter, 2022). As the examples suggest, there is increasing research interest in investigating how facilitated gaming can be used as a pedagogical tool to socially include vulnerable groups, also in other services outside the STU framework.

In this article, we will focus specifically on facilitated gaming activities at three STUs (Specially Planned Youth Education), all of which offer esports courses where vulnerable young people game together in teams. More specifically, we investigate the following research question: *How do STU teachers and municipal guidance counsellors, who are in regular contact with the young people at STU, experience the vulnerable young people's participation and benefit from the esports courses?* Our analysis is driven by an educational domain perspective (Hanghøj et al., 2018), where we are particularly interested in the ways in which facilitated gaming can contribute to creating new possibilities for participation across specific domains in the young people's lives.

2. Specially Planned Youth Education

STU is a specially designed youth education program for young people (16-25 years old) with special needs who, for various reasons, are unable to complete another youth education program despite special educational support. The purpose of the STU program is for young people with special needs to "gain personal, social and academic skills" to support "independent and active participation in adult life" and provide them "with the prerequisites for further education and employment" (STU Act, 2023).

The target group includes a broad group of young people with various physical and mental challenges. Approximately half of young people at STU are referred due to general learning difficulties and approximately one third due to developmental disorders such as autism or ADHD (Ministry of Education, 2017). Moreover, STU students often suffer from longer periods of school refusal. There are approximately 250 different STU offers in Denmark (stuguiden.dk), which are offered by both private and public institutions. According to the Guidance Act (2017), municipal youth counsellors are tasked with guiding young people about educational and employment opportunities and referring them to relevant programmes after completing primary school. Some counsellors may have followed the individual young person throughout their entire education and have a good knowledge of his/her life and school situation as a basis for an STU course. The counsellors have conversations with the young person before, during and at the end of the STU programme, in which both teachers and parents often also participate.

3. Esports Education at STU

Esports is a common term for competitive approaches to playing digital games, often multiplayer games such as *League of Legends* or *Counter-Strike*, where two teams play against each other. Esports as a course or elective is offered at almost 20 STUs nationwide (stuguiden.dk). The young people who take the esports courses have often chosen the courses themselves in consultation with their youth guidance counsellors based on their gaming interests. The primary purpose of the esports education at the three STUs participating in our project is to qualify the young people's professional gaming skills, but first of all to promote the young people's opportunities to be part of a physical community as well as to promote personal and social skills that can also be important outside the esports course.

Esports education is organized in different ways at the three STUs participating in this project. At STU 1, esports take up two half-days of teaching, while at STU 2 there are three full days of esports education and one day of other gaming activities. At STU 3, esports is part of a programme that also includes media subjects and fitness, and the number of hours varies during the year but corresponds to approximately one day per week. All three STUs have specific "gamer rooms", where the tables are set up so that the young people can sit in rows or in groups of 5, which is the typical number of players on an esports team. The team size varies from approximately 5-20 young people with one to two associated teachers. Esports education often follows a fixed pattern with a short teacher introduction, where, for example, focus is placed on specific roles or tactics in a game, followed by exercises in the game and then a match, which can be between two teams in the class or with other online players.

4. Theoretical Perspectives

We understand the young people's participation in esports education as interplay and crossings between different domains that involve specific knowledge practices, framings and social norms for understanding what counts and does not count as valid knowledge (Hanghøj et al., 2018). More precisely, we understand esports education at STU as an interplay between four domains: 1) the young people's *gaming domain* in their leisure time, 2) the STU as an *educational domain* that also includes other pedagogical activities than esports education,

e.g. cooking together or trying out other programmes such as music or media production, and, 3) the young people's *adult domain* in the form of e.g. internships, help with everyday life, further education after the STU, etc., as well as a 4) *guidance domain*, where municipal youth guidance counsellors have meetings with the young people, often together with STU teachers and possibly parents. The model below shows how esports education at STU relates to the four domains:



Figure 1: Domains related to esports education at STU

In relation to our study, it is important to understand the significance of different social norms and values associated with playing computer games - both at home with young people in their leisure domain and as part of esports education at STU (the educational domain). According to Goffman (1961), gaming activities are always associated with situated norms and frameworks for playing. The social norms of gaming have both been empirically explored within the context of leisure gaming (Deterding, 2019) and educational gaming (Hanghøj, 2011).

In this paper, we understand esports education at STU as a form of *social inclusion*, which involves the students' level of participation in their communities, access to schools, and opportunities to build and sustain friendships (Koller & Stoddart, 2021). In this way, social inclusion of the STU students can thus be understood as a way of increasing their participation in a formal education programme through development of social and communicative skills as well as friendships and other positive social relations. Building on the involved domains (gaming, education, adult life, guidance) in esports education, we might further hypothesize that the process of social inclusion involves translation and legitimisation of the students' gaming experiences across domains. According to domain theory (Hanghøj et al., 2018), crossing boundaries between domains are often associated with negotiations and discontinuities that can accommodate many different and even opposing values and perspectives. We thus understand the young people's participation in esports education at STU as a process of social inclusion that requires negotiations, but which at the same time provides the opportunity to translate, explore and reflect on gaming experiences in relation to several different domains and thus create meaning for the individual young person.

5. Methodological Approach

The empirical material in this article is based on 10 semi-structured interviews with five youth guidance counsellors ("KUI-counsellors") from three different municipalities and five esports instructors from STU 1, 2 and 3, respectively. Each of the three STUs has appointed two guidance counsellors for the purpose of conducting interviews, of which five agreed to be interviewed. Two of the five guidance counsellors had a teaching

background, while the other three were trained educators. In addition, some have furthered their education through master's degrees and/or guidance counsellors training. The five KUI-counsellors had several years of experience working with vulnerable young people. The esports instructors at the three STUs also had different educational backgrounds: schoolteacher, educator, multimedia designer, master's degree in pedagogy, diploma in special pedagogy. The guidance counsellors all had gaming experience, but in relatively different ways and levels. Some of the teachers identified strongly with playing esports in their free time, for example, one of them was the head coach of the local esports association.

The two sets of interviews with guidance counsellors and STU teachers, respectively, were planned and conducted independently of each other. Interviews with the teachers focused on their educational background, gaming experiences, the purpose of the esports education, and the organization and benefits of the education. Similarly, we asked the guidance counsellors about their educational background, as well as their knowledge of the esports courses and the benefits they experienced. All interviews were then transcribed as a basis for an inductive thematic analysis (Braun & Clarke, 2021), where we condensed and coded data based on the various informants' understanding of the STU target group and their experiences of the opportunities and limitations of the esports courses. Examples of coding include the informants' experiences of the STU students' prerequisites in the form of specific diagnoses and psychological challenges, experiences from previous school courses, gaming preferences, or their social and professional benefits from the education. In addition, we have drawn on theoretical perspectives to identify patterns in data that address young people's social norms and experiences across the different domains (Hanghøj et al., 2018b), which we describe in more detail below. All informants have been anonymized and given pseudonyms.

6. Analysis

We will now present three analytical themes that have emerged from our work with both data-based and theory-driven coding of interview data: 1. Esports education as an entry point to STU, 2. Esports education as a safe and structured framework, and 3. Esports education as a springboard to new communities.

6.1 Esports Education as an Entrance to STU

This theme is about how the guidance counsellors in particular view esports education as an entrance for the young people to the STU, where the young people cross boundaries from predominantly being at home (leisure domain) to participating in the teaching at the STU (educational domain). This transition to the STU is referred to by both teachers and the KUI-counsellors as an "entrance", i.e. a way of getting the young people out of isolation and into an education. The counsellors describe in detail the young people's prerequisites and challenges during their entrance, as in several cases they have followed the young people through the school-leaving period and therefore have good knowledge of their life and school situation. Several of the KUI-counsellors characterize the young people as predominantly boys with autism diagnoses who often suffer from school refusal and loneliness:

"They are often young people with some autism and maybe also some learning difficulties. They are often young boys who have been sitting at home and have had a lot of school refusal, right? ...And have not been part of a school environment for a very long time and have turned their circadian rhythm upside down" (Klara).

The STU teachers also describe how the young people often live extremely isolated lives in their room at home, with virtually no contact with the outside world:

"We have a young man of 16. He has had severe school refusal for two years and a pedagogical home support, who has been unable to do anything other than throw small notes under his door. 'Do you want to come out today?' And he didn't want to. When he came here, he smelled stuffy. He was unkempt, and he didn't say anything. He had to be driven to and from school. He could be here three days a week. He could be here from 9:30 to 12:30, and then he was driven home again." (Martin)

The STU teachers describe how the young people are so isolated and socially challenged that they simply have to learn to enter into ordinary social contexts and communicate with others. In addition, both KUI-counsellors and teachers mention that young people often have difficulty regulating their circadian rhythm in relation to their gaming activities, which has an impact not only on the young people's social skills, but also on their physical well-being and appearance:

"With hygiene and getting up in the morning and things like that, those are some tendencies that may be associated with these gamers. They don't sleep at night, then they play, and maybe they don't care

so much about health, diet and exercise and outdoor life and all that. It's a tough knot to solve, I think"
(Karen, KUI-counsellor).

Another common point for KUI-counsellors and teachers is that the young people at STU have a particular need for structure and predictability and for learning to deal with very ordinary everyday things:

"Many of them need structure, fixed frameworks. They need to know what is going to happen, all the time. There are also some who need peace and quiet around them. It is also often the case that they do not really need a big social life." (Karen).

In contrast to the STU teachers, who all have many years of gaming experience, the KUI-counsellors do not know much about gaming and esports. The counsellors do not necessarily see their lack of knowledge as a problem, but rather as something that can be disarming and open to conversation with the young people. However, several counsellors express that they have been concerned that esports as an STU line would help to keep the young people in some inappropriate behavioural patterns, if they, for example, play too much in advance. However, the KUI-counsellors no longer have that concern, as they can see that the esports education strengthens the community and their motivation to attend:

"I have so many young people who can't get started with anything because they can't change their circadian rhythm, and (...) I find that worrying! Not that I think gaming is only bad, because I think there are really many young people who get a huge social community out of [gaming] and get an insane amount of benefit" (Klara).

"Right at the beginning I thought, oh no, [gaming] already takes up so much, and now it should also apply at school, but the young people are motivated, so I've changed my attitude towards it" (Karen).

The motivation aspect of esports is also central to the teachers, who say that there are generally major problems with absenteeism at STU. Many of the students have had a long history of school refusal and have low motivation to attend classes. One of the teachers says of a young person that: "... as soon as something looked like a classroom, he was on his way out the door." (Peter). Conversely, the teachers experience that the young people are generally motivated to participate in esports classes: "We had a young person who hadn't been to school for a long time who suddenly comes to school every day because it's about esports – and can just as easily be in the other subjects" (Niklas). For the same reason, it is an advantage that esports classes are held in the morning, so that the young people are more willing to come to STU.

Thus, both teachers and KUI-counsellors experience a transformation of the young people occurs, when they are admitted to STU. This can be described as a translation process, where counsellors and teachers differentiate their view of the young people in relation to the fact that they can both draw on their identities as "gamers" at home (leisure domain), but also seize the opportunities, skills and new identities that are made available to them as esports athletes under the auspices of STU (educational domain). Both supervisors and teachers thus experience that the young people move from being lonely and isolated gamers at home to being active participants in the physical learning community of STU.

6.2 Esports Education as a Safe and Structured Framework

This analysis theme focuses on what happens in esports education. The theme is based primarily on interviews with esports educators, as they have direct experience with teaching. One of the goals that is clearly reflected in the STU educators' descriptions of their teaching is a desire to create a safe framework with fixed structures for the young people.

"My experience of what esports can do for these young people (...) is that it is a space that many of them know about, and which is safe to land in, for many of the profiles we have. In this way, there is a recognizability in meeting up at a computer and being together around it" (Martin).

The teachers agree that they have chosen certain computer games - primarily *Counter-Strike* and *League of Legends* - as a consistent starting point for the teaching.

"[The framework] is 100 percent set by me, no matter what their wishes are. Of course I am responsive, but as a starting point I have set a framework because it works. If there are 10 young people sitting around and each playing their own computer game - Roblox, Terraria, Minecraft. First of all, I have no knowledge of that, and secondly, I don't think it has anything to do with esports. We need to have something in common, preferably where some have some kind of preconception, and where some are

completely new. Because then we can create a learning space together. So, the framework becomes LoL, and that's what we have" (Niklas).

The teachers emphasize the importance of esports lessons following the same structure and rhythm. In addition, both teachers and KUI-counsellors emphasize how the fixed framework in esports education allows young people to try to communicate precisely and focused when they have to solve tasks in a game together with their teammates. A KUI-counsellors reflects in the following way:

"It's like, you're forced together, you're sitting and playing with some other people from school in a very, very defined context, and they really benefit from that with that context defined" (Lise).

Communication is also about creating a reflective awareness in young people about how they speak to each other in the heat of battle, and how important it is to have a good tone of voice:

"So, we talk a lot about what is good and bad communication. Good communication can be precise, relevant messages. Relevant communication is not what I had for dinner last night, or 'I think your mother is ugly and she smells'. That's really bad" (Martin).

Many of the young people are used to the fact that there can be a harsh tone when gaming, also known as being "toxic". Similarly, it is also relatively common for online players to have difficulty controlling their temper, a behavior known as "tilting". Regulating tone of voice and outbursts of anger takes up a lot of the teaching. Some of the teachers further describe how the young people can learn to give and receive feedback within the framework of the game:

"They are incredibly good at influencing each other. They can sometimes tell each other a little rawer and more unsweetened what they should have done differently. I actually think that many times Søren and I give them space to do that – to correct, it may sound a little harsh, or to set demands on each other. I really think they benefit from that: 'We meet here, we solve it together. When it's difficult, we can tell each other'. But they are also incredibly good at giving each other positive feedback" (Martin).

As the examples show, esports education is largely about being able to create a safe and structured space for togetherness, where there is room for the players to be challenged and practice communicating with others. Communication on esports teams is thus very different from the ways in which young people are used to playing online from home "in the wild", where there is no facilitator present, and where they are not obligated to each other in the same ways as in the physical space of the STU. In the STU context, they have to communicate together in order to cope and gain joint momentum in the games through team performance.

6.3 Esport as a Springboard to new Communities

If we look at the benefits of esports education at the STUs, the experiences of the KUI-counsellors are generally positive - especially in relation to the young people's social skills and the opportunity to strengthen their relationships. The KUI-counsellors primarily see the STU as a legitimate springboard to be able to socialize the vulnerable and isolated young people to get out of the room, into the physical community of the STU, where there are also opportunities to participate in other activities:

"I often use the esports programmes (...) as a springboard. It is something safe, something they know, and they can say that they are interested (...) It can get the young people out of bed and into a school and that is really positive... The young people come out and suddenly find out that it is actually very cool to be part of a community. (Klara).

"I use [esport] as an entry point (...) [When the young people] have been there for maybe half a year or a whole year, they become curious about what they are doing [elsewhere at STU]: 'It's new, but now I dare to step out of my comfort zone and I would actually like to be up in the kitchen, because they are also doing something exciting there'" (Pernille).

In this way, physical attendance at the STU can give young people the opportunity to enter into mutually committed communities, become better at forming relationships and try new activities that may be relevant to their future. The KUI-counsellors therefore not only see esports and gaming at STU as a springboard for young people to continue their education, but also as an opportunity for young people to gain some experiences and knowledge that will benefit a healthier and less isolated adult life:

"It's something about getting ready for adulthood in some way, right? And it includes both the private part, something about being able to get up in the morning and maintain a fairly normal circadian rhythm

and personal hygiene and things like that. And then there's the social part. It's something about having a leisure life (...) Having different opportunities, at least when you suddenly find yourself alone [later in life] (Karen).

"Well, I find that they get a community, and they meet other people socially who have the same interest. So, I think that's the social part, so of course I make a big deal of explaining that it's not just about sitting around and playing. It's also about being able to get along in the community, and that also requires that when we train, you have to be part of it too" (Pernille).

Across our interviews, the KUI-counsellors thus highlight the social aspect as the great strength of esports education. It is particularly the experience of being part of and engaging in a community that recurs when the counsellors have to describe the benefits of the education. In addition, the KUI-counsellors contrast the negative aspects of the young people's gamer life at home, such as isolation, disrupted circadian rhythms, unhealthy and sedentary activity, etc., with the advantages that they experience associated with gaming under the auspices of STU. In this way, they attribute formal educational legitimacy to gaming, as the activity can pave the way for this particular vulnerable group of young people to be lured out of their rooms and into a physical social community with the opportunity to find their way out into the large communities that are associated with adult life.

Where the relationship-building and community-supporting aspects are clear, the academic benefit and not least the academic relevance for both career opportunities and the students' adult lives are more unclear to the counsellors. For the KUI-counsellors, the academic benefit appears weak and although they express a curiosity about esports academics, they have difficulty both understanding it and finding information about it in general.

"This thing about esports that they have created as programmes... Without really thinking about the academic element and thinking about what we really want with this?... I perhaps don't think that it is something that the STUs themselves describe much, what exactly academically they get out of it. I think [that] there is actually a lot that they learn and become skilled at and such, but you can hear my ignorance. I actually don't know exactly what it is" (Klara)

Moreover, the KUI-counsellors request descriptions of the academic content and tools that can help translate gaming-related competencies into labour market-relevant competencies. Tools that the young people themselves can use in meetings with, for example, job centres.

These two general findings are repeated among the STU teachers, who also emphasize the community that esports education facilitates with a special focus on the students' social and communicative competencies, while at the same time downplaying the academic benefit of esports education. Some of the teachers tend to describe the academic content as being about social and communicative competencies. Another teacher goes so far as to call the academic benefit sparse, but at the same time points out that the academic aspect is mainly about "communicative skills" (Niklas).

The unclear academic aspect means that esports education by other actors, for example parents, is experienced as a kind of introductory subject before the actual academic content at the STU starts:

"It's a misconception of what esports is, that they just sit there and play computer games. When we meet the parents, it's a "soft subject," and "when are they going to come over and have something professional?" We meet that all the time" (Martin).

Both KUI-counsellors and teachers experience that the primary benefit of esports education is that young people become part of and can act in new communities. The specific esports subject is thus connected to the skills required to be part of such a community, such as being aware of one's own behavior and role, and the ability to communicate with others.

In summary, teachers and KUI-counsellors experience how the young people at STU, through their crossing of domains, move from gaming at home to being gamers who are legitimate participants in STU education. This also means a change in the way young people can become active participants in communities and even develop friendships at the STU. The esports content is often unclear to the KUI-counsellors and to some extent also to the teachers. However, the unclear professionalism is largely offset by the many positive opportunities that open up for young people in terms of attending the STU, forming social relationships and becoming aware of other activities at the STU.

7. Discussion and Conclusion

Our analysis shows that both the teachers and the KUI-counsellors generally have positive experiences of the participation of vulnerable young people in the STU's esports courses. This applies both to the "entrance" of the young people to the STU's esports programmes, the esports education itself, and the benefits thereof. It is clear that the KUI-counsellors only have limited insight into the young people's gaming experiences and have difficulty identifying the professionalism of the esports courses and possible links to other domains outside the world of games. Despite this, the counsellors are predominantly positive about the young people's increased motivation to attend the STU, their active participation in social communities and their increased motivation to try other courses or activities at the STU. The teachers are also positive, and highlight specific activities in the teaching, where they particularly use the games to work with communication in relation to strengthening the players' mutual cooperation in the game and regulating the young people's tone of communication.

It is a clear limitation of this study, that it does not include data on the actual "doings" of the esports programmes. For further analysis of this, we refer to on-going work on how the STU students participate in esports activities (Jensen et al., in review) and how the STU students perceive the esports programmes (Jensen et al., 2024).

In conclusion, both KUI-counsellors and teachers experience that esports education can help vulnerable young people cross boundaries between being at home (leisure domain), where they are often isolated, and transforming into active participants in the STU (educational domain). The young people are socially included into communities where they are given the opportunity to draw on their gaming interests, but at the same time new opportunities are opened up and offered.

Ethics declaration: The research has clearance from the Aalborg University research ethics committee.

AI declaration: No AI have been used for writing this paper.

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Comic4Welfare: An Interactive Comic-Based e-Learning Platform for Animal Welfare Education

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Abstract: Traditional methods in agricultural and animal welfare education often fail to convey ethical complexity or engage learners meaningfully. To address this, the project Tierschutz erleben introduces Comic4Welfare - a digital learning platform that combines gamified storytelling, interactive comics, and a unique comic-creation tool, the Comic Automaton, to support engaging and effective learning in animal welfare. By combining factual knowledge with emotionally resonant scenarios, the platform promotes empathy, critical thinking, and learner engagement. It guides users from structured reading modules through decision-based comic tasks to the creation of their own comics, fostering experiential, constructivist learning. Developed through iterative, user-centered design and tested in workshops with students, Comic4Welfare has shown strong potential to enhance usability and educational impact. The Comic Automaton empowers learners to visually narrate and reflect on their understanding, bridging affective and cognitive domains. This approach centers on the concept of “learning through creation,” making complex content more accessible and personally relevant.

Keywords: Gamified learning, Storytelling, Interactive comics, Comic creation, Animal welfare education

1. Introduction

The keeping of livestock such as cattle and sheep plays a vital role in ensuring food security and maintaining cultural landscapes. At the same time, livestock farming has become the subject of increasing public scrutiny, often marked by emotionally charged debates and a declining appreciation for animal agriculture (Boehm et al., 2010). In light of these developments, improving animal welfare has become a key ethical and legal priority (Spiller et al., 2015). Meeting this responsibility requires well-trained farmers, educators, and veterinary professionals who possess current and practice-relevant knowledge of animal needs, species-specific husbandry systems, and early indicators of illness or distress.

However, a persistent gap between scientific findings and their practical implementation on farms has repeatedly been pointed out (Jansen et al., 2009; Merle et al., 2024; Shiels et al., 2021). In many cases, established findings fail to reach the people who make day-to-day decisions in animal husbandry, or they are not sufficiently integrated into educational settings. This disconnect is further reinforced by outdated teaching approaches, which often focus on lecture-based instruction rather than active learning. Yet, modern learning theory emphasizes that sustainable learning outcomes are best achieved when learners are encouraged to take ownership of the learning process and engage with the material in self-directed, situated, and socially meaningful ways (Ragland et al., 2023).

One key challenge in animal welfare education lies in conveying the consequences of inadequate decision-making in a comprehensible and pedagogically effective way. Such consequences cannot be demonstrated realistically or ethically in practical training environments. Digital media and interactive simulations provide a promising alternative, particularly for younger learners and students in agricultural education. They help make complex systems accessible and enable learners to explore the outcomes of their actions without exposing real animals to harm (Veenema et al., 2024). This paper presents a novel digital approach to address these challenges by combining interactive storytelling with simulation-based learning. Building on interdisciplinary collaboration between animal scientists, media designers, educators, and developers, we have developed an educational platform (*Comic4Welfare*) that integrates narrative learning and user participation. In this context, we introduce the concept of an integrated comic creation tool (Comic Automaton), which serves as an authoring environment enabling learners to engage with animal welfare issues creatively and reflectively.

¹ The authors are listed in alphabetical order of first names.

This paper presents the development process of the *Comic4Welfare* platform, focusing on the conceptual, technical, and design decisions involved in creating its interactive comics and comic creation tool. It outlines how pedagogical principles were translated into digital formats and how interdisciplinary collaboration shaped the implementation of narrative-based learning components in the context of animal welfare education.

2. Theoretical Framework and Pedagogical Approach

To ground the development of *Comic4Welfare* in established educational principles, the following section outlines the theoretical framework and pedagogical approach that informed its design. Our analysis of the animal welfare education landscape revealed the need for a more engaging, accessible, and learner-friendly methodology — one that moves beyond the limitations of conventional, text-heavy materials. Traditional textbooks often fail to capture the practical and emotional dimensions essential in this field.

In response to the limitations of conventional materials, we adopted a design approach grounded in constructivist learning theory, which emphasizes active engagement, self-directed learning, and contextualized meaning-making. *Comic4Welfare* integrates narrative elements, role-playing, and decision-making with factual content and is intended to create immersive and experience-oriented learning environments. This learner-centered strategy may support personal meaning-making and enhance knowledge transfer through active participation. A key platform feature is the Comic Automaton, which enables learners to create their own stories and explore individual perspectives on animal welfare practices. This process is expected to foster deeper engagement and may support cognitive strategies such as active recall, potentially strengthening memory and comprehension through creative expression. Learner-generated comics can also be shared and discussed with peers, which might promote the exchange of diverse viewpoints and collaborative reflection.

The use of comics may further encourage emotional and empathetic responses, for example by portraying animals in vulnerable situations through expressive visuals. This approach is conceptually aligned with socio-emotional learning principles, which emphasize compassion, ethical awareness, and reflective thinking as relevant components of animal welfare education. As Goodbrey (2015) points out, interactive or "game" comics represent an emerging narrative medium with underdeveloped design frameworks and theoretical foundations. These limitations become particularly evident when attempting to implement branching narratives in educational contexts. Neo and Mitchell (2016) similarly describe a conceptual tension between interactivity and narrative coherence, which can hinder the effectiveness of learning experiences.

Considering these challenges, we opted against the use of a drama management system. Instead, we implemented a simplified "string of pearls" structure, which maintains authorial control while allowing for limited narrative flexibility. This design is intended to balance learner agency with a clear and coherent storyline, thereby offering a potentially engaging and pedagogically sound alternative to traditional self-directed learning tasks. It may also lower the threshold for content creation, both for educators and learners.

3. Platform Overview and Learning Environment

Tierschutz erLeben (Welfare Xperience) is a modular digital learning platform that provides foundational knowledge on animal welfare through a blend of illustrated instructional texts, short videos, and interactive media elements. The platform is structured around a central landing page that serves as the entry point to all key features, including basic learning modules, the Comic Automaton, and a personal Learning Diary (Figure 1). These components are designed to support different learning styles and levels of prior knowledge. While the platform offers a broader theoretical framework and complementary materials beyond comic-based learning, this paper focuses specifically on its two core interactive elements: the decision-based interactive comics and the Comic Automaton (*Comic4Welfare*). In addition to these content-based features, the platform incorporates tools to support reflection and self-regulated learning.

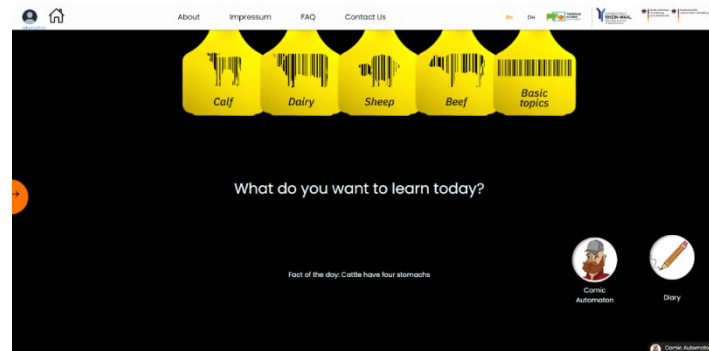


Figure 1: Screenshot of the landing page that greets every user. The main features - the Comic automaton, the basic study modules and the learning diary are clearly defined

4. Learning Support and Feedback Tools

To foster self-regulated learning, the platform includes a *Learning Diary* where users can document their progress, take notes, and plan future learning activities. Learners are invited to add manual or automatically generated reflections after each exercise, whether based on comics or theoretical content. This diary is organized chronologically according to the learner's journey and serves as a repository for completed comics and a planning tool to support self-regulated learning (Figure 2).

These pedagogical features are supported by a robust technical foundation that enables seamless integration of interactive and reflective elements across the platform.

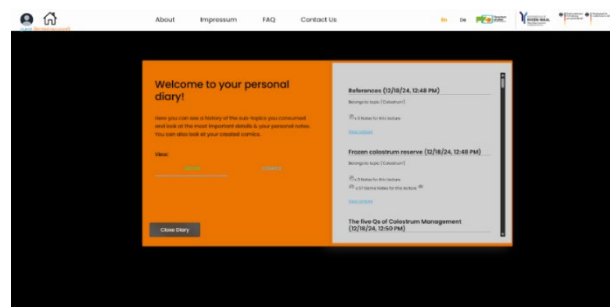


Figure 2: Screenshot of the Comic Automaton, showcasing all the interactive features of the learning platform in one accessible hub

5. System Architecture and Implementation

The learning platform is a full-stack educational web application that supports a multimodal blend of text, images, videos, and interactive content, including interactive comics and a comic creation tool. Its system architecture follows a modular client-server model. The front end was implemented using Angular and Ionic, with WebGL employed to render interactive elements and Apollo Client facilitating communication with the back end via GraphQL. Unity (version 2021) was selected to develop both the Comic Automaton and the interactive comics, based on the development team's expertise and Unity's flexibility in accommodating evolving creative concepts during the innovation process. Figma prototypes were created and iteratively refined to guide and streamline the design phase. This technical foundation enables the implementation of the platform's key interactive elements, particularly the interactive comics and the Comic Automaton, which are described in the following section.

6. Interactive Comics and Comic Creation (Comic4Welfare)

At the heart of the platform are the decision-based, interactive comics and the Comic Automaton (*Comic4Welfare*), which serve as the primary focus of this paper (Figure 3). The interactive comics present decision-based scenarios in which users actively apply their knowledge and experience the consequences of their choices in a safe, simulated environment. These narrative sequences are embedded in thematic modules and can be repeated with different outcomes, encouraging exploration and critical thinking.

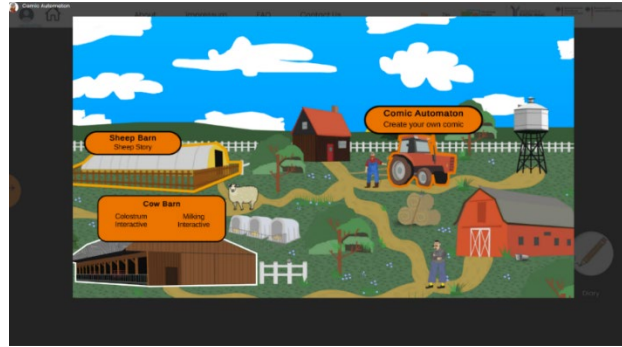


Figure 3: Screenshot of the learning diary. The diary acts as a collection of notes entered automatically from interactive comics and manually by the user

In a subsequent phase, learners use the Comic Automaton to create their own comics, drawing on characters, scenes, and events introduced in earlier stages. This creative process supports reflective learning, emotional engagement, and value-based reasoning. It also allows learners to reframe and express their understanding of animal welfare topics through personal storytelling. Optional sharing features encourage peer feedback and dialogue, supporting collaborative reflection and exposure to diverse viewpoints.

7. Interactive Comics

Comic4Welfare includes three comics aligned with core learning modules: Colostrum and Milking, both interactive, and a linear sheep-focused comic designed to explore more emotionally driven storytelling and narrative structure. The interactive comics exemplify the principle of learning through decision-making and acting, where users encounter branching points that illustrate the consequences of their choices in subsequent panels. Due to the constraints of a research-driven development process, the branching structures are intentionally limited to a few key decision points or simple equivalent tasks. All narrative paths ultimately converge back to the main storyline. Typically, one path represents an optimal outcome, while alternative paths reveal the potential negative consequences of poor decisions. Animals like cows and sheep are featured as central characters, with expressive visual cues to enhance emotional resonance. Their interactions with human figures—farmers, veterinarians, and trainees—serve to guide learners through complex processes related to animal welfare (Figure 4). These comics are designed as dialogic experiences, interspersed with instructional slides, and delivered through interactive speech bubbles that simulate a guided conversation between the learner and the system.



Figure 4: Screenshot of a slide where a friendly character guides the user through making choices to move the comic forward

For instance, the Colostrum comic follows the decision-making process surrounding administering first milk to newborn calves. Alongside storytelling elements, the comic provides factual information on the tools, techniques, and timing required for effective care (Figures 5 and 6). The correct path in the narrative results in healthy calves, while poor decisions, such as neglecting hygiene or mismanaging storage time, alerts the user of the adverse outcomes.

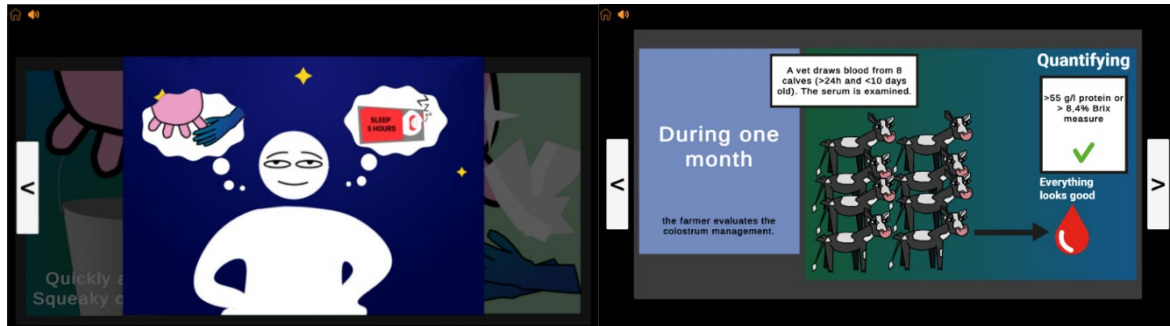


Figure 5: (Left) Screenshot of the screen where the user realizes the impact of their hygiene-related choice, shown through a clear and engaging visual outcome. (right) Screenshot of the screen where the user gains knowledge by encountering various facts shared throughout the comic journey

8. Comic Automaton

The *Comic Automaton* is designed as a creative editor for constructing linear comics, granting learners significant agency to visualize and articulate their understanding of animal welfare. The automaton welcomes users and introduces key features on the initial screen (Figure 6). Users begin by adding empty panels that serve as a canvas for story development. The tool offers a rich asset library that includes characters frequently encountered in prior modules, such as farmers, veterinarians, and trainees, as well as imaginative additions like an alien or a rubber duck, intended to foster creativity and engagement. The asset pool also includes objects ranging from brix scales (a tool to measure colostrum quality) to fences and animals depicted with varied emotional expressions, broadening the tool's applicability across diverse learning scenarios.



Figure 6: Screenshot of the initial screen displaying basic guidelines, where the comic automaton introduces itself and explains the different features available to the user

While many learners welcomed the creative freedom, some found it challenging to generate narratives independently and maintain alignment with learning objectives. To support such users, the *Comic Automaton* includes two modes of use: a **Free Mode**, allowing unrestricted storytelling; and a **Task Mode**, which provides narrative scaffolding via a set of four randomly drawn “task cards” (Figure 7). Each card represents one of four categories: a learning goal, a main character, a tool, and an out-of-context element. Inspired by the metaphor of a deck of cards, this structure stimulates imaginative storytelling while keeping the narrative anchored in educational objectives. Completed comics can be saved, retrieved, and exported as PDF files, enabling learners to present their work in classroom settings, share with peers, or use as a personal record of learning progress. An example of a comic created shows the usage of various components of the comic automaton (Figure 8). This combination of creative freedom and structured guidance makes the *Comic Automaton* a powerful tool for reflective and expressive learning.

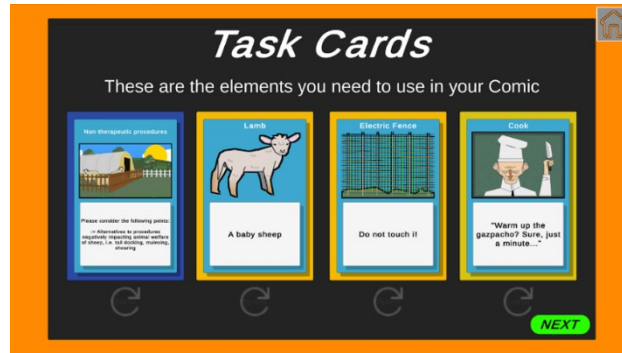


Figure 7: Screenshot of the task cards mode, which prompts a combination of four play cards that acts as a foundation for the student's narrative



Figure 8: Screenshot of a comic sequence generated using the comic automaton, illustrating the story of a perceptive farmer who consults a veterinarian in a timely manner to ensure his calf's well-being

9. Usability

Comic4Welfare offers a simplified user journey by placing its core features, the *Comic Automaton* and interactive comics within a single hub, the *Playground*. After each topic, learners can return to this space to actively apply knowledge through creative and interactive exercises. The platform's visual design prioritizes clarity and accessibility, combining dark mode to reduce eye strain with lighter reading screens that enhance legibility, all within a consistent comic-inspired design language. Development was shaped through iterative user testing and participatory workshops, ensuring usability remained central. To close the feedback loop, a learning diary tracks user progress and supports continuous reflection. Meanwhile, the flexible backend empowers educators to adapt content, enabling the platform to serve a wide range of pedagogical needs and educational contexts.

10. User Testing and Workshops

Over the course of the project, four workshops and user testing sessions were conducted involving a range of 10-20 participants in-person for each of the sessions. The participants were students of agriculture and animal husbandry at the university between second to fourth semesters, guided by a human-centered design approach. These sessions played a pivotal role in shaping the platform, offering valuable insights that directly influenced decisions related to style, functionality, and user engagement strategies.

The first workshop introduced students to the platform concept, focusing on topics such as cattle and sheep. As early adopters, they engaged in brainstorming sessions with preliminary mock-ups, including paper prototypes of 3D simulations and learning strategies. The goal was to gather impressions, emotional responses, and expectations, with feedback emphasizing how learners acquire knowledge and what resources they use. A key insight was the need for immersive, visually engaging tools. This guided development toward narrative storytelling and 2D comic-based learning, which proved more effective for motivation and clarity, while 3D simulations were seen as time-intensive, less visually clear, and offering limited active participation.

The second workshop applied the dot-voting method on paper prototypes to evaluate features such as the comic storyline, button layouts, and linear storytelling format. This exercise helped identify the most desirable elements and tested whether users could intuitively navigate the interactive flow. The session marked a shift from exploratory, qualitative feedback toward more data-driven evaluation of design decisions.

The third workshop tested early versions of the Comic Automaton, envisioned as a creative playground for learners. Combining A/B testing with UEQ surveys, it assessed factors such as clarity, attractiveness, and efficiency, while also observing how students approached story creation (Figure 9). The results showed enthusiasm but also difficulties in generating narratives and staying focused on learning goals. These findings led to the development of a task mode, offering structured guidance to better support comic creation and align with educational objectives.

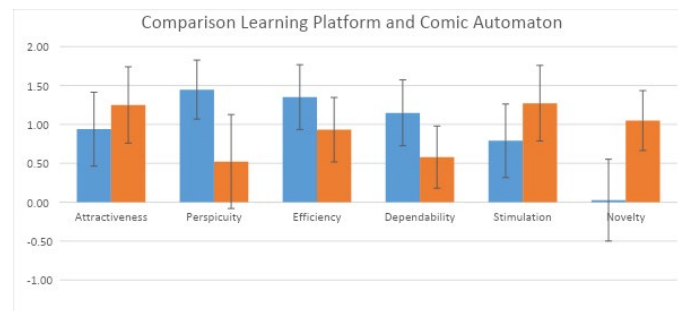


Figure 9: The comparison results from UEQ across 6 measured dimensions shows the learning platform as clearer, more efficient, and reliable, while the Comic Automaton is seen as more attractive, stimulating, and novel feature but less effective

The fourth workshop evaluated the usability and effectiveness of the nearly complete platform, focusing on the Comic Automaton, interactive comics, and their integration with the learning diary. Using a think-aloud protocol, participants provided real-time insights into the interface's intuitiveness, uncovering several usability challenges and technical pain points that informed final refinements. The session concluded with a brief interactive exercise using post-it notes, which captured quick feedback. The responses were positive, affirming the design choices and highlighting the platform's potential to engage learners effectively. Together, the workshops ensured that user needs remained central throughout development.

11. Reflection and Conclusion

At its inception, the *Comic4Welfare* Platform was conceived in response to a growing need for innovative, user-centered pedagogical approaches in agricultural education (Boehm et al., 2010; McGrath et al., 2024). Traditional methods often struggle to engage learners with the ethical complexity and emotional dimensions of animal husbandry. The project was therefore designed to integrate established pedagogical strategies, such as narrative framing, visual communication, and the didactic potential of comics, with the principle of learning by doing, to address the challenge of creating immersive and engaging educational experiences appropriate to the domain of animal husbandry. This approach aims to foster not only knowledge acquisition but also critical thinking, empathy, and reflective decision-making within playful, but realistic scenarios. The current version of *Comic4Welfare* is designed to guide learners through interactive, branching storylines and ultimately enable them to create their own comics. This fosters a dual learning role as both recipient and creator of knowledge, an approach grounded in participatory culture and learner agency (Jenkins et al., 2015). While the present narrative structure relies on largely predefined story paths and simplified interaction logic, the platform's underlying architecture is intentionally modular and scalable, laying the groundwork for future expansion and technical sophistication. Unity was selected as the development environment due to its robust multimedia capabilities and flexibility in rapid prototyping. This choice aligned with available development expertise and the ambition to create a visually rich user experience. In retrospect, however, frameworks dedicated to 2D interactive storytelling, such as Ink or Twine, might have proven more efficient for handling complex branching logic and deploying lightweight, text-driven applications (Letonsaari, 2019).

Artificial intelligence (AI) is not yet integrated but is envisioned as a key element in future development. Its implementation could help experts generate content more efficiently and expand the Comic Automaton's capacity for adaptive, user-driven narratives - for example, by dynamically adjusting storylines based on learner choices or providing intelligent feedback during comic creation. At present, narrative progression is limited by technical and design constraints, leaving the potential of fully emergent, non-linear storytelling untapped.

However, the system's open architecture and authoring model are designed to support such enhancements, aligning with the project's vision of fostering individualized, engaging, and pedagogically grounded learning experiences.

Comic4Welfare is being continuously tested with 2nd–4th semester students in agricultural and animal welfare programs. In one practical, 22 students created comics as an assignment and rated usability, engagement, and continued use of the Comic Automaton at 3 out of 5. Feedback highlighted the value of visual storytelling for addressing complex ethical issues. Ongoing surveys with added study material aim to further evaluate the platform's continued relevance and design effectiveness. However, the long-term educational effects remain to be systematically evaluated. Continuing future research along the lines of meaningful gamification, as demonstrated in our project and informed by Massler et al. (2022), will require assessing learning outcomes, user retention, and transferability to other subject areas. Moreover, the scalability of the platform and its adaptability to diverse user groups, ranging from vocational trainees to university students and even practitioners, will be critical factors for its sustainable implementation. *Comic4Welfare* thus represents a promising, but still evolving, approach to transforming agricultural education through creative digital pedagogy.

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Exploring Sustainability Through Board Game Design as a Learning Approach in Schools

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Abstract: Sustainability and environmental education aiming to foster a nuanced understanding of environmental sustainability is receiving growing attention in schools. Simultaneously, board games have gained popularity as a pedagogical tool in primary and lower secondary education, especially in design-based approaches where students engage in iterative prototyping and developing games with various mechanics. This study explores the potentials and pitfalls of integrating board game design processes into sustainability education, focusing on how students engage with environmental issues through various game mechanics. The study uses principles from Education for Sustainable Development (ESD) as a framework to understand students' development of systems thinking, anticipatory thinking and problem-solving. The paper is based on a pilot study conducted in 2024 at a school in Copenhagen, using a Design-Based Research approach. The study involved students aged 12-15 redesigning board games to explore oceanic climate challenges. Through a six-weeks iterative process inspired by design thinking processes, students analysed games to develop game literacy while progressing through phases of inquiry, interpretation, ideation, prototyping and testing. The empirical data consists of field notes and photos from observations of the students' design processes. Furthermore, we conducted workshops and interviews with selected teachers. The theoretical framework draws on game theory, design-oriented approaches and creativity. The analysis highlights potentials and challenges in students' engagement with board game prototyping, particularly in balancing educational content, aesthetic expression, and functional game mechanics. The three redesigned game: Pictionary, Dixit, and Ego, each demonstrated specific affordances for supporting sustainability-related learning, including perspective-taking, emotional engagement, and values-based reflection. However, the process also revealed a need to explicitly support iterative work, as many students struggled with revisiting and refining their prototypes, often aiming for polished products rather than engaging in open-ended experimentation. Based on the analysis, the paper presents a series of design principles aimed at using board game design as an approach to working with ESD in schools.

Keywords: Sustainability, Environmental education, Education for sustainable development, Board games, Design processes, Learning

1. Introduction

Board games are becoming increasingly popular in primary and lower secondary schools for teaching sustainable development (Tan and Nurul-Asna 2023; Fjællingsdal 2025). This includes uses of many different types of games, for example the use of learning games and commercial board games, as well as design-based approaches where students modify or create games to explore environmental themes. There are various reasons for using “green games” as a tool for sustainability education. One reason is that sustainability can be difficult for students to comprehend as a concept as it often involves complex and interconnected challenges. Board games can help make abstract environmental issues more tangible by revealing systemic aspects and allowing students to interact with them in a structured way. Furthermore, board games can provide immersive and engaging learning experiences by allowing students to take an active role in problem-solving, creative design, and collaboration. By playing and designing games, students can develop an understanding of sustainability topics while using strategic and analytical skills. However, there is also a risk of oversimplifying sustainability issues.

In sustainability education, the goal for students is to understand and engage with environmental challenges. This can evoke feelings of climate fatigue (Thystrup Mehlsen et al. 2023). Education for Sustainable Development (ESD) seeks to address this fatigue and feelings of powerlessness by providing students with the competencies to navigate and address sustainability issues. A systematic review of sustainability competences in primary education highlights five core competences: systems thinking, futures thinking, action-oriented competence, values thinking, and collaboration (Vesterinen and Ratinen 2023). Laugesen and Elf (2023) further emphasize that ESD should be integrated within individual subjects as well as across disciplines. A central point in their

approach is the inclusion of an aesthetic-affective dimension alongside cognitive, moral, and psychological aspects. This dimension emphasizes the importance of considering students' emotions, sensory experiences, and more embodied engagement when teaching in sustainability. They argue that teachers should invite students to connect with sustainability issues through visual expression, hands-on experiences, and more direct experiences with nature. In this way, the aesthetic-affective dimension in sustainability teaching should focus "on embodiment, sensations, and emotions – in other words, what sustainability teaching feels like" (Laugesen and Elf 2023, p.168). Their understanding of teaching quality builds on pragmatism inspired by Dewey, which emphasizes that quality in teaching emerges through experiments and experiences, is context-dependent and must relate to a particular content or topic.

Similarly, Lene Tanggaard (2020) argues from a creativity perspective that education plays a vital role in making students feel that they are a part of life in their society and culture and have the ability and responsibility to contribute to it. Tanggaard's perspectives also build on a pragmatic approach to creativity, emphasizing that students' contribution depends on their sense of creative agency and social responsibility, which should be taught and cultivated within the subject areas. When we work with ESD perspectives, we aim to support the students' experiences of being part of society having the agency to act together with others. Thus, we build on an understanding of "collective creativity" (Tanggaard 2020, p. 4) where students collaborate to design games that tackle the complex aspects of sustainability.

In this study we explore creative approaches to ESD by investigating secondary students' design and redesign of board games with a focus on complex sustainability issues. We understand board game design in learning situations as an inquiry process that involves navigating various framings and choices regarding aspects such as the target group, subject-matter integration, and the balance between gaming and learning — what Hanghøj (2023) refers to as design dilemmas. This brings us to the following research question: What design dilemmas arise when secondary students design board games addressing environmental challenges, particularly in relation to perspective-taking and aesthetic aspects?

2. Board Games and Game Design in Education

Board games have a long history in education. They represent appealing spaces for learning because of the simplicity and hands-on quality of many game mechanics, which are often fairly easy to understand and change (Bayeck 2020). Moreover, games enable focused face to face communication across the board and shared bodily orientations. In this way, the affordability and accessibility of board games make them ideal for providing social and playful learning experiences (Ruberg and Shaw 2017). Moreover, board games allow for various interactions that result in students engaging in problem-solving, teamwork, and creativity (Zagal et al. 2006; Hanghøj and Karnøe 2024).

There exists a growing body of research on the educational use of board games for teaching environmental education (Tan and Nurul-Asna 2023; Fjællingsdal 2025). Most of these studies focus on the use of existing board games, either educational games or commercial games, for teaching. However, other studies have investigated design approaches to board games, i.e. where students learn by designing or redesigning board games in relation to specific educational aims (Hanghøj 2023; Hautopp et al. 2023; Bernier et al. 2024). In contrast to using existing board games, design approaches focus on developing students' creative competencies, e.g. by learning how to recreate board games through a design processes - often inspired by the various phases of design thinking (Rusmann and Ejsing-Duun 2022).

To understand how the students worked with game design processes, we draw on the MDA framework, which has been developed by game designers as a tool to analyse games (Hunicke et al. 2004). The MDA framework formalises the properties of games by breaking them down into three components: *mechanics* (the base components of the game involving rules and every basic action the player can take in the game), *dynamics* (how players respond and enact the mechanics, e.g. through tactics or collaboration), and *aesthetics* (the desired emotional responses evoked in the player). For example, the creative word association game Dixit uses game mechanics such as drawing cards, taking turns giving ambiguous clues, and trying to vote on the right card. Playing the game enact game dynamics such as guessing relations between the given word and the cards and trying to follow the perspective of the assumed card holder. This involves aesthetic experiences related to the visual perception of the ambiguous cards, using the imagination, and engaging in collaborative storytelling around different meanings of words and cards.

3. Collective Creativity from a Pragmatic Perspective

Creativity is often misunderstood as an expression of artistic talent that is only carried out by especially talented people (Brinkmann and Tanggaard 2013; Tanggaard 2020). Contrary to this belief, Tanggaard (2020) argues that creativity is a craft that can be learned, and what is perceived as new and creative work can vary across different domains. Tanggaard (2020) emphasizes that creativity in education "requires that students are taught to share perspectives, to get things done, to take risks, to not always ask for permission and to understand the roles of others in relation to their own creativity" (p. 12). This calls for a we-paradigm where "collective creativity" is a focal point of students group work addressing subject areas and not seen as a detached meta-competence (p.13).

Brinkmann and Tanggaard (2013) advocate for the establishment of 'creative communities' in education that focus on the epistemology of the hand. They emphasize craftsmanship and pragmatic inquiry processes, which involve 'grasping' the world through hands-on activities. This approach contrasts with the traditional understanding of learning based on the epistemology of the eye, where students are merely presented with knowledge in lectures by omniscient teachers. According to the epistemology of the hand, learning through practical activities and experimentation is emphasized, aligning with John Dewey's pragmatic approach to inquiry. Dewey argues against the traditional separation of theory and practice, stating that the "so-called separation of theory and practice means in fact the separation of two kinds of practice" (p. 69). Thus, the process of inquiry is central to testing ideas and actions that lead to reflections on solutions. In a pragmatic approach to learning, theories and methods are viewed as 'tools' to be applied and reflected upon in relation to practical experiences in the world (Brinkmann and Tanggaard 2013).

In our study, this means providing students with a variety of materials and game mechanics as tools to develop games and reflect upon ESD issues. Moreover, our analysis will identify changes in students' perspectives as they redesign and play their games. As Tanggaard (2020) argues, "The creative capacity concerns the ability to imagine the perspective of another person and thus put oneself in their shoes" (p. 8).

4. Method and Data

Our methodological approach builds on Design-Based Research (DBR), which is a participatory and interventionistic research approach to developing educational designs, creating changes in the specific contexts as well as generating knowledge for the research field (Anderson and Shattuck 2012). The empirical data in this study is based on a pilot study conducted in 2024 at a project-oriented school in Copenhagen involving approx. 30 students aged 12-15 spanning 6 weeks. The intervention was part of a cross-disciplinary project-based course with learning goals from science, mathematics, cultural studies, L1(Danish), and practical subject competencies. The guiding question that framed the project was how climate change affects the oceans. The course organisation was familiar to both the teachers and students. As part of this course, the intervention aimed to redesign commercial board games (Pictionary, Dixit, and Ego) that involved expressing or interpreting ideas, emotions, or intentions to communicate oceanic climate challenges to potential players. The empirical data consists of field notes and photos from observations of the students' design processes, prototype testing, and presentation of game designs. Six researchers were involved in gathering data. Furthermore, we conducted *in situ* interviews with students and teachers as part of classroom observations. In line with the DBR participatory methodology, we involved the teachers in the planning phase of the study. Based on our DBR interventions, we developed design principles aimed at providing guidance for researchers and practitioners conducting similar studies (Hanghøj et al. 2022). The principles developed here is a continuation of the principles concerning teacher redesign of board games presented by Hautopp et al. (2023).

5. Analysis

In the following analysis, we explore the empirical data through two themes that reflect different orientations and dilemmas in students' board game design processes. The themes do not reflect fixed binary oppositions but represent continua of different configurations found in the data. The first theme focuses on the role of aesthetics in supporting or complicating sustainability learning, while the second theme explores how game design can support or constrain students' ability to adapt new perspectives and engage with sustainability from different viewpoints. Across both themes, we draw on theoretical perspectives from creativity (Tanggaard 2020), aesthetic-affective (Laugesen and Elf 2023), and the MDA (Hunicke et al. 2004).

5.1 Theme 1: Balancing Game Design and Aesthetic Dimensions

This theme explores the tension between the aesthetic dimensions of game design and the ESD learning goals. The students worked with visual and material design by sketching, drawing, and using digital tools like Canva, which revealed both potentials and challenges. In summary, the aesthetic dimension worked as a hook to engage students but there was also a risk of overshadowing the sustainability learning goals.

5.1.1 Visual creation as a motivational entry into the game design

In several cases, the graphic design of the game board and components served as a motivational entry into the project. One group of students, Alicia, Allan and Lena, redesigned Pictionary and created a game board with a “trash island” and cards to play with. The group’s redesign featured a game board with spaces to move a meeple on, (fig. 1) and playing cards with three colors (fig. 1) matching the spaces. Each color on the card had a word or phrase. So, when a player landed on an orange space the player took a card and drew the phrase for the orange color and the team should guess what it was.



Figure 1: The playing board is shown on the right. On the left is an example of a game card with the phrases: “dried out sea”, “factory” and “suffocated turtle”

Initially, the group had approached the task with a detached attitude, but their engagement shifted once they began working on the visual layout. Alicia was skilled in Canva and engaged with the overall design of the board, the colors of the spaces and particularly how they could make an aesthetically pleasing trash island in the middle of the board. She first used Google searches to look for images of trash islands, finding out that they were called rubbish patches. However, none were deemed to fit the theme she aimed for. So, she ended up using the Canva AI tool to work with a lot of templates for bottles, plastic cups and other kinds of waste to create their own image of a trash island. During this, Allan used a considerable amount of time to design a dock-theme on the upper left corner of the board. As the group worked on their design, they began humming and singing which can indicate a sense of comfort and engagement in their creative process.

There are several examples that point to aesthetic competence as a valuable form of expertise in the classroom which resonates with Tanggaard’s (2020) notion of “collective creativity,” where students contribute to the shared culture of the classroom. One example is the student, Samira, from another group, who was impressed by the design by Alicia and asked Alicia for help with the design of her own group’s board.

5.1.2 Translating knowledge into playable games

Although the sustainability content was not always explicit, there were indications that students used visual design to explore and express complex ideas. This process required students to make decisions about how to represent environmental issues in ways that were meaningful and playable. One example comes from a group of two girls working on a Pictionary-style game. They searched the internet for information about environmental issues and discussed how to translate this information into game content. Their goal was to create cards that

were not only grounded in facts but also open to interpretation—a feature of this game’s mechanics. In this way, the group tried to get initial insight into the environmental phenomenon before they could visualise it and then abstract it into a term or image that would work in the game. Their reflections indicate an awareness of the need for ambiguity in game design, and how this ambiguity must be grounded in elements that can mean different things. This example highlights how the process of designing for ambiguity potentially can support learning. The students were not just copying information—they were striving to interpret, transform, and recontextualize information within a creative framework. One could argue that these students undertook an inquiry and experimental process where their knowledge is tested and reshaped through practical activity.

In the testing phase, students had the opportunity to observe how others interacted with their games and whether their game was playable. One group noted that the visiting students were engaged and entertained by the gameplay. This indicates that the mechanics of scoring points captured the players’ attention and limited the opportunity for a dialogue or reflection on the sustainability themes in the game. This highlights the importance of balancing these elements in educational game design.

Several students encountered new knowledge during the design process as they searched the internet for information about environmental issues. This often sparked emotional reactions. One student exclaimed, “I didn’t know a coral reef could die before this project,” while another, upon seeing images of the Pacific garbage patch, simply said, “ew!”. These moments illustrate a shift from vague awareness to more concrete understanding. However, they also highlight a pedagogical dilemma: as the students gained insight into environmental problems, they might experience discomfort or apathy.

5.1.3 When “pretty” becomes the main goal

The strong focus on visual design among the students also had a downside. In several cases, students became absorbed in wanting to perfect the look of their games, which backgrounded the sustainability content that remained underdeveloped or was rather vague. One student questioned this directly by saying: “But maybe it is not the point that it should be pretty?”.

One group of students redesigned *Dixit* with a marine theme but struggled to link the visuals to environmental issues. When the teacher encouraged them to brainstorm using post-its, one of the students wrote: “The game should look nice.” The atmosphere remained disengaged until they began using computers and Canva, which improved their engagement. Although their collaboration improved, their focus remained on visuals rather than sustainability. This was also evident when a student remarked: “I just need to use flames” while designing a card about forest fires, illustrating how visual appeal and expression, often overshadowed the educational goals.

In several cases the teachers also drew attention to this focus as they explicitly praised the visual quality of the games. One teacher commented: “Wow, the games are pretty in here.” This contains the risk to further support a norm where pretty aesthetics is related to successful game design. The risk is that students base design choices solely on what looks good and pretty, and not on what supports the game mechanics or the ESD learning goals. From the perspective of the MDA framework, the goal is not to prioritize one aspect but to balance the aesthetics (the emotional and sensory experience) with the mechanics (rules and actions) and dynamics (player interaction) to support meaningful learning.

5.1.4 The difficulty of unfinished work and redesigning a prototype

Another recurring challenge was the students’ struggle with the iterative manner of prototyping which they were not familiar with. Many students expected to produce a finished product at an early stage in the process and found it difficult to work with incomplete or continuously evolving designs. As one teacher observed: “They [the students] really had a hard time with the idea that it didn’t have to be completely finished.” This resistance among the students towards working iteratively and with more sketchy prototypes indicate a norm where more “polished” and finished products sometimes are preferred and valued over the process of design and continuously revisiting a prototype. Tanggaard (2020) emphasizes the importance of working with more open-ended processes, where students learn through experimentation and revisions. However, in this case, some students struggled to hold their motivation when their work remained in a sketching or prototyping phase.

One group had completed a prototype of their *Dixit* redesign, and they were not particularly interested in continuing the development. The teacher encouraged them to explore new ideas, but the students were resistant. In their first version of the game, the students used hand-drawn cards and mostly copied the playful style of *Dixit*—just with an ocean theme. When playing the game, the environmental problems were simplified into short phrases like ‘plastic in the ocean,’ which made the complex issues seem too simplified.

5.2 Theme 2: Balancing Game Design and Perspective-Taking

This theme explores how game mechanics and design processes can foster the shift of perspectives among students, while also highlighting the risk that such reflections can remain superficial and fail to support the ESD learning goals.

5.2.1 *Imagining “the other” in design processes*

In the design process, students had to imagine “the other” and consider how future players might play their game or how they would navigate the sustainability themes. This process of designing with someone else in mind required students to step outside their own perspective and imagine how others would make meaning through their game mechanics and the visual design.

One group emphasised that their target group were 9-30 year old, “who have grown up with climate issues”. They aimed to design figurative cards that could be interpreted in multiple ways, reflecting on how technology can both solve and contribute to environmental problems. They strived to express this duality visually. It can be argued that these students were aware about different perspectives (Tanggaard 2020) on technology’s influence on the environment which they wanted to adress in their game. However, these students had a hard time illustrating this ambiguous dimension through their analogue drawings. The introduction of Canva allowed them to better realise their intentions and refine their message for the imagined player. Another group preferred to draw their cards by hand and resisted using digital tools. For them, analogue drawing was a meaningful way to engage with the topic and imagine how others might experience the game.

This act of designing for someone else can be seen as a form of perspective-taking, where students try to see the topic from another person’s point of view. From an aesthetic-affective perspective (Laugesen and Elf 2023), this way of working helped the students feel more emotionally connected to the theme, while also developing their creative capacity to consider different viewpoints and imagine the perspective of others (Tanggaard 2020).

This was also noticeable in another group where a student reflected on a card about second-hand clothes: “I think the card is good... it makes you think, for example, about second-hand clothes. I like wearing second-hand... it’s much cheaper and you can get more expensive brands. And it has already been bought, so less clothes need to be produced.” Here, the student connects personal values to broader sustainability themes, while also considering how the card might prompt others to reflect.

In one example, the students wrote in their reflection paper that their game should create a “good atmosphere” for players, but they also expressed a concern that it might become “too sad”. This indicates an early shift of perspective, where the imagined player becomes part of the group’s design considerations where students tried to imagine how others would experience their game and how they tried to balance various emotional responses to their design and game mechanics.

5.2.2 *Game mechanics based on dilemmas*

A group of students designed games that included dilemmas and voting mechanics, which created dialogues on ethical dilemmas. They drew inspiration from the game called Ego, which is a party game where players respond to personal or ethical questions and others guess their answers. This game mechanic can prompt reflections on values and assumptions about the other players. In their redesign, students discussed whether they would pick up trash in public. One student said, “You would just look at it and do nothing, Amanda,” to which Amanda replied, “Yeah, I am a terrible person,” followed by, “I thought you were better than that!”. In another dialogue, the dilemma of choosing between plane, train, or car travel sparked discussion about environmental impacts. One student said, “You don’t like flying, it gives you a headache,” implying the choice was driven by personal discomfort rather than environmental concerns. The dialogue nevertheless also included pro and con arguments on the various types of travel. Even though the tone in these dialogues was often humorous, the examples show that the students started to reflect on social norms and personal responsibility. This aligns with Tanggaard’s (2020) concept of collective creativity, where learning involves negotiating values and imagining others’ perspectives. One could argue that the game format showed potentials to support the students to talk about difficult topics in a playful way and a space where they could express their opinions and guess what others might think or do. In this way, the game mechanics supported perspective-taking and somewhat value-based dialogue.

5.2.3 *Shifting perspectives through narratives and everyday experiences*

Some groups used storytelling to connect abstract environmental issues to familiar experiences. One group created a game titled “Gaia”, which represented: “Mother Earth who gets angry, when we as humans do not

treat her nice". The students further elaborated: "Just like our parents, who can get angry and say that we are not allowed to watch TV or use our mobile phones. Gaia gets angry when we don't behave properly, for example, it causes landslides and floods. And when we treat the Earth well, it also becomes happy". One could argue that the students in this example connected the climate crisis to an everyday conflict they have experienced with their parents. The analogy potentially helped the students to make sense of complex issue through everyday family dynamics.

From an educational perspective, this can be seen as a form of perspective-taking, where the students attempted to imagine the Earth having emotions and reactions. In line with Tanggaard's (2020) notion of creative capacity, the students engaged in a process of imagining the perspective of others and relating it to their own lived experiences. This narrative move reflected a shift from abstract complex global problems to a more embodied and emotionally resonant understanding, which aligns with the aesthetic-affective dimension of ESD (Laugesen and Elf 2023). However, while the narrative made the issue more relatable, it also risks oversimplifying the causes and consequences of environmental challenges, reducing complex and more systemic issues to individual moral behaviour. Another group also used narrative elements to make their games emotionally involving for their future game players. They designed a card with forest fires. Even though forest fires can be linked to environmental challenges, the students did not articulate this connection. Instead, they focused on creating a dramatic scene. As one student explained, "there needs to be a story," indicating that this student imagined that this would stimulate emotional engagement and maybe open for multiple interpretations. The students seemed to imagine how future players might respond to the visual and emotional cues in the game. However, the environmental meaning behind these elements remained vague in this example.

6. Discussion

In this study we have explored how students in school can work with sustainability topics by designing and redesigning board games. We found that many students became highly engaged in the visual and creative parts of the design processes. Especially the aesthetic part was important for motivation but also contributed to a shared culture of collective creativity in the classroom. Sometimes however, focusing on making the game "look nice" backgrounded the focus on the sustainability content. This can be a problem if the learning goals from one aspect overshadow learning goals from other aspects. In this context, the teacher's role was to facilitate the making of meaningful connections between aspects. Connected to this was challenges in the prototyping process. Many students were not used to working with unfinished products and found it difficult to change their ideas repeatedly. Thus continuing to work on their first prototype had more appeal than discarding it and starting on a new iteration. Early on, some students perceived their games as being finished and did not like to change them, as it felt like going backwards. This shows how important it is to support students in understanding that design is also a process and not only a final product. Furthermore, we saw that some students started to think in new ways about sustainability. For example, they tried to imagine how other people would play their game or how others would feel about the environmental topics. This kind of perspective-taking is important in Education for Sustainable Development (ESD). But not all students had the language or knowledge to engage deeply with the topics. Some seemed to just search random things on the internet and uncritically use what they found. This shows that students need help to build knowledge both about ESD and about game design, and that the design process should incorporate more explicit opportunities for this. In the examples above Canva was involved as the turning point for many of the groups, however this was not always the case and other groups also found Canva a limiting factor. The role of digital vs analogue drawing tools in the design process would be interesting to explore further. Based on our findings, we identified the following design principles that can help teachers when using board game design in sustainability education:

- Design for compound creation between aesthetics and learning: support opportunities for students to make meaningful connections where creativity, sustainability and game mechanics complement each other.
- Consider being explicit about how the learning design supports iterative work: Students who are not familiar with iterations need support to learn the value of changing and improving their ideas and design.
- Consider using specific game mechanics to support the learning goal: If the learning is perspective-taking, games with dilemmas, voting or storytelling can help students think about other people's views and values.
- Consider using emotional and narrative engagement: support opportunities to use stories and emotions to make abstract environmental issues more relatable while avoiding oversimplification.

- Support a classroom culture of shared and collective creativity where student groups can be inspired by each other.

7. Conclusion

This study shows that board game design can be a useful method to involve students in learning about sustainability, especially when it includes creative work, collaboration, and trying to see things from different perspectives. However, it is important to pay attention to how the visual and playful elements of the game are balanced with the educational content. Also, students need support during the process, and they should be encouraged to work with their ideas in an open and iterative way. The design principles proposed in this paper may serve as a framework for other educators and researchers seeking to use game design and integrate it into sustainability education.

Ethics declaration: The research follows the ethical research guidelines from the *Danish Code of Conduct for Research Integrity*.

AI declaration: We have used AI as thesaurus and for proofreading.

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Board Games and Mathematics: A Winning Strategy for Teaching Rational Numbers

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Abstract: The use of games in educational context has been widely recognised as an effective strategy for making learning more engaging and meaningful. Educational games create a dynamic environment where students not only consolidate academic knowledge but also develop soft skills such as teamwork, decision-making, and communication. In mathematics education, where student motivation is often a major concern, the incorporation of gamification strategies has shown a very positive impact on learning. Through playful challenges, students are encouraged to apply mathematical concepts in a practical and interactive way, increasing their engagement and improving their understanding of the subject matter. Moreover, the use of games in mathematics education extends beyond reinforcing curricular content. It also helps foster a more positive attitude towards the subject. This paper presents a study which explores the use of non-digital games as a pedagogical strategy in the teaching and learning of rational numbers in primary school. The main objective was to assess the effectiveness of non-digital board and card games as a teaching strategy for non-negative rational numbers among Year 5 students. The methodology adopted was a qualitative case study with quantitative statistical analysis, involving the implementation of three physical board/card games in three classes. Data collection techniques included surveys, direct observation by the teacher-researcher, and analysis of students' written work produced during gameplay. This study provides significant contributions, namely expanding knowledge on the effectiveness of non-digital games in mathematics education, offering evidence of their use as a pedagogical tool, and presenting a model that can be replicated and adapted by other educators. The results suggest that non-digital board and card games can be an effective strategy for teaching non-negative rational numbers, particularly due to increased student motivation, positive perceptions of mathematics, and improvements in self-confidence, self-esteem, willingness to overcome difficulties, and the development of social and collaborative skills.

Keywords: Educational non-digital games, Motivation, Mathematics education, Game-Based learning

1. Introduction

In recent years, the use of games as pedagogical strategies has gained prominence in educational contexts, particularly in mathematics education. Research has shown that educational games make learning more interactive, engaging, and effective by fostering the assimilation of complex concepts and encouraging active student participation (Gee, 2003; Prensky, 2003). These tools not only enhance conceptual understanding but also promote the development of collaborative and social skills essential in school environments (Johnson et al., 2011).

Researchers such as McGonigal (2011) argue that games have strong potential to motivate and engage people, suggesting they can be used to solve real-world problems and enhance personal and professional skills. Whitton (2014) emphasises that games support learning by tapping into players' intrinsic motivation. Schell (2019) highlights the importance of thoughtful game design—both for education and entertainment—stressing that user experience should be intuitive, enjoyable, and motivating. He also notes that elements such as narrative, mechanics, and feedback must be carefully planned, and that games should be adaptable to individual needs, allowing learners to progress at their own pace. Altogether, these authors see games as versatile and effective tools to address current educational and developmental challenges.

Didactic games are specifically designed to teach particular curriculum content, with clear learning objectives and structured activities aimed at deepening students' understanding of a subject (Kapp, 2012). In contrast, pedagogical games have a broader focus on overall student development, targeting emotional, social, and behavioural skills, and promoting general competencies such as critical thinking, problem-solving, collaboration, and creativity (Gee, 2003). The main distinction lies in their purpose: didactic games focus on content knowledge, while pedagogical games emphasise holistic skill development. Given the dual focus of the games in

this study—on both content and competencies—the term “educational games” will be used throughout the paper.

2. Educational Games in Mathematical Education

Game-based learning has long been recognized for its ability to promote motivation, problem-solving, and critical thinking. In mathematics—a subject often associated with high levels of anxiety and low engagement—the use of games presents a promising strategy for transforming the classroom into a more inclusive and dynamic learning space (Malone and Lepper, 1987; Vankúš, 2021).

According to the Portuguese Mathematics Curriculum (ME/DGE, 2021), learning activities should be mathematically rich and intellectually challenging, encouraging students to construct their own knowledge. In this context, educational games can foster logical reasoning, strategic thinking, and greater engagement. As noted by several researchers (Grando, 2000; Debreñti, 2024), games can also reduce maths anxiety, making learning more accessible and enjoyable for all students.

The literature (Bezerra, 1962; Grando, 1995; Kishimoto, 1998) shows that when games are used pedagogically, they enhance student motivation and support the development of key skills necessary for learning mathematics. These skills include strategic analysis, the anticipation and validation of results, critical reflection on actions, and the ability to attribute meaning to calculations. Therefore, it is essential for teachers to create a classroom environment that fosters logical reasoning through active teaching methodologies. In such an approach, students take a central role in the learning process, while the teacher acts as a facilitator of stimulating and effective experiences. Within this context, games emerge as ideal teaching tools, as they capture students’ interest and engagement.

Board and card games, in particular, offer tactile and social experiences that complement digital resources. Espinoza-Espinosa et al. (2022) highlight several key benefits of physical board and card games for learners of all ages. These include fostering social interaction, which helps develop communication, cooperation, and conflict resolution skills (Gobet et al., 2004); supporting motor development through physical movement and coordination (Nelson et al., 2015); enhancing cognitive stimulation by encouraging strategic thinking and problem-solving (Ferguson, 2007); offering sensory immersion through visually, tactilely, and auditorily engaging components (Whitebread, 2012); and promoting inclusion and accessibility, as these games can be adapted for players with different abilities and needs (Koster, 2013).

Erşen and Ergül (2022) concluded that game-based learning in mathematics significantly enhances student engagement and motivation while also deepening conceptual understanding. However, their study emphasises that the effectiveness of games depends largely on their alignment with curriculum objectives and thoughtful integration into instructional planning.

Taking all this into account, the first author of this study, under the supervision of the remaining authors, developed three non-digital games for teaching rational numbers to Year 5 students, which formed the basis of her master’s thesis (Hilário, 2024). The games were inspired by two Italian researchers, Paola Morando and Maria Spreafico, who have extensive experience in designing and implementing didactic games across a wide range of educational levels (from primary school to university) and in diverse educational contexts—both formal, such as schools and prisons, and informal, such as museums and botanical gardens (La Fortuna, Morando and Spreafico, 2022; Morando and Turconi, 2022; Morando and Spreafico, 2023).

This paper explores the pedagogical use of these games, with the main objective being to assess whether they could positively influence student motivation, support collaborative and interactive learning, and improve the understanding of mathematical concepts. The games were implemented, and data was collected and analysed to evaluate the outcomes.

3. Methodology

This study employed a qualitative case study approach, complemented by quantitative data analysis (Yin, 1994).

The main research questions were:

- Can non-digital board/card games enhance student motivation and engagement in learning rational numbers?
- Do such games contribute to a better understanding of mathematical content?

The objectives were:

- To design and implement non-digital games targeting rational numbers;
- To analyse the pedagogical impact of these games;
- To assess students' perceptions and learning outcomes.

Three original non-digital games were designed and implemented in Year 5 classes during the 2023/2024 school year. The study involved a total of 84 students, aged 10–11, all enrolled in the fifth year of basic education. These students were distributed across three separate classes, each comprising approximately 28 students. The school is part of the Portuguese public education network in the Lisbon district. The games were implemented during regular mathematics lessons, ensuring integration with the official curriculum.

Three primary methods were used for data collection:

- *Questionnaires*: Administered before and after the intervention to gauge perceptions and attitudes.
- *Classroom Observations*: Conducted by the teacher-researcher to record behaviours and interactions.
- *Student Work*: Analysis of written records produced during gameplay, along with photographs to assess students' learning outcomes.

Due to space constraints, this paper will only address the first research question.

Quantitative data were analysed using Excel, generating bar and pie charts to illustrate trends. Qualitative data were interpreted thematically to highlight recurring patterns and insights.

4. Description of the Educational Games Developed

The games — Maths Twins, Tartarugas, Cavalos-Marinheiros e Polvos (Turtles, Seahorses and Octopuses), and Caça ao Tesouro na Ilha da Matemática (Treasure Hunt on Maths Island) — were planned to align with the learning goals outlined in the Portuguese mathematics curriculum regarding non-negative rational numbers. Each game was developed with attention to simplicity, clarity, curricular integration, and active student participation. Simultaneously, the games were designed to be varied in nature, using different materials and mechanics. They not only cover different aspects of the topic addressed, but also contribute to achieve different learning goals, ranging from specific concepts (such as the use and meaning of percentages) to critical thinking, mathematical communication, and problem solving.

4.1 Maths Twins

Maths Twins is a memory-based card game designed to deepen students' understanding of multiplication and division involving decimal and fractional representations of non-negative rational numbers. The mechanics of matching equivalent expressions aim to support mental calculation, flexible thinking, and concept equivalence. Timed play and collaborative group structure foster both motivation and teamwork.

The version used in this study has the following characteristics:

- *Learning Topics*: Decimals, fractions, multiplication and division, mental calculation, and multiple representations.
- *Learning Goals*: Carry out calculations involving decimals and natural numbers; relate multiplication and division by 10, 100, and 0.1; interpret mathematical expressions in various formats.
- *Materials*: A set of 28 cards per group (14 matching pairs with equivalent expressions), paper, pencils, calculators, and a projector for teacher demonstration.
- *Game Objective*: Identify the greatest number of “maths twin” pairs—cards with expressions yielding the same result.
- *Gameplay*: Students work in teams of 3–4. Each team receives a deck of 28 cards and has 15 minutes to match as many equivalent expression pairs as possible. The competitive aspect and time constraint encourage engagement, group collaboration, and development of mental calculation skills. Assistance using calculators or written algorithms is allowed to ensure inclusivity.

This game can be adapted to various content areas and played in different ways. For instance, Pais and Hall (2024) describe three versions of gameplay using a deck addressing measurement units.

Figure 1 shows some examples of the expressions found on the cards and two photos of the students playing the game.

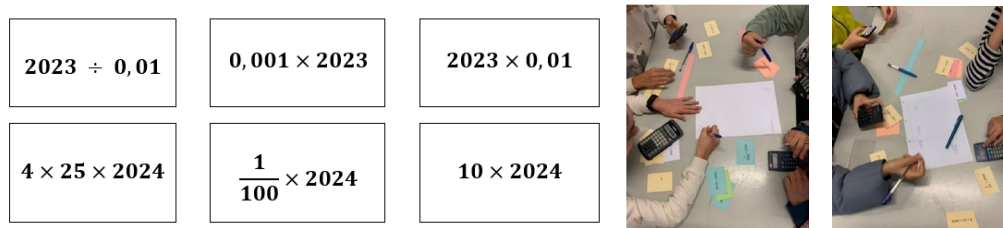


Figure 1: Maths Twins: examples of card contents and photos of the gameplay

4.2 Turtles, Seahorses and Octopuses (Tartarugas, Cavalos-Marinheiros e Polvos)

This game is an adaptation of *Caterpillars and other animals* developed by La Fortuna and Morando (2022). It was tailored to help Year 5 students explore percentages, fractions, and decimals through logical reasoning. The activity engages students in identifying relationships among quantities represented in various forms (fractions, decimals, percentages). The use of illustrated animal cards, coupled with mathematical conditions, provides a visual and engaging way to interpret symbolic information, thereby encouraging analytical thinking, mathematical communication and strategic decision-making.

- *Learning Topics:* Percentages, fractions, decimals, multiple representations, and symbolic mathematical language.
- *Learning Goals:* Establish connections between fractional, decimal, and percentage representations; apply these representations in problem-solving; use mathematical communication.
- *Materials:* A set of 26 illustrated cards with animal representations (see Figure 1 for some examples) and another set of 36 cards with mathematical conditions (e.g., “Turtles represent 50% of the total,” or “The number of turtles is 25% of the number of octopuses.”).
- *Game Objective:* Identify cards that meet specific conditions regarding the quantities of animals (turtles, seahorses, octopuses) based on percentage clues provided.
- *Gameplay:* Players play in groups of two teams of two students each. At each table, six animal cards are placed face up, while the rest form a face-down draw pile. Condition cards are also placed in a separate face-down pile. Teams take turns drawing one condition card and collecting all face-up animal cards that meet the condition (collected cards act as points). Each time an animal card is taken, it is immediately replaced from the face-down pile to maintain six face-up cards. If no animal cards satisfy the condition, the team passes its turn.
- When the condition pile ends, the team with the greatest number of points wins.

Figure 2 shows some examples of animal cards and a photo of students playing the game.

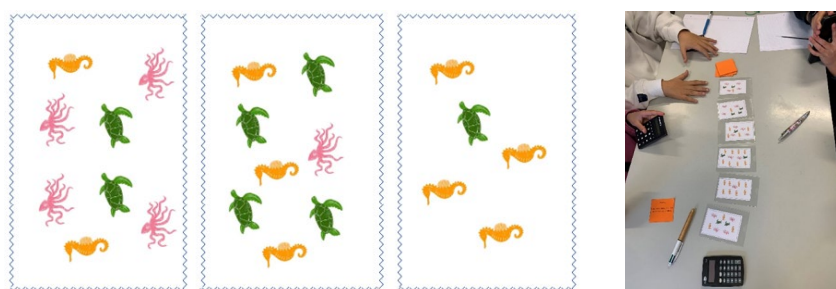


Figure 2: Turtles, Seahorses and Octopuses: examples of cards and photos of the gameplay

4.3 Treasure Hunt on Maths Island (Caça ao Tesouro na Ilha da Matemática)

Inspired by treasure hunt activities and classic educational games involving maps, this original game was developed by the first author of this paper to explore fractions, equivalences, and problem-solving with rational numbers. Designed as a map-based problem-solving adventure, this game integrates narrative with mathematical challenges, requiring students to solve fractional problems to navigate through a graph. The goal is to promote critical thinking, sequencing, and application of knowledge in context, while encouraging collaboration and persistence.

- *Learning Topics:* Fractions, decimals, equivalence, estimation, and rounding.

- *Learning Goals:* Identify equivalent fractions, solve word problems using rational numbers, and strengthen understanding through graph-based reasoning.
- *Materials:* A treasure map with a graph, instructions sheet, 9 challenge cards (one for each graph edge), hint cards (one for each vertex), and blank squared paper.
- *Game Objective:* Follow a path across the island by solving a series of mathematical challenges, ultimately revealing a hidden message (the treasure).
- *Gameplay:* Students play in teams of 3-4 members each. Each team receives all the materials. They must interpret the challenge cards and solve problems to determine the correct path on the graph (following the minimum distance edge at each vertex). Each correct solution advances the team closer to uncovering the final message.

The game emphasizes critical thinking, collaborative problem-solving, and application of mathematical concepts in context. Figure 3 shows the map of the game.



Figure 3: Treasure Hunt on Maths Island: map

5. Results and Analysis of Questionnaire Data

Each game was implemented in three Year 5 classes, following a structured pedagogical approach and adapted based on real-time classroom dynamics and student responses.

In *Maths Twins*, students worked in groups of four, applying mental and calculator-assisted strategies to identify matching "pairs of cards. Early observations showed that the initially planned game time was insufficient for both problem-solving and strategy development, leading to extended playtime in subsequent sessions. Students adapted quickly by employing whispering strategies to avoid revealing answers and to optimise their internal group coordination.

In *Turtles, Seahorses, and Octopuses*, students were tasked with matching marine animal image cards to condition cards involving percentages. The game effectively reinforced the link between different representations of rational numbers (fraction, decimal, percentage). Strategic use of calculators allowed students with varying skill levels to participate equally and remain engaged.

Treasure Hunt on Maths Island presented a narrative-based challenge where teams navigated a map by solving fraction-based riddles. The immersive storytelling and competitive structure encouraged collaboration and sustained focus.

Across all sessions, the teacher-researcher documented strong student engagement, collaborative behaviour, and active problem-solving. Group discussions at the end of each session supported reflective thinking and knowledge consolidation. These results support the idea that non-digital educational games can foster both conceptual understanding and essential soft skills in mathematics learning.

To assess the effectiveness and reception of the educational games, a series of questionnaires were administered to the students at various stages of the study. These included:

- An initial questionnaire (prior to game implementation),

- Post-game questionnaires for *Maths Twins* and *Turtles, Seahorses and Octopuses*,
- A final questionnaire following all game activities.

Each survey aimed to evaluate students' engagement, learning experiences, and suggestions for improvement, using multiple-choice questions, quantitative Likert scale items and open-ended questions.

5.1 Initial Questionnaire: Students' Familiarity and Preferences

Out of a total of 84 students, 42 responses were collected, representing a 50% response rate. The results revealed a unanimous appreciation for games among respondents — 100% indicated that they enjoy playing games, with no neutral or negative responses. While half of the students preferred digital games, a significant proportion (38%) reported enjoying board and card games, highlighting a strong openness to non-digital formats. Paper-and-pencil games (7%) and other types (5%) accounted for the remaining responses. When asked which board or card games they enjoyed most, students mentioned popular titles such as *Monopoly*, *Uno*, and *Chess*.

When asked whether they would like to play board or card games that address mathematical content, the majority of students (93%) responded positively. This strong interest suggests a high potential for integrating such games as pedagogical tools in mathematics education.

These findings suggest that while digital games are more familiar, educational board/card games are also appealing and have potential in the classroom setting.

5.2 Maths Twins Questionnaire

Following implementation, 30 students (38% of the total) responded to a questionnaire on the *Maths Twins* game.

When asked if they enjoyed playing the game the responses were unanimous: 100% of respondents replied "yes".

Students were also asked to rate their level of agreement with a series of statements about the game, using a five-point Likert scale (1 = Strongly Disagree; 5 = Strongly Agree). The heatmap in Figure 4 summarizes the responses.

The game Maths Twins:	1	2	3	4	5
was fun	0	0	2	11	17
was very difficult	0	5	7	10	8
helped me enjoy Mathematics more	0	0	5	10	15
helped me better understand the content taught in class	0	0	4	10	16
only served to distract me for a few minutes, nothing more	18	6	5	1	0
had an appropriate duration	0	1	6	9	14
promoted good interaction among classmates	0	1	3	8	18
increased my motivation to learn Mathematics	0	0	3	12	15

Figure 4: Students' perceptions of the Maths Twins game.

The heatmap in Figure 4 shows a strong positive reception of the *Maths Twins* game. Most students agreed that the game was fun, promoted peer interaction, and enhanced both their understanding of the material and motivation to learn mathematics. While some found it challenging, the difficulty level was generally seen as appropriate. Importantly, the majority disagreed with the idea that the game was merely a distraction, confirming its educational value. Overall, the results support the effectiveness of *Maths Twins* as a motivating and engaging learning tool.

Students' qualitative responses highlighted that the game *Maths Twins* significantly enhanced their motivation to learn mathematics. They emphasised that the game helped them think faster, made learning more enjoyable, facilitated group work, made mathematical calculations more engaging, and boosted their self-esteem and confidence.

Among the comments written by the students in the open-ended question of the questionnaire, the following stand out as representative:

- “The game was great fun, so I think maths can be fun too.”.
- “The game helped to increase my motivation, because the game asked me to do calculations and it increased my self-esteem”.
- “It helped motivate me to learn Maths because it was a lot of fun and it helped me to socialise more with my classmates”.
- “It has increased my motivation because I don't like maths VERY much, but I like games and so it has been a way of having fun and learning more”.

Overall, these comments suggest that the game not only supported mathematical understanding but also transformed learning into a more positive and motivating experience.

5.3 Turtles, Seahorses and Octopuses Questionnaire

This survey was completed by 10 students, one per team, in one of the classes. When asked if they enjoyed playing the game all respondents replied “yes”. As in the previous section, students were asked to rate their level of agreement with a series of statements about the game. The heatmap in Figure 5 summarizes the responses.

The game Turtles, Seahorses, and Octopuses:	1	2	3	4	5
was fun	0	0	2	6	2
was very difficult	1	3	6	0	0
helped me enjoy Mathematics more	0	0	3	4	3
helped me better understand the content taught in class	0	0	1	5	4
only served to distract me for a few minutes, nothing more	0	1	0	2	7
had an appropriate duration	0	0	1	6	3
promoted good interaction among classmates	0	1	1	4	4
increased my motivation to learn Mathematics	0	0	4	3	3

Figure 5: Students’ perceptions of the Turtles, Seahorses and Octopuses game.

The heatmap in Figure 5 shows that students generally had a positive perception of the game *Turtles, Seahorses, and Octopuses*. Most agreed it was fun, helped them understand class content, and had an appropriate duration. Although fewer students strongly agreed compared to other games, responses still reflected that the game supported learning and motivation. The responses indicate that the game was not perceived as overly difficult, with most students rating the difficulty as moderate or low. Overall, the game was seen as enjoyable and educational, with potential for further development.

Students’ qualitative responses indicate that the game *Turtles, Seahorses, and Octopuses* contributed positively to their motivation to learn mathematics. They highlighted that it helped them better understand fractions and percentages, made learning more enjoyable, encouraged practical application of mathematical concepts, and increased their willingness to learn through games.

Among the comments written by the students in the open-ended question of the questionnaire, the following stand out as representative:

- “It helped me to understand fractions and percentages a little more.”
- “It increased my motivation to learn maths because I could apply maths (percentages) to the game.”
- “Playing makes me want to learn maths even more.”

Overall, the game was seen as both educational and motivating, enhancing students' engagement with mathematical content.

5.4 Final Questionnaire

The final questionnaire was completed by 52 students (62% of the total).

As illustrated in Figure 6, the vast majority of students (96%) reported enjoying the games played during the lessons. When asked which game they preferred, students' responses were distributed across the three options (see Figure 7), with *Maths Twins* emerging as the most favoured, possibly due to its simple mechanics and immediate feedback. *Treasure Hunt on Maths Island* and *Turtles, Seahorses and Octopuses* were also well-

received, demonstrating that the variety of games successfully catered to different preferences and learning styles. This variety likely contributed to sustaining student interest and engagement across multiple sessions.

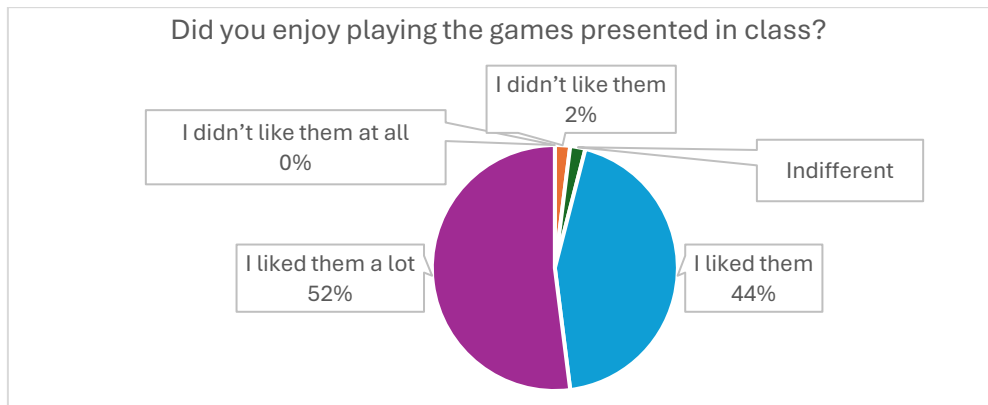


Figure 6: Students' enjoyment of the games

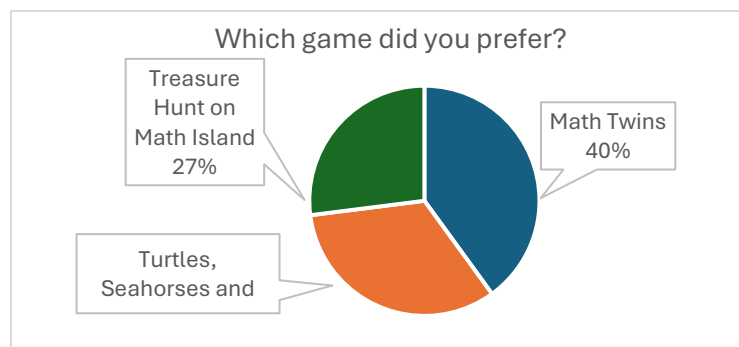


Figure 7: Students' preferences of the games

Figure 8 summarizes students' perceptions regarding the educational value of the games with 90% of students stating that they would like to continue playing games in the class. A large majority indicated that the games contributed to a better understanding of the mathematics content covered in class.

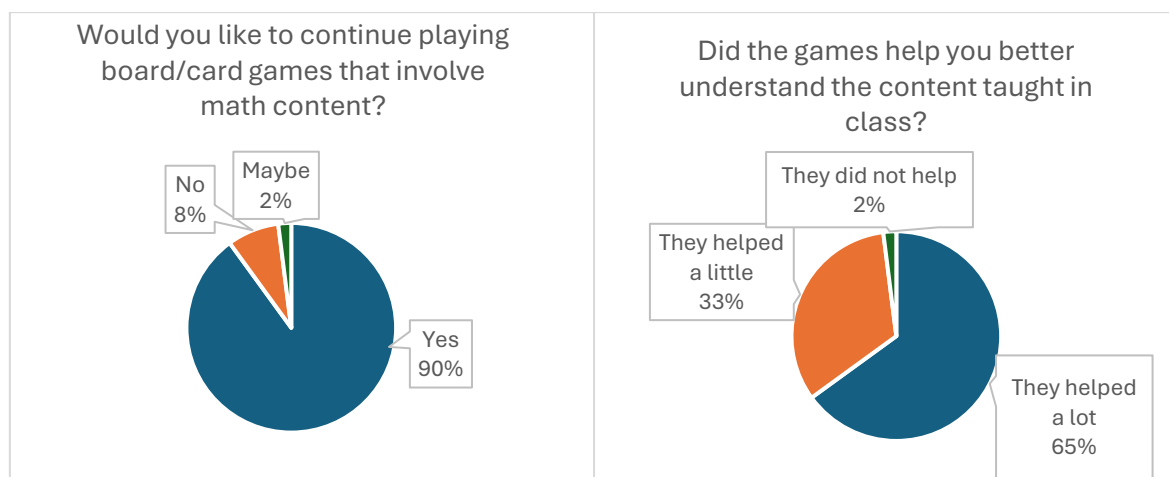


Figure 8: Perceived impact of the games in the class context and on learning

When asked whether the games increased their motivation to learn Mathematics, 90% of students responded "Yes," while only 10% answered "No." Similarly, 83% of students felt that the board/card games were useful for improving their relationship with classmates, whereas 17% did not perceive a benefit in this regard.

Across all questionnaires, student responses consistently emphasised that the games increased their motivation to learn mathematics, made learning more enjoyable and less stressful, encouraged teamwork and peer support, and helped consolidate and apply mathematical knowledge.

Although some improvements were suggested (e.g., more time and content variety), the overall reception was highly positive. These findings align with existing literature on game-based learning's impact on motivation, engagement, and collaborative skills.

6. Conclusions

This study aimed to explore the impact of non-digital board and card games as pedagogical tools for teaching rational numbers to Year 5 students. Drawing on the development and classroom implementation of three original games — *Maths Twins*, *Turtles*, *Seahorses*, and *Octopuses*, and *Treasure Hunt on Maths Island* — the research aimed to assess whether such physical games could enhance student motivation, engagement, and conceptual understanding in mathematics.

These games were purposefully designed not only to strengthen mathematical competencies but also to foster student engagement, teamwork, and confidence in handling abstract numerical concepts. Their adaptability and curricular alignment make them valuable resources for both formal lessons and reinforcement activities.

Findings from classroom observations and student questionnaires indicate that the use of these non-digital games fostered an interactive and collaborative learning environment. Students reported increased enjoyment and motivation to learn mathematics, which translated into improved participation and better grasp of mathematical concepts, particularly those involving rational numbers. The tactile and social dimensions of board and card games appeared to support knowledge retention while also reducing maths anxiety and encouraging active involvement.

In addition to academic gains, the games promoted the development of transversal skills such as teamwork, communication, and strategic thinking. These outcomes highlight the broader educational value of integrating playful learning approaches into traditional mathematics curricula.

By explicitly mapping the mechanics of each game to specific curricular goals, this paper contributes to the literature on game-based learning by offering a practical, replicable model for the integration of physical games in mathematics teaching.

Nevertheless, the study was subject to limitations, including a small sample size, a limited timeframe for game application, the absence of a control group, and its confinement to a specific educational context. These constraints suggest the need for further research to validate and expand upon the present findings.

Future work could explore the use of similar game-based strategies across different age groups, mathematical domains, or cultural contexts. Comparative studies between digital and non-digital game formats, as well as hybrid approaches, may also provide further insights into how best to make use of games in mathematics education.

In summary, this research reinforces the potential of non-digital educational games to transform the mathematics classroom into a more engaging, meaningful, and student-centred space. Their capacity to create inclusive, engaging, and conceptually rich learning environments makes them a viable alternative or complement to more traditional instructional approaches.

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Ethics declaration: The paper contains the result of a non-interventional study, i.e. a survey (qualitative questionnaires), which does not need ethical approval. The completion of the questionnaire was voluntary and anonymous; moreover school is the guarantor of data processing and privacy for activities performed in the curricular framework.

AI declaration: Use of generative AI in some paragraphs to improve the language, as English is not the authors' first language. Specifically used the question 'Check grammar and coherence without adding new sentences'. This prompt provides minimal suggestions for grammar, clarity and coherence in sentences, does not reorganise the sentences in the paragraph and does not add new sentences.

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

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Abstract: *Quest: Journey Through the Lifespan*, an interactive simulation from McGraw-Hill Education, was integrated into a community college developmental psychology course to examine its impact on engagement, conceptual understanding, and social-emotional learning. Across 14 narrative-based quests, students navigated authentic dilemmas tied to lifespan stages—ranging from infancy and middle childhood to late adulthood—while making choices grounded in psychological theory. A mixed-methods evaluation included quantitative surveys (N = 42) and qualitative thematic analysis of student reflections. Survey results indicated that 88% of participants reported increased engagement, 89% reported strengthened understanding of course concepts, and 92% recognized the game’s relevance to everyday life. Thematic analysis revealed recurring patterns of embodied perspective-taking, empathy-driven decision-making, identity and culture reflection, and practical problem-solving tied to developmental milestones. Students frequently linked in-game scenarios to personal experiences, challenged stereotypes, and proposed real-world solutions to character dilemmas. Findings position *Quest* as a culturally responsive, narrative-rich tool that fosters both academic mastery and critical engagement with human development. Purposeful integration of game-based learning can bridge abstract theory with lived experience, enhancing cognitive, emotional, and social learning outcomes in higher education.

Keywords: Gamified learning, Developmental psychology, Empathy, Student engagement, Serious games, Cultural responsiveness

1. Introduction

Game-based learning has become a central innovation in educational technology, especially in the social sciences where context, empathy, and real-life application matter deeply. In psychology classrooms, simulations, and serious games like *Quest: Journey Through the Lifespan* offer a rare opportunity: to move beyond passive content absorption into applied, emotionally resonant engagement. This paper explores how *Quest* can be used to bridge the gap between theory and real-world understanding of developmental psychology, offering both student outcomes and theoretical rationale for this pedagogical approach.

2. Literature Review

2.1 Gamified Assessments and Competitive Engagement

Game-based elements such as leaderboards, feedback systems, and challenge-based quizzes have been shown to significantly enhance both motivation and learning outcomes. Competitive structures, when paired with timely feedback, sustain student attention and encourage persistence. Nadeem et al. (2023) found that students participating in leaderboard quizzes reported greater sustained attention and motivation. Similarly, Springer STEM (2024) demonstrated that competitive quizzes with instant feedback improved test performance. Hasselmann and Lurkin (2023) confirmed these benefits in engineering courses using an AI-driven board game tournament, showing that competitive collaboration enhanced both engagement and learning outcomes.

2.2 Simulations and Real-World Transfer

Simulations that mirror authentic decision-making environments promote deeper learning and skill transfer across disciplines. Gordillo and López-Fernández (2024) used escape-room style simulations to teach software engineering, finding improved collaboration and retention. Straubinger et al. (2025) reported similar results in computing courses when narrative-driven debugging games were introduced. In the field of special education, Sharma et al. (2024) demonstrated that realistic teaching simulations improved problem-solving skills and motivation among preservice teachers. These findings underscore that simulations grounded in real-world relevance can bridge theory and practice effectively.

2.3 Cognitive, Emotional, and Motivational Gains

Video games and game-based learning environments offer measurable cognitive, emotional, and motivational benefits. A meta-analysis by Bediou et al. (2018) revealed that gameplay can enhance cognitive skills such as memory, attention, and problem-solving. Granic et al. (2014) emphasized the emotional benefits, including improved regulation and empathy, while Hamari et al. (2016) showed that well-designed games foster flow,

intrinsic motivation, and persistence. More recently, Facchino et al., (2025) found that game-based tools in psychology enhance intrinsic motivation and skill acquisition when grounded in authentic, real-world scenarios.

2.4 Narrative, Feedback, and Cultural Context

Narrative immersion, timely feedback, and personal relevance operate together as core drivers of effective gamified instruction. When these elements align, they not only sustain engagement but also promote meaningful learning transfer (Lamb, 2024). Hmoud, Salah, & Altalib, (2024) demonstrated that motivation increased among Jordanian university students when narratives reflected their lived experiences. Comparable results in vocational contexts, as reported by Whitt & Morris (2023) and Facchino, Marchetti, Colasanti, Fontanesi, & Verrocchio, (2025), showed that connecting game scenarios to learners' cultural backgrounds and professional aspirations significantly enhances motivation, relevance, and long-term retention.

2.5 Empirical Foundation for Quest

Meta-analytic findings from NCBI (2023) and MDPI (2023) confirm that serious games in psychology education are most effective when they are contextualized, feedback-rich, and socially embedded. *Quest: Journey Through the Lifespan* aligns with this model by integrating life-span development theory into realistic, character-driven challenges. Its design incorporates immediate feedback, immersive storytelling, and culturally diverse scenarios, providing students with a meaningful bridge between academic concepts and lived experience.

3. Methodology

This study used a mixed methods design to explore how *Quest: Journey Through the Lifespan* supports student engagement, conceptual understanding, and real-world application in a developmental psychology course. Special attention was given to themes of empathy, cultural awareness, and identity development, based on student self-reports and qualitative reflections.

3.1 Participants

Participants were forty-two undergraduate students (ages 18–42) enrolled in an introductory developmental psychology course at a US Community College in Spring and Summer 2025. The classes reflected a diverse student population in terms of age, race, socioeconomic background, and life experience. Participation in the research was voluntary, anonymous, and approved by the college's instructional research review board.

3.2 Intervention

Quest was embedded as a required activity across an eight-week developmental psychology course. Students completed 5 narrative-driven quests in the course, each tied to a stage of the lifespan (e.g., early childhood, adolescence, late adulthood). In-game decision-making allowed students to explore dilemmas related to parenting, career, health, identity, and relationships. Each quest concluded with built-in reflection prompts. Classroom debriefs and structured journaling reinforced connections to course theory and prompted deeper reflection on cultural and social influences.

3.3 Data Collection

Two complementary data sources were collected to triangulate findings and capture both measurable and narrative perspectives.

- **Surveys:** Students completed pre- and post-intervention surveys assessing engagement, perceived relevance, and perceived conceptual understanding. Items were rated on a 5-point Likert scale (e.g., "*Quest* helped me apply psychological theories to real life.").
- **Reflections:** Students submitted written reflections (150–300 words each) after completing the simulation. Prompts asked about their emotional reactions, decision-making process, and connections to real-life experiences.

Quantitative survey responses were analyzed using descriptive statistics to identify patterns in engagement, conceptual understanding, and perceived real-world relevance. To explore potential variation in student experiences, results were also compared by age group and cultural background.

Survey results indicated overwhelmingly positive perceptions of *Quest: Journey Through the Lifespan*. A large majority (88%) reported that *Quest* increased their engagement in the course, 89% agreed that it strengthened their understanding of developmental psychology concepts, and 92% recognized its relevance to their everyday lives.

These findings align with prior research showing that serious games can enhance executive functioning, emotional regulation, empathy, and motivation—particularly when integrated with reflective prompts and guided discussion (Bediou et al., 2018; Granic et al., 2014; Hamari et al., 2016; McGraw-Hill Education, 2023).

Qualitative data were analyzed through thematic coding. An initial round of open coding identified emerging concepts; a second round grouped these into the following categories:

- **Cognitive integration** (e.g., “It helped me understand Erikson’s theory in a real situation.”)
- **Cross-cultural empathy** (e.g., “It made me think about family roles in different cultures.”)
- **Identity reflection** (e.g., “I related to the character’s struggle with gender norms.”)
- **Real-world application** (e.g., “I’ve actually seen this happen in my own family.”)

Codes were checked for reliability by the instructor and a peer reviewer to reduce bias. Themes were then linked back to course objectives and literature on effective game-based learning.

4. Overarching Themes Across All Quests

4.1 Embodied Perspective-Taking and Personal Connection

Students frequently “inhabited” the character’s perspective and linked in-game experiences to their own histories, family life, or caregiving roles. Rather than engaging in abstract recall, students applied course concepts through concrete, first-person reasoning.

“It didn’t feel like homework... it felt like I was living through the course material.” (Overall Thoughts)

“I asked my parent what I was like at 9 months... I was always on the move, super curious.” (Gabi)

4.2 Conceptual Understanding Through Everyday Anchors

Learners correctly identified age-linked abilities and constraints—such as motor control, object permanence, separation anxiety, and changes in memory or processing speed—and tied these observations directly to course content.

“I had the pharmacy worker read the instructions out loud while Emilio wrote them down... then repeat it.” (Emilio)

“The teen character I played clearly faced an identity vs. role confusion crisis... seeing it play out helped me remember.” (Course Reflection)

4.3 Empathy, Ethics, and Fairness as Decision Drivers

Across quests, moral reasoning played a significant role. Students justified choices in terms of fairness, justice, and social responsibility.

“I chose the assertive dialogue... girls should feel confident standing up for what’s right.” (Abby)

“I told the operator about the boy cheating; nobody likes a cheater.” (Abby)

4.4 Gender, Culture, and Identity Reflection

Students engaged deeply with stereotypes and cultural norms, often challenging assumptions about gender roles and discussing bicultural stressors.

“I had her choose a harder route—not to prove anything, but to show she doesn’t need to limit herself.” (Abby)

“Being Mexican American might expose him to microaggressions... and amplify homesickness because family is everything.” (Martinez)

4.5 Aging, Independence, and Community Scaffolding

Quests involving older adults prompted students to identify practical supports (e.g., carts, label readability, pharmacy clarification) and social resources (e.g., volunteering, rides to church).

“I asked workers to cut up the chicken... and help with the cat food onto the cart.” (Emilio)

“Sensory-friendly hours help seniors shop when it’s quieter.” (Emilio)

4.6 Agency with Supportive Constraint

Students balanced autonomy with wise help-seeking, deciding when to accept assistance and when to persist independently.

"I watched the girl climb first, then tried it—seeing her succeed made me feel confident." (Abby)

"I made sure to pick a normal cart, not a basket, so he could push it instead of carrying." (Emilio)

4.7 Usability and Engagement Value of the Medium

Most students described *Quest* as the "most fun" and "most effective" learning activity of the course, while also noting occasional minor usability issues during initial play.

"The games... were the most effective at making me remember the lesson later on." (Overall Thoughts)

"They took a little troubleshooting at first but were my favorite part." (Overall Thoughts)

5. Game-Specific Highlights

Gabi at Home (Infancy – Sensorimotor Stage)

Students demonstrated strong recognition of sensorimotor behaviors such as crawling, mouthing, banging objects, and peek-a-boo. They accurately connected these observations to object permanence, early communication, and emotional milestones like stranger anxiety. Many drew personal parallels by asking family members about their own infancy.

Abby at the Carnival (Middle Childhood – Gender Roles & Moral Reasoning)

Students frequently identified and resisted gender stereotypes and engaged in principled reasoning when confronting unfair behavior. They navigated tensions between independence and accepting help, reflecting a nuanced understanding of self-efficacy and social support.

Martinez at the Military Base (Young Adulthood – Culture, Identity, and Stress)

Responses highlighted the physical, cognitive, and emotional demands of military life. Students applied a bicultural lens to discuss family obligations, resilience, and potential microaggressions, deepening their appreciation of identity development in early adulthood.

Emilio at the Grocery Store (Late Adulthood – Cognitive/Physical Changes & Social Support)

Students proposed practical strategies to support older adults, from physical accommodations to community initiatives. Social engagement emerged as a recurring protective factor, reinforcing concepts of active aging and socioemotional selectivity.

This thematic and quantitative analysis indicates that *Quest: Journey Through the Lifespan* effectively engages students, strengthens conceptual understanding, and fosters empathy, cultural awareness, and identity reflection—all key goals of the developmental psychology curriculum.

6. Discussion

This study demonstrates that *Quest: Journey Through the Lifespan* exemplifies best practices in game-based learning, including student autonomy, narrative relevance, emotional engagement, and real-world decision-making. By confronting players with developmental dilemmas and requiring them to make meaningful choices, the game bridges abstract psychological concepts with lived experience. This narrative structure allows students to not only recall course content but to actively apply it in context—mirroring findings in the literature that authentic, decision-rich environments promote deeper comprehension and long-term retention (Facchino et al., 2025).

One of *Quest*'s most notable strengths lies in its culturally responsive design. Cross-cultural and gender-relevant scenarios prompted students to engage in nuanced reflection about identity, bias, and personal growth. Many students critiqued stereotypes or shared experiences related to bicultural stressors, suggesting that the simulation served as a safe yet challenging space for exploring issues of equity and diversity. As one student noted, *"Being Mexican American might expose him to microaggressions... and amplify homesickness because family is everything."* By integrating culturally responsive design within a strong narrative framework, *Quest* embodies the very elements that research identifies as essential for bridging course concepts with real-world

understanding. This connection between culturally grounded scenarios and narrative immersion reflects the literature review's discussion of how personal relevance, timely feedback, and cultural context work in tandem to sustain engagement and promote meaningful learning transfer.

Reflection activities embedded throughout the game emerged as a key mechanism for learning. As several responses indicated, the opportunity to pause, process, and articulate their thinking helped students connect in-game experiences to core developmental psychology concepts. Consistent with research on reflective practice, these moments allowed students to bridge the gap between "what is expected" and "what is experienced" (Facchino et al., 2025), reinforcing metacognitive awareness and the ability to transfer learning beyond the classroom.

The findings also highlight the game's role in promoting social-emotional learning. Ethical reasoning, perspective-taking, and care-based decision-making were consistently observed across gameplay responses. Students were not simply memorizing terminology; they were using psychological frameworks to justify choices, evaluate moral dilemmas, and empathize with characters. These outcomes align with the growing recognition that social-emotional competencies are integral to academic success and lifelong learning.

In terms of engagement, *Quest* consistently ranked among students' most enjoyable and memorable course activities. While some noted minor usability challenges, these were more accurately described as small points of navigation or acclimation; brief learning curves that, once overcome, contributed to a sense of accomplishment. Such manageable challenges can enhance motivation, as students experience a balance between skill and difficulty that keeps them invested in the learning process.

6.1 Implications for Teaching with Quest

The analysis suggests several concrete recommendations for educators integrating *Quest* into developmental psychology courses:

- Retain and strengthen the reflection prompts, as these are central to linking gameplay with learning outcomes.
- Make equity, identity, and stereotype-challenging elements explicit in discussion and assessment.
- Scaffold strategies for adaptive self-regulation, such as "wise help-seeking," within the game context.
- Provide brief onboarding guidance to reduce initial usability barriers.

6.2 Limitations and Future Directions

While these results are promising, they reflect data from a single course and instructor, which limits generalizability. Future research should compare *Quest*-based sections with non-*Quest* sections, incorporate structured assessment rubrics, and examine subgroup differences in engagement and learning outcomes. Additionally, exploring *Quest*'s adaptability for other psychology subfields or related disciplines could expand its impact.

6.3 Gamified Learning as a Catalyst for Student Success

Ultimately, *Quest* illustrates how well-designed gamified learning experiences can move students beyond passive content absorption toward applied, empathetic reasoning. By integrating narrative, choice, cultural relevance, and reflection, the game creates a dynamic environment where students can *live* the concepts they study. As digital education continues to evolve, such approaches hold significant promise for cultivating not only content mastery but also the critical, reflective, and socially aware thinking that defines successful global citizens.

Ethics Statement: This study involved anonymous, voluntary student reflection data collected during a for-credit psychology course. No identifying information was gathered. Institutional permission was obtained in accordance with the US Community College's internal review policies.

AI Statement: An AI-based writing assistant was used for grammar, clarity, and tone refinement; all ideas, analysis, and conclusions are solely those of the author.

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Tailored Gamification in Manual Assembly: System Implementation and Study Design for Long-Term Evaluation

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Abstract: The potential of gamified didactic scenarios in promoting intrinsic motivation, readiness to learn, and long-term efficiency improvements has been extensively confirmed in numerous studies. While there is abundant research on gamification in educational contexts and digital learning environments, its transferability to industrial contexts—particularly manual assembly processes—remains insufficiently explored. Employees in manufacturing environments characterized by short product life cycles, single-piece production, and increasing product variants continuously engage in agile adaptation and learning processes, making adaptively designed gamified assistance systems highly promising. Traditional rigid assistance systems initially improve process reliability and facilitate standardized training phases, yet they can lead to increased cognitive strain, reduced autonomy, and declining motivation over the long term. Intensive, rigid assistance in particular may provoke cognitive overload due to constant information overload and restricted freedom of action. Our preliminary studies further indicate that, although gamified elements initially boost performance, sustained use may similarly result in increased stress and diminished autonomy. To address these challenges, an adaptive assistance system incorporating a flexible gamification platform was developed and practically implemented within a medium-sized enterprise (SME) specializing in the assembly of safety-critical components. This system enables employees to individually select and activate gamification elements such as point systems, levels, badges, and leaderboards. Furthermore, an adaptive information provision mechanism was integrated, dynamically reducing information complexity and density, thereby promoting targeted learning processes and sustainably mitigating cognitive strain. For comprehensive evaluation of the system's long-term effects on employee motivation, autonomy, process quality, and efficiency, a mixed-methods approach combining both quantitative and qualitative techniques was adopted. Objective interaction data (e.g., task completion times, error rates) are continuously captured through real-time behavioural logging, while subjective aspects (system usability, perceived cognitive load, motivation, technology acceptance, and perceived autonomy) are assessed through standardized Likert-scale questionnaires. This paper describes in detail the conceptual framework, practical implementation, and study design. It systematically explores how individually tailored gamification influences employee motivation, autonomy, process quality, and efficiency improvements within manual assembly tasks.

Keywords: Tailored gamification, Human factors, Industry 5.0, Intrinsic motivation, Cognitive ergonomics

1. Introduction

Industrial manufacturing is increasingly characterized by growing challenges from shortened product life cycles, rising product and process variability, and volatile global markets (Schuh et al. 2022). As a result, companies are compelled to continuously increase the degree of digitalization in their production systems and integrate innovative technologies efficiently into existing structures (Zhong et al. 2017). However, technological modernization alone is insufficient to address the escalating complexity of industrial value creation; instead, a holistic approach to flexibility is required to systematically incorporate both technological and human resources (Liao et al. 2017). Building on this need for human-centred flexibility, gamification – the deliberate use of game-design elements in non-game contexts (Deterding et al. 2011) – has emerged as a promising strategy to foster worker motivation, reduce cognitive load, and stimulate adaptive skill development in industrial settings (Sailer and Homner 2020; Oliveira et al. 2023). The necessity to dynamically adapt production units to fluctuating requirements makes agile and reconfigurable production systems indispensable (ElMaraghy 2005). Modular plant architectures, digital networking, and data-driven control concepts form the technological foundation of this new production paradigm. However, technological agility alone is inadequate if human labour, as a flexible and adaptive resource, is not simultaneously integrated into system design (Gorecky et al. 2014). Unlike automated systems, human operators possess the unique ability to make situational decisions under uncertainty, flexibly assume various tasks, and intuitively respond to unforeseen changes (Akhtar and Carlo 2024). This universal deployability renders humans an indispensable element of agile production systems. However, this flexibility is not without risk: the constant adaptation to new processes, technologies, and task profiles can lead to cognitive overload, elevated stress levels, and long-term declines in motivation (Wollter Bergman et al. 2021). Safeguarding the sustainable performance of human workers in highly dynamic production environments thus necessitates innovative support concepts beyond traditional, static assistance systems. Conventional systems, which provide standardized recommendations for action, quickly reach their limits under high variability and uncertainty (Longo et al. 2017; Villani et al. 2017). Consequently, adaptive assistance systems

are gaining importance, offering dynamic support tailored to individual skills, experience levels, and situational demands (Yigitbas et al. 2023). An auspicious approach to designing such adaptive systems is the targeted integration of gamification elements. Using game-like mechanisms such as points, badges, or challenges can systematically enhance motivation and learning effectiveness, provided that these elements are implemented in an evidence-based and context-sensitive manner (Smiderle et al. 2020; Rodrigues et al. 2022). Recent studies show that gamification yields the most sustainable effects when individual differences in motivation, cognitive load, and learning styles are carefully considered (Oliveira et al. 2023). Against this backdrop, the present paper explores the interplay between humans and adaptive technology within flexible and agile production systems. Particular emphasis is placed on the role of gamified assistance systems as key technologies for promoting adaptability, motivation, and cognitive relief in dynamic manufacturing environments.

2. Literature Review: Assistance Systems and Gamification

The evolution of assistance systems in industrial assembly has been driven by the need to increase efficiency, reduce errors, and manage the growing complexity of production tasks. Over the past years, numerous technological approaches have been developed and evaluated to support human workers during manual assembly processes.

2.1 Evolution of Assistance Systems

In recent years, traditional paper-based work instructions have increasingly been replaced by digital work instructions (DWIs). Empirical studies demonstrate that DWIs can significantly reduce task completion times and perceived cognitive workload compared to paper-based instructions, thereby improving assembly efficiency and quality (Eversberg and Lambrecht 2023). In laboratory studies, object-based, context-enriched 3D instructions have demonstrated a reduction in task completion time by 14.94%, accompanied by a substantial decrease in perceived cognitive load (Alessa et al. 2023). Projection technologies, which visualize work steps directly onto the workpiece, have led to a 50% reduction in error rates during assembly tasks, as demonstrated in large-scale virtual experiments (Pietschmann et al. 2023). Pick-to-light (P2L) systems, combined with Poka-Yoke logic, have demonstrated significant improvements in assembly performance. Field studies report up to 20–35% reductions in assembly times and approximately 35% decreases in error rates (Trojanowska et al. 2023). Augmented reality (AR) technologies further expand this approach: the use of AR smart glasses enables hands-free and immediate interaction with digital instructions. Empirical studies involving 188 learners indicate high usability and a reduced cognitive load, thereby freeing cognitive resources that can be redirected toward learning (Warkentin et al. 2025).

It is important to note, however, that many of these studies primarily focus on learning phases or the support of novice users. For experienced workers, digital assistance systems can potentially have counterproductive effects.

2.2 Limitations of Static Assistance Systems

While digital assistance systems have proven valuable in supporting novice users during learning phases, their effectiveness becomes increasingly questionable when applied to experienced workers in dynamic production environments. Studies suggest that for experts, such systems can even be counterproductive (Funk 2016). As demonstrated by the expertise reversal effect, instructional support that is beneficial to novices may become redundant or distracting for advanced users, leading to increased cognitive load and longer task execution times (Kalyuga et al. 2003). In addition to performance drawbacks, static assistance systems raise motivational concerns. According to the Self-Determination Theory, autonomy is a fundamental psychological need that fosters intrinsic motivation (Gagné and Deci 2005). When workers are locked into step-by-step instructions without flexibility or choice, their perceived autonomy may be diminished—which in turn appears to be associated with reduced engagement and potentially lower learning transfer. Beyond motivation, such systems may discourage deeper cognitive processing. Users might adopt copy-paste behaviour, mechanically following instructions rather than internalizing procedures or reflecting on process logic. This could inhibit procedural learning and reduce adaptive expertise (Branzetti et al. 2022). Moreover, prolonged reliance on external support can lead to skill atrophy. Instead of fostering competence, static systems may create dependence, which becomes particularly problematic in cases where improvisation, troubleshooting, or system failures demand independent action. In such cases, assistance may not only fail to help—it can actively undermine performance (Dr.A.Shaji George et al. 2024). Finally, overly prescriptive guidance structures can limit opportunities for creative problem-solving and bottom-up process optimization. In lean production philosophies, continuous improvement thrives on worker autonomy and reflection. Assistance systems that restrict deviation from

predefined paths may suppress innovation and hinder the iterative refinement of work practices (Costa et al. 2019). Given these limitations, there is growing recognition that next-generation assistance systems must move beyond standardized, one-size-fits-all paradigms. Instead, they should support both procedural correctness and individual agency, allowing experienced users to maintain control, engage cognitively, and contribute to continuous improvement. Given these findings, it is increasingly recognized that future assistance systems must support procedural correctness and preserve and enhance user autonomy, cognitive engagement, and skill development. From the perspective of Industry 5.0, there is an apparent demand for human-centred, adaptive assistance concepts that dynamically align with workers' evolving capabilities and situational needs (Moenck et al. 2025).

2.3 Advantages of Gamified Learning Scenarios

In response to the limitations of static assistance systems, research in educational psychology and instructional design has increasingly focused on gamified learning environments. Gamification—the strategic use of game design elements in non-game contexts—aims to enhance motivation, engagement, and cognitive processing during learning activities (Deterding et al. 2011). Multiple meta-analyses demonstrate that gamified interventions can significantly improve learning outcomes by promoting voluntary engagement, self-directed exploration, and deeper cognitive investment (Sailer and Homner 2020; Subhash and Cudney 2018). Game elements such as points, badges, leaderboards, and challenges foster goal setting, provide immediate feedback and sustain user motivation over more extended learning periods (Kim and Castelli 2021). Moreover, gamified learning scenarios have been shown to support the development of autonomy and competence—two critical components of intrinsic motivation as described by self-determination theory (Ryan et al. 2006). Studies report that learners in gamified environments often exhibit higher persistence, greater task enjoyment, and improved problem-solving performance compared to conventional instructional settings (Sailer and Homner 2020). Thus, gamification offers promising mechanisms to address precisely those shortcomings that static assistance systems impose over time: maintaining engagement, promoting adaptive learning, and sustaining motivation even under repetitive or complex task conditions.

2.4 Emergence of Gamified Assistance Systems

Building on these insights, integrating gamification principles into industrial assistance systems has emerged as a promising approach. Gamified assistance systems aim to combine procedural guidance with motivational enhancement, offering structured yet engaging task support.

By embedding elements such as performance feedback, progression tracking, goal challenges, and adaptive difficulty levels within digital or augmented work instructions, these systems seek to maintain user engagement, support skill acquisition, and reduce cognitive fatigue during repetitive or highly complex assembly tasks (Ulmer et al. 2024).

3. Research Methodology

The development of an adaptive, gamified assistance system for high-variability manual production environments necessitates a modular and flexible technological foundation. In agile production contexts, where product variants, process steps, and operator profiles change frequently, system architectures must be capable of rapid adaptation without extensive reprogramming or system downtime.

To address these requirements, three core technological prerequisites were identified:

3.1 System Architecture and Technological Implementation

3.1.1 *Modular software architecture*

A scalable and component-based backend capable of orchestrating diverse workflows through standardized information objects. This architecture ensures that new work steps, components, or product variants can be integrated dynamically without impacting system stability.

3.1.2 *No-Code platform for process design*

A no-code environment is essential to enable fast and decentralized workflow adaptation by production planners and shopfloor personnel. It allows non-programmers to define, modify, and deploy work instructions independently, accelerating innovation cycles and reducing dependency on IT specialists.

3.1.3 Modular gamification platform

A modular gamification backend is required to flexibly configure motivational mechanisms. This backend enables the activation, adjustment, or deactivation of elements such as progress bars, scoring systems, and reward structures without code-level changes.

3.2 Information Provision in the Adaptive Assistance System

Effective human-centered assistance systems must deliver information in a way that aligns with their users' cognitive needs, skills, and situational demands. This requires a modular, scalable, and context-sensitive approach to information delivery in highly variable manual production environments. The presented system organizes instructional content into six standardized information classes, each supporting a specific cognitive and procedural requirement:

1. Tool Information: Identification and visualization of the tools necessary for the current work step.
2. Component Information: Context-sensitive allocation of required parts and materials.
3. Skill Information: Instruction for operating specialized fixtures or equipment correctly.
4. Process Flow Information: Animated visualizations (GIFs or videos) depicting ideal procedural sequences to strengthen procedural memory and enhance operational reliability.
5. Quality Control Information: Visualization of target states and typical defect patterns to guide manual inspection processes.
6. Inspection Result Recording: Structured input of inspection results and quality feedback by operators.

All information objects are created within a cloud-based no-code environment and can be flexibly reused across various workflows ("flows").

Process descriptions are fully declarative, multilingual, and scalable, enabling rapid adaptation to new products, processes, or user needs without requiring system reprogramming. Information is delivered via displays and interactively linked to plug-and-play devices such as P2L systems, camera-based verification modules, and barcode scanners. This integration ensures that users receive context-relevant information directly at the point of need, minimizing cognitive search effort and maximizing procedural focus.

3.3 Rule-Based Information Granularity

While structured and accessible information provision forms the basis for effective task support, static information density may hinder autonomy development and motivation over time, particularly for experienced workers. To mitigate this, the system employs an adaptive model of information granularity based on an eight-level support framework. Table 1 shows the granularity of the framework, which defines a stepwise reduction of available instructional support:

Table 1: Reduction of information density

Support Level	Available Information	Reduction compared to previous level
Level 1	Full Information: Tools, Components, Skill, GIF/Video, P2L (Tools/Components), Quality Control	-
Level 2	Tools, Components, GIF/Video P2L (Tools/Components), Quality Control	No Information how to use the assembly fixture (Skill)
Level 3	P2L (Tools/Components), GIF/Video, Quality Control	No further Information about necessary Tools/Components than P2L
Level 4	P2L (Components), GIF/Video, Quality Control	No P2L for Tools
Level 5	P2L (Tools), GIF/Video, Quality Control	No P2L for Components
Level 6	GIF/Video, Quality Control	No P2L
Level 7	P2L (Tools/Components, Quality Control	No GIF/Video
Level 8	Quality Control	Full Autonomy

Critically, users are not automatically transitioned between support levels based on system performance evaluation. Instead, users maintain full autonomy to choose their current support level and task difficulty. This preserves intrinsic motivation, respects user competence, and aligns with principles of self-determined learning. Performance-related data is still collected passively to provide feedback and create opportunities for

motivational triggers. However, advancement is not imposed — users are encouraged, but not required, to explore and master higher autonomy levels. Figure 1 shows the User-Interface (UI) of the assistance system (A) and the manual workstation with the assistance-system and gamification-platform (B).

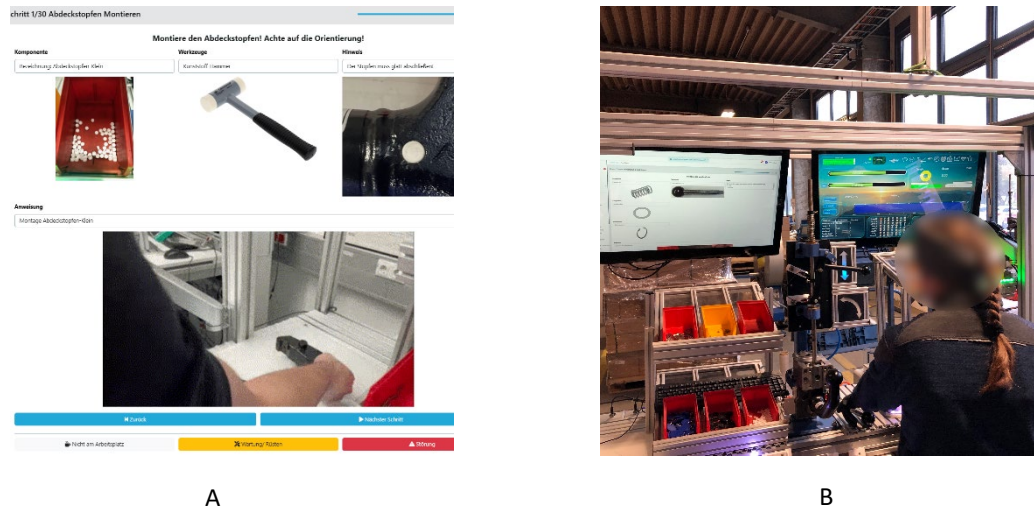


Figure 1: (A) Assistance-System-Interface Level 1. (B) Assembly-Station with Assistance- & Gamification-Platform

3.4 User Interaction Analysis

In order to objectively assess the cognitive and procedural demands associated with individual task steps, the system systematically captures key metrics of user interaction during task execution. The primary aim of this data collection is to analyze which phases of task performance consume significant time resources, thereby identifying potential cognitive bottlenecks, procedural inefficiencies, or error-prone stages.

Each work step is segmented into three distinct temporal phases:

- *Interpretation Time*: The time span from the presentation of a task instruction to the user's correct interaction with the relevant tool or component. This phase reflects the effort required for task comprehension, decision-making, and cognitive orientation.
- *Execution Time*: The net duration required to correctly complete the task using the intended tools and materials, serving as an indicator of procedural fluency and operational efficiency.
- *Correction Time*: The cumulative time spent on erroneous interactions (e.g., selection of incorrect tools) until a successful correction is achieved, either autonomously or through system feedback. This metric provides insight into adaptive behaviour, error recovery capabilities, and process robustness.

Real-time data capture is enabled through integrated sensor technologies, including P2L verification, camera-based selection monitoring, and software-side event logging. Collected data are anonymized in compliance with applicable data protection regulations and stored for subsequent aggregated analysis. By evaluating the distribution and trends of these time metrics across users and task types, the system enables the identification of critical phases where cognitive load, procedural complexity, or decision uncertainty are particularly pronounced. Such insights form the empirical basis for subsequent system adaptations, ergonomic improvements, and the refinement of motivational support mechanisms.

3.5 Integration of Gamification

The systematic analysis of user interaction metrics reveals clear patterns of cognitive load distribution, procedural efficiency, and error resilience across different task phases and support levels. However, while these insights enable a nuanced understanding of individual and system-level performance dynamics, they do not, by themselves, ensure voluntary engagement with higher autonomy stages or increase task difficulty. Given that users retain full autonomy over their selected support level and task configuration, fostering continuous competence development requires more than the mere availability of performance feedback. It necessitates an active motivational architecture that encourages users to challenge themselves, explore more demanding task variants, and deliberately reduce informational support over time. To address this challenge, the presented system integrates a comprehensive gamification framework to motivate users to pursue voluntary skill advancement intrinsically. Rather than enforcing progression through prescriptive mechanisms, the system

leverages game-inspired incentives to transform autonomous upskilling into a rewarding and self-directed experience. The following section details the structural elements of this gamification approach and its role in promoting sustainable engagement, intrinsic motivation, and long-term competence development within the adaptive assistance environment.

3.6 Core Mechanics of Gamified Motivation and Progression

The developed system structures voluntary skill progression by providing a defined set of challenge scenarios.

Each of the eight Information Support Levels, representing varying degrees of instructional density, combines seven Difficulty Stages that modulate the allowable execution time for a complete product assembly.

Thus, the system generates a total of 56 distinct challenge scenarios, each uniquely defined by:

- the amount of instructional support provided, and
- the allowed total time for completing a full assembly cycle.

Each Support Level is assigned A benchmark assembly time based on its informational density.

The Difficulty Stage adjusts this benchmark by a defined factor, ranging from:

- Very Easy: benchmark $\times$ 1.25 (extended time)
- Additional 5 Sub-States
- Insane down to benchmark $\times$ 0.75 (tightest time constraint)

Throughout the assembly process, users are accompanied by a paced timer, transparently communicating the remaining time for completing the current product assembly. This mechanism transforms each assembly cycle into a discrete challenge unit, linking performance to informational support and time pressure—without external enforcement. For each successfully completed scenario—defined as the correct and timely assembly of a full product at the selected Support Level and Difficulty Stage—users earn a unique Badge.

Consequently, 56 Badges are achievable across the system. Figure 2 shows the correlation of information-density and the benchmark.

Badges fulfil two parallel functions:

- They provide symbolic recognition of task mastery under specific cognitive and procedural demands.
- They award virtual currency (Coins), scaled based on the selected Support Level and Difficulty Stage:
- Higher autonomy levels (lower informational support) and stricter time constraints yield exponentially greater Coin rewards.

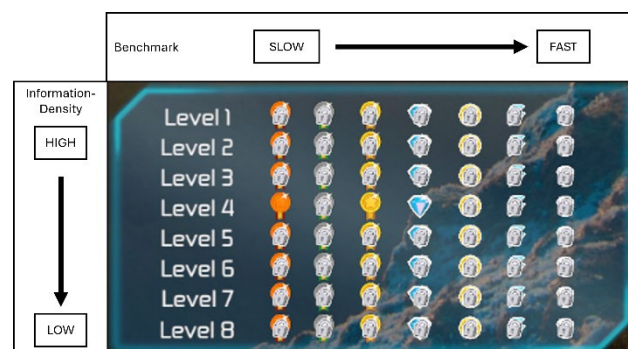


Figure 2: Badge-System with Relation between Information-Density and Benchmark

Accumulated Coins can be spent within the integrated Shop System to unlock personalization features, such as:

- Custom visual backgrounds for the UI,
- Animation effects are triggered upon successful assembly cycles.

To maintain long-term engagement, the shop employs a non-linear pricing structure:

Higher-tier customization options require exponentially greater Coin investments.

To accelerate progression after mastering multiple challenges, the system offers a Prestige Cycle:

- Users can voluntarily reset their Badge collection after meeting predefined Badge and Score thresholds.
- Their Prestige Level increases, resulting in a multiplicative boost to all future Coin earnings.
- This cyclical mechanism fosters repeated voluntary skill expansion, encouraging sustained system engagement and iterative personal growth.

As illustrated in Figure 3, users who regularly activate the Prestige mechanic gain access to significantly more coins over time, allowing them to afford new shop items more frequently. While non-Prestige users accumulate currency at a constant rate, resulting in increasing delays between item unlocks, Prestige users benefit from a reset-and-multiplier logic that keeps item acquisition intervals consistently short.

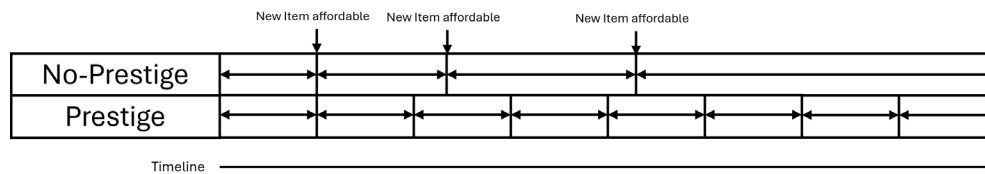


Figure 3: Illustration of progression dynamics in the gamification system. Users who activate the prestige mechanic benefit from accelerated coin accumulation, allowing more frequent buying of shopitems

4. Further Work

A dual-layered strategy captures behaviour and perception. The system logs each assembly cycle's support level, difficulty stage, interpretation, execution and correction times, plus error events, enabling longitudinal analyses. Perception is polled at scheduled UI prompts with validated five-point Likert scales: the System Usability Scale (SUS; Brooke 1996), key items from the Technology Acceptance Model (TAM; Davis 1989), NASA-TLX for cognitive load (Hart & Staveland 1988), and motivation/engagement via the User Engagement Scale (UES; O'Brien & Toms 2010). Optional free-text comments add qualitative depth. This protocol yields a fine-grained view of how operators use and experience the adaptive gamified assistance system. Data collection is ongoing; results will be reported separately.

5. Conclusion

The system presented in this work addresses the central challenges of highly variable assembly environments through the targeted combination of a modular, adaptive assistance framework and a fully configurable gamification platform. Introducing an eight-level Support Model enables the systematic adjustment of information density to users' individual development trajectories, fostering both process reliability and autonomous skill acquisition. The dynamic regulation of support intensity helps prevent cognitive overload and monotony, facilitating a gradual promotion of user autonomy within the assembly process. The integrated gamification platform addresses key motivational factors through individualized progress visualizations, reward mechanisms (Coins, Badges), and customizable user experiences. In particular, implementing a Prestige Mode enables a cyclical motivational structure that encourages both repetition and deepening of acquired competencies. The complete digitalization of process descriptions via a no-code framework allows complex assembly workflows to be created, adapted, and deployed flexibly without requiring advanced programming skills. The strict separation of content, logic, and presentation ensures high scalability and international applicability. The comprehensive system logging architecture and the integration of standardized evaluation instruments provide a robust methodological basis for an evidence-based assessment of system effects. By systematically capturing both objective performance metrics and subjective user experiences, the approach enables a holistic analysis that goes beyond purely operational indicators. Overall, the developed system represents a promising foundation for the next generation of adaptive, human-centered assistance systems in industrial manufacturing. It contributes to the operationalization of Industry 5.0 concepts by designing technological support systems that are flexible, individualized, and intrinsically motivating.

6. Outlook and Further Work

Building on the presented concept, several extensions and deepening activities are planned for the next project phase. A multi-month field study will be conducted under near-production conditions to evaluate the system further. The aim is to generate insights into the long-term effects on efficiency, quality, user autonomy, and motivation through detailed longitudinal analyses. Particular attention will be paid to the impact of different

gamification configurations and support level progressions. In parallel, the development of an AI-based recommendation system is being prepared. Based on aggregated usage data, this system will be designed to generate individualized optimization suggestions for support levels, difficulty stages, and information densities. This will enable adaptive responses to learning progress, performance changes, or shifts in user motivation. Another focus area is the integration of additional sensor-based interaction channels, such as wearable devices for real-time strain measurement or AR-interfaces for dynamic context support. The framework will evolve into an open platform in the long term, facilitating cross-domain experimentation with adaptive assistance concepts. The goal is to generate transferable insights applicable to various industrial and non-industrial contexts — including maintenance, education, and healthcare. Through this systematic expansion, the project aspires to make a substantive contribution to the future design of human-technology interactions, oriented not only toward productivity goals but equally toward human learning capacity, motivation, and sustainable competence development.

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Ethic clearance declaration: This publication describes the development and intended evaluation of a gamified assistance system. No empirical user data were collected at this stage. Therefore, no formal ethics approval was required for the study setup presented.

AI declaration: During the preparation of this article, AI-based tools were utilized to assist in the filtering and evaluation of literature sources. The authors confirm that all scientific interpretations, evaluations, conclusions, and manuscript writing were performed independently without substantive AI-generated content.

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Needs Analysis to Define a Digital Learning Game Aimed at Coping with Mathematics Anxiety

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Abstract: Mathematics anxiety is a well-documented phenomenon affecting students' learning experiences, engagement, and long-term career choices. This research is part of a wider effort to mitigate and prevent mathematics anxiety through the development of a digital learning game, supported by a follow-up teacher professional development programme. Previous research highlights a critical gap in the availability of games specifically designed to mitigate mathematics anxiety and promote learning and emotional well-being. This paper focuses on the needs analysis phase of a game development process. The research follows the design-based approach, in which the first step involves identifying needs and defining educational objectives. The needs analysis is designed on a multinational basis by an interdisciplinary research team from five European countries. It aims to identify the requirements of teachers and students for the digital learning game based on a literature review, an analysis of mathematics curricula in the five European countries, as well as surveys conducted among teachers, students, and parents. Focus group interviews in these five countries deepen the understanding of teachers' needs and perspectives. Results from the analysis will guide the design stage and contribute to the creation of game mechanics that align with the learning goals. Later, the game will be iteratively built, tested and improved together with teachers and students. The needs analysis and definition of game requirements are carried out by a multidisciplinary team using co-design methods. The team includes experts from the fields of mathematics, game development, pedagogy, mental health and co-design. In addition to developing a digital learning game, the game is particularly aimed at supporting emotional well-being and engagement of the player in order to mitigate anxiety related to learning maths. Preliminary results from needs analysis reveal that specific game mechanics, modular design, and a positive psychology approach are considered essential in supporting student's learning and well-being. The results form the basis for the further game design.

Keywords: Mathematics anxiety, Game-Based learning, Needs analysis, Digital learning tools, Digital learning games, Teacher professional development

1. Introduction: Understanding Mathematics Anxiety: Causes, Consequences and Interventions

Mathematics anxiety (MA) is widely recognized as a distinct form of academic anxiety that disrupts learning, logical reasoning, and decision-making in mathematical contexts (Ahmmed et al., 2024; Kaushal et al., 2022). Building on this understanding, it is noteworthy that although MA has been conceptualized from educational, psychological, and clinical perspectives, it consistently affects both low- and high-achieving students. It often emerges early, triggered by negative classroom experiences, high-stakes assessments, or unsupportive teaching practices (Rada & Lucietto, 2022). The relationship between MA and mathematical performance is complex and bidirectional: anxiety can impair performance, while repeated struggles may reinforce anxious feelings (Carey et al., 2016). Recent studies estimate that approximately one in six students experiences moderate to high levels of MA, with symptoms often emerging already in primary school (Hill et al., 2016).

Furthermore, gender differences are consistently reported, with girls experiencing higher levels of anxiety despite performing similarly to boys, contributing to persistent gender gaps in STEM (Science, Technology, Engineering and Mathematics) engagement and careers (Levy et al., 2021; Stoel et al., 2016). If left unaddressed, MA can lead to a self-perpetuating cycle of avoidance, underachievement, and reduced future opportunities, even among capable students.

Given the well-documented impact of MA, game-based learning (GBL) – particularly digital GBL – has gained attention for improving student engagement, motivation, and confidence in mathematics (Barz et al., 2023; Cole et al., 2023). Serious educational games offer interactive and accessible ways to explore mathematical concepts (Hwa, 2018), and previous studies show their potential to enhance learning outcomes and foster positive attitudes toward mathematics (Vanbecelaere et al., 2020; Moyer-Packenham et al., 2023). However, it is essential to recognize that a recent meta-analysis (Dondio et al., 2023) revealed that while non-digital games can moderately reduce MA, digital games have had only a negligible impact, possibly due to the lack of games specifically targeting anxiety as well as the dominance of single-player designs. A study on the digital game *Seven Spells* (Almo and Amaral, 2024) showed that competition against human players intensified MA effects, emphasizing the need for careful consideration of game mechanics and social dynamics when designing games for emotionally vulnerable learners.

This paper is part of a broader European research initiative involving Finland, the Netherlands, Croatia, Malta, and Portugal, aimed at developing a digital learning game and a related teacher professional development programme to help reduce MA among 5–16-year-old students. Following a design-based research (DBR) approach, the work begins with a design of comprehensive needs analysis to identify learner needs and contextual factors. The co-designed game will draw on expertise in education, mental health, game development, and co-design, with goals extending beyond cognitive improvement to fostering emotional well-being, resilience, and long-term positive engagement with mathematics.

This article is structured as follows. It presents the needs analysis that serves as the foundation for the development of both a digital learning game and a teacher professional development programme. The needs analysis consists of four interrelated components: (1) a review of existing literature on MA and digital learning game development (2) a comparative curriculum analysis across five European countries, (3) electronic questionnaires (eQuestionnaires) targeted at teachers, students, and parents, and (4) focus group interviews with teachers. As the research is still ongoing, this article focuses on the needs analysis and its methodology and design. The findings presented are preliminary and provide an initial overview of emerging themes and user needs. The article concludes with key insights and outlines future steps in the development process.

2. Methodology

The needs analysis in this research included several components: a literature review, a comparative analysis of mathematics curricula, eQuestionnaires for teachers, students, and parents, and focus group interviews with teachers (Figure 1). The integration of findings from these components enables a comprehensive understanding of mathematics anxiety and the specific needs of both learners and educators. This multi-layered methodological approach not only elucidates the challenges inherent in mathematics learning but also provides a robust foundation for the design of a targeted digital learning game. Additionally, the insights generated will inform the development of a teacher professional development program that aligns with empirically identified needs and pedagogical objectives.

To establish a solid theoretical foundation, the literature review was conducted using international peer-reviewed research literature, in English, published between 2015 and 2025 – including studies on mathematics anxiety and existing educational games designed to reduce it. The review focused on identifying the key causes and contributing factors of mathematics anxiety, its cognitive and academic consequences, and relevant game-based intervention strategies.

In the curriculum analysis the structure and flexibility of mathematics education were compared across five participating European countries with particular focus on curriculum detail, teaching methods, integration of innovation, and considerations for MA. This comparison highlighted critical differences and similarities, informing the game design and professional development strategies.

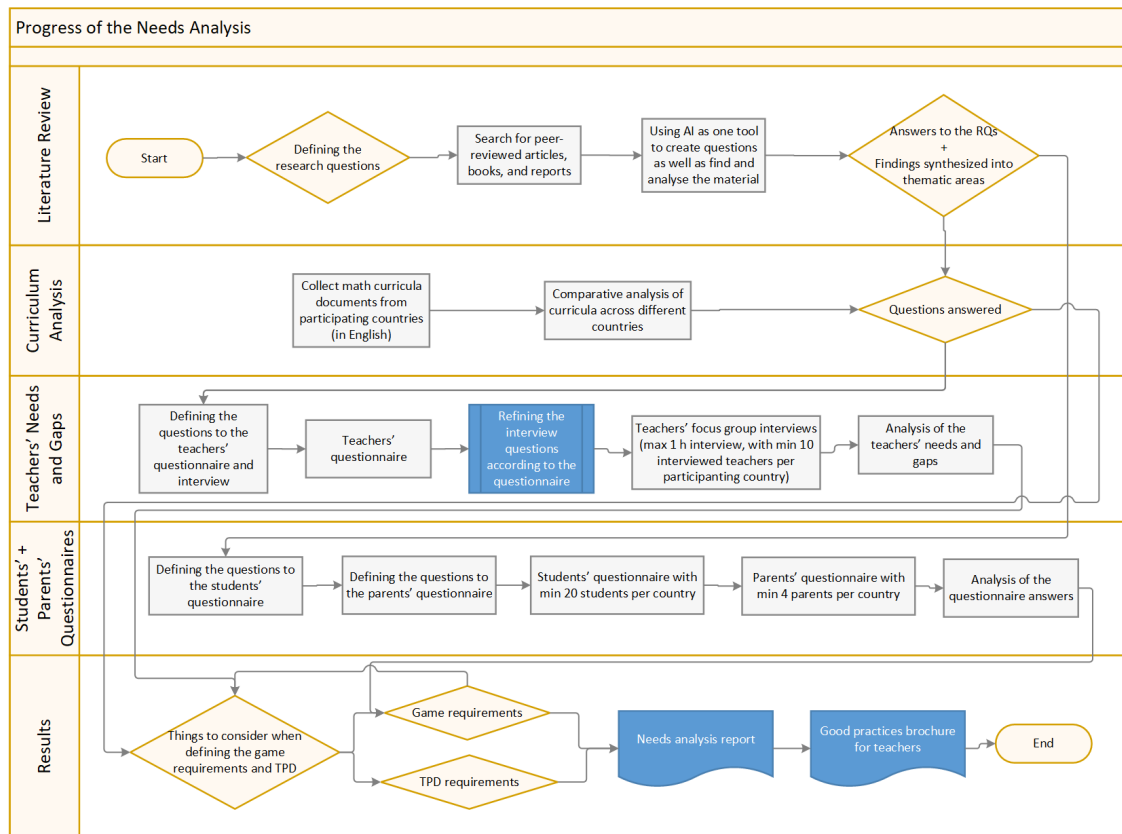


Figure 1: Progress of the needs analysis

To gain insights from various perspectives, teachers', students' and parents' perspectives on maths anxiety and good practices for mitigating and coping with it were identified through eQuestionnaires. Separate eQuestionnaires were designed and implemented for each group of respondents. The main objective of the teachers' eQuestionnaire was to find answers on the extent to which teachers identify maths anxiety, what tools they have to mitigate maths anxiety and help students with MA, and what kind of digital game they would like to have available for this purpose. Following participation in the eQuestionnaire, the teachers had the possibility to register in focus group interviews, which deepened our understanding of teachers' needs and knowledge gaps.

In parallel, the students' eQuestionnaire explored their feelings during maths tasks and lessons, their coping strategies, and their interest in learning through games. Questions differed between elementary and middle school students, with older students expected to provide more reflective responses. The questionnaire for 4th–6th graders was slightly more detailed than for 1st–3rd graders. The term "mathematics anxiety" was not used; instead, students were encouraged to describe their experiences and coping methods. Complementing these insights, the parents' questionnaire – the most concise of the three – focused on their perceptions of their children's maths anxiety, the school's mitigation efforts, and their satisfaction with these approaches. Together, these components provide a comprehensive view of the experiences and expectations related to MA across different stakeholders.

3. Key Outcomes of the Needs Analysis

3.1 Causes and Contributing Factors

The literature review, which included 39 peer-reviewed articles, highlights several emerging themes related to multiple factors contributing to MA, often categorized in personal, psychological, cognitive, and environmental domains (Kaushal et al., 2022; Mammarella et al., 2023). Among personal traits, gender is frequently discussed: although female students often perform equally well in mathematics, they tend to report higher levels of anxiety, possibly due to internalized societal stereotypes (Szűcs & Toffalini, 2023; Hadley, 2025).

Self-efficacy, or belief in one's ability to succeed in math, is a major psychological predictor of MA. Lower self-efficacy is strongly correlated with higher anxiety and poorer performance (Rozgonjuk et al., 2020; Khasawneh

et al., 2021). Other internal factors include perfectionism, general anxiety, and low confidence. Externally, negative teacher feedback, parental pressure, rigid instruction, and performance-focused assessments increase stress and reduce perceived control, further fuelling MA (Ahmmed et al., 2024; Rada & Lucietto, 2022). Recent studies have also revealed that genetic factors may play a role in MA development. For instance, Malanchini et al., (2020) found that up to 75 % of the variance in MA could be explained by genetic links to attitudes and abilities in math, while Wang et al. reported a 40 % heritable component (as cited in Ahmmed et al., 2024).

3.2 Cognitive Mechanisms and Academic Consequences

At the cognitive level, MA interferes with working memory, which is essential for holding and manipulating numerical information. As a result, anxious students often struggle to concentrate, switch strategies, or solve multi-step problems due to cognitive overload (Jiang et al., 2021; Justicia-Galiano et al., 2016). This inflexible persistence can trap students in inefficient problem-solving loops (Ramirez et al., 2016), undermining their ability to improve or adapt.

MA is consistently linked with reduced math performance, lower academic motivation, and negative attitudes toward mathematics (Mammarella et al., 2023; Khasawneh et al., 2021). Students with high MA tend to avoid math-related courses and careers, contributing to a long-term skills gap in STEM fields (Kaushal et al., 2022; Rada & Lucietto, 2022). Over time, this avoidance may lead to decreased confidence, school disengagement, and reduced socioeconomic opportunities.

3.3 Intervention Strategies

Because MA is multi-causal, its effective management requires multi-layered interventions. Promoting a growth mindset, where students see mistakes as learning opportunities, has shown positive effects in reducing anxiety and increasing resilience (Mammarella et al., 2023). Additionally, enhancing self-efficacy through positive reinforcement, step-by-step scaffolding, and real-world applications helps students regain confidence and motivation (Rozgonjuk et al., 2020; Khasawneh et al., 2021). Cognitive-behavioral strategies such as expressive writing, mindfulness, and relaxation techniques help students regulate anxiety before assessments (Beilock & Maloney, 2015; Ramirez et al., 2016). Meanwhile, instructional approaches that emphasize conceptual understanding, reduce time pressure, and offer varied assessment formats (e.g., projects, portfolios) can reduce classroom-based stressors (Hadley, 2025; Rada & Lucietto, 2022). Finally, the role of teachers and parents is crucial. Educators should foster a safe learning environment where effort is valued over speed or correctness, and parents should avoid negative math talk and focus on constructive support (Ahmmed et al., 2024; Kaushal et al., 2022).

Building on these insights and based on the reviewed literature, we define mathematics anxiety as an emotional reaction characterized by feelings of fear, tension, and apprehension when engaging with mathematical tasks or situations. It involves cognitive, emotional, physiological, and behavioural responses that can impair mathematical performance, lead to avoidance of math-related activities, and affect academic and career trajectories, even among individuals with sufficient math skills.

3.4 Game-Based Learning (GBL) and Emotional Regulation

Findings on the different effects of digital and non-digital games highlight the importance of purposefully designed learning games that support both cognitive development and the emotional well-being of math-anxious students. Drawing from these insights, effective elements from non-digital games, such as scaffolding, adaptability, and positive feedback, will be incorporated into the mechanics and progression of the digital game currently under development.

Digital games offer opportunities for iterative learning without the fear of failure, helping students build resilience and a more positive attitude toward mathematics (Chen et al., 2021). Incorporating principles of positive psychology—such as encouragement, goal orientation, and autonomy—can enhance learners' self-confidence and reduce mathematics anxiety (Almo et al., 2024).

Key game design features identified in the literature include scaffolding, adaptive difficulty, narrative and storytelling elements, personalized feedback, and emotional regulation support. These mechanisms allow learners to progress at their own pace, stay motivated, and develop a sense of control (Bilgin, 2021; Abbacan et al., 2025). Gamification elements like points, badges and evolving game characters can further boost engagement when integrated thoughtfully within a strong pedagogical framework (Jutin & Maat, 2024; Alt, 2023). The promising design principles, mechanics, and their expected outcomes identified from the literature review are illustrated in Figure 2.

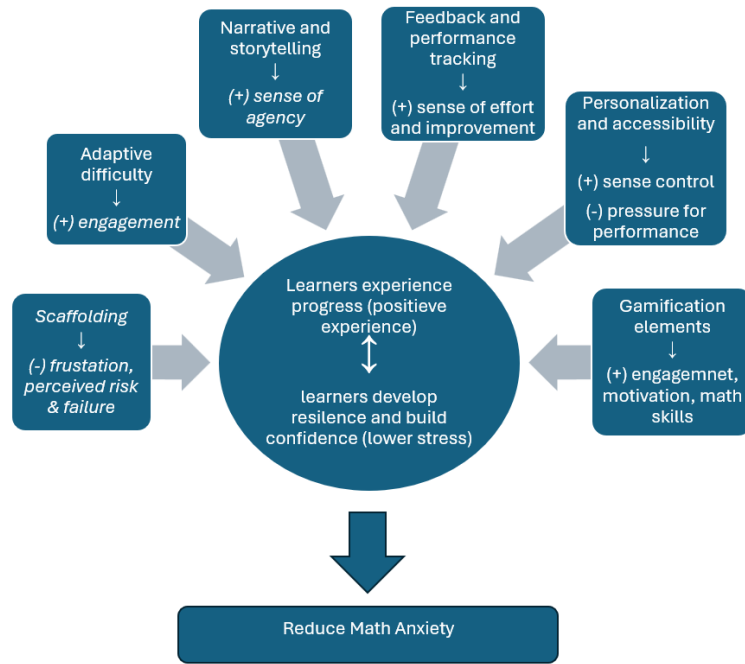


Figure 2: Design principles and game mechanics

To conclude, mathematics anxiety is shaped by a wide range of factors and has far-reaching effects on academic paths and well-being of learners. Educational games have the potential to play a meaningful role – both now and in the future – in supporting learning, emotional regulation, and overall student well-being.

3.5 Curriculum Analysis

The curriculum analysis used the mathematics curricula of all five countries (TIMSS 2015 Encyclopedia, 2015), which the researchers analysed from the perspective of the literature review and the research objectives. Table 1 presents the results of the curriculum analysis are presented from the perspectives of: curriculum detail and structure, teaching methods and guidance, use of teaching materials, flexibility and integration of games, consideration of mathematics anxiety, teacher motivation and support for innovation, integration of digital tools and gamification, as well as curriculum obligations.

Table 1: Results of the curriculum analysis

Mathematics Curriculum Comparison	Finland	Netherlands	Croatia	Malta	Portugal
Curriculum Detail and Structure	National framework, clear goals, local flexibility	Greater school autonomy within national objectives	Highly detailed curriculum with defined outcomes per grade	Structured curriculum; variation by school type	Structured curriculum with implementation flexibility
Teaching Methods and Guidance	Pedagogical freedom, recommended practices, hands-on learning encouraged	High flexibility for teachers in methods	Balance of methods encouraged; traditional methods prevail	Some pedagogical recommendations	High flexibility; traditional methods common
Use of Teaching Materials	Aligned with curriculum, supports goals, varied formats	Materials align with objectives; school choice	Teachers supplement textbooks with various resources	Government-approved textbooks aligned with curriculum	Teachers supplement textbooks with various resources
Flexibility and Integration of Digital Tools and Gamification	Supports the use of digital tools, games, and innovation.	Flexible use of games, but integration is not prioritized without assessment.	Games encouraged; limited use and training in grades 7–12.	Games seen as supplementary tools; actual use varies.	Games perceived as supplementary; limited training for grades 7–12.

Mathematics Curriculum Comparison	Finland	Netherlands	Croatia	Malta	Portugal
Consideration of Mathematics Anxiety (MA)	Limited mention, supports positive self-image and attitudes	Limited mention; verification needed	Not systematically addressed	A recent local study suggests growing awareness amongst teachers	Curriculum creators vs. teachers questioned
Teacher Motivation and Support for Innovation	Freedom to teach creatively and professionally	Innovation supported at school level	Encouraged innovation, but traditional practices dominate	Institutional support via guidelines and training	Encouraged innovation, but time/content limits
Curriculum Obligations	Mandatory national goals, implementation is locally flexible	Mandatory, with optional components in secondary education	Mandatory curriculum	Mandatory curriculum	Mandatory content; flexible scheduling

All five countries have national mathematics curricula, but their level of specificity and flexibility varies. Finland and Croatia provide detailed grade-specific learning objectives, with Finland emphasizing a national framework that sets clear goals while allowing local flexibility. The Netherlands gives schools greater autonomy in structuring instructional time and implementing the curriculum. Malta and Portugal offer clearly defined curricula, though private schools in Malta have more freedom in content organization.

Curricula generally recommend rather than mandate teaching methods. Finland emphasizes pedagogical freedom and encourages recommended practices and hands-on learning. Malta includes some pedagogical suggestions, while teachers in the Netherlands and Portugal enjoy broader flexibility. In Croatia, a balance of exposition and exploration is encouraged, though traditional methods are often used due to practical constraints. Across the board, teachers retain considerable autonomy in instructional delivery.

Learning materials in all countries align with national curricula. In Finland, materials are aligned with the curriculum and support learning goals using varied formats. Malta also uses government-approved textbooks, while in Portugal and Croatia, teachers often supplement textbooks with various resources such as handouts and digital tools. In the Netherlands, school decisions influence textbook selection. Although digital tools and games are allowed everywhere, their integration varies. Finland supports gamification, digital tools, and innovation, whereas Croatia and Portugal tend to perceive games as supplementary. The Netherlands encourages game-based learning, while in Malta, games are seen as additional tools.

Mathematics anxiety is rarely addressed explicitly in national curricula. Finland mentions it briefly and supports the development of a positive self-image and attitudes in mathematics. Malta has a recent study indicating growing awareness (Grech, 2024), but overall, MA is not systematically considered. Support for innovation also differs: Finland allows teachers freedom to teach creatively and professionally, and institutional support is present in Malta. Croatia and Portugal face challenges due to time constraints and heavy content loads. In the Netherlands, innovation is supported at the school level.

Despite the differences in the mathematics curricula of the five countries, all of them allow and support using digital tools in teaching. In addition, considerations related to MA are still rare. These results are encouraging for developing a digital learning game targeted to mitigate MA. Implementation of such game may require a customised approach in each country.

3.6 Teachers' eQuestionnaire and Focus Group Interviews

So far, we have preliminary findings as 13 Finnish teachers who teach mathematics in grades 2 to 9 have responded to the teachers' eQuestionnaire. All respondents reported observing signs of math anxiety among their students. Two teachers stated that they notice signs of math anxiety often, nine said sometimes, and two reported observing it rarely. The most common indicators of math anxiety observed by the teachers include students having difficulty concentrating during math lessons, expressing negative emotions toward mathematics, and avoiding or not completing math-related tasks.

To help students cope with mathematics anxiety, teachers reported using encouragement, reduced assessment pressure, interactive activities, and flexible timing. They highlighted the need for more practical tools and greater collaboration with support staff. Teachers were mainly of the opinion that a digital maths learning game could help students to be motivated and, on the other hand, to repeat their learning sufficiently.

To explore how mathematics anxiety is perceived, identified, and addressed in school settings, we conducted semi-structured thematic interviews with seven teachers. This qualitative approach allowed a flexible examination of teachers' lived experiences and professional insights. At this stage of the research, interviews were conducted exclusively with primary school teachers. The interview guide was structured around five thematic domains: identifying mathematics anxiety; effects of MA on learning; support strategies used by teachers; school-level support; and opportunities for digital game-based learning.

Teachers identified mathematics anxiety across all primary grades, with older students articulating it more clearly and younger students showing indirect signs. Anxiety was often linked to academic pressure, attention difficulties, and peer comparison, particularly in test settings, and intensified by the evaluative nature of mathematics. While anxiety reduced engagement, performance, and motivation, supportive environments and individualized approaches were seen to improve students' experiences.

Teachers addressed MA using encouragement, differentiated tasks, and small group support, adjusting their strategies to students' developmental needs. However, formal school-level support was limited, relying largely on peer collaboration, with special education services often insufficient and welfare professionals focusing on general well-being. Teachers saw digital game-based learning as a way to boost motivation, offer safe practice spaces, and support students with mathematics anxiety. Adaptive features, clear structure, and storytelling were especially valued, while flexibility between digital and paper-based formats was considered important. Students using digital tools before assessments often performed better, suggesting games' potential to reduce anxiety and improve learning outcomes.

3.7 Students' and Parents' eQuestionnaires

The results of the parent and child eQuestionnaires are preliminary, as data have so far been collected only in Finland. The eQuestionnaires were open only for 11 days before this initial analysis, during which 22 students and 104 parents responded. Of the parent respondents, 9 % had children in grades 7-9, 61 % in grades 4-6, and 31 % in grades 1-3. The high response rate suggests that parents view the topic as important. The most common signs parents observed when their children experienced difficulties in mathematics were frustration, giving up, and feeling inadequate. Nearly half (49 %) reported their children faced at least some challenges in mathematics learning, and 74 % had observed negative emotions during maths tasks or exams, most commonly frustration, giving up, and feelings of inadequacy. Interestingly, 13 % of parents stated they often noticed negative feelings, underscoring the persistent nature of these emotional responses.

Of the students who responded to the survey, 15 were aged 11, five were aged 12, one was aged 13 and one aged 15. In total, 21 students said they liked maths at least sometimes. When asked how they felt when they had to solve a difficult mathematical problem, students were allowed to choose as many feelings as they wanted. The reported emotions included: happy (4), excited (2), confident (9), okay (12), nervous (3), frustrated (4), unsure (2), annoyed (1). Notably, none of the students reported feeling bored or anxious during math task.

To summarize, the preliminary findings reveal that this design of comprehensive needs analysis is valuable and suitable for need mapping offering a recognisable and multifaceted view to the issue. Teachers consistently reported observing signs of MA, most seen as difficulty in concentrating, negative emotions, and task avoidance. While teachers employed strategies such as encouragement, reduced assessment pressure, and interactive activities, they also expressed a need for more concrete tools and greater collaboration with special education professionals and school psychologists.

Despite the early-stage nature of the data, the students' and parents' questionnaires offer valuable insights. Although the term "anxiety" was not explicitly used in the student questionnaire, feelings such as frustration and uncertainty emerged when facing difficult math problems. The terminology used in the student questionnaire was intentionally kept neutral to avoid priming, but this also highlights the challenge of identifying MA in younger learners, who may lack the vocabulary or self-awareness to articulate their emotional experiences. Meanwhile, nearly three-quarters of parents reported observing negative emotions in their children when engaging with mathematics. This emphasizes the role of families in identifying and addressing MA and suggests that future interventions may benefit from actively involving parents alongside educators.

These findings emphasize the potential of digital games as supportive tools. Based on the literature review five design principles were identified to guide the development of the first version of the game. Teachers saw digital games as motivating and helpful – particularly when they include features such as adaptivity, clear structure, and emotionally safe environments. However, such tools should complement, not replace, traditional

instruction and be paired with teacher professional development. Further visualisation of the game design as well as the learning process are our future work.

Limitations include the small sample size and the focus on a single country at this stage. However, the results already offer valuable input for the co-design of a game that targets both emotional well-being and math engagement. As the research expands across partner countries, a more comprehensive understanding will guide the game development and teacher training program.

4. Conclusion

This study presented early findings from a multinational needs analysis supporting the development of a digital learning game and teacher professional development programme to address mathematics anxiety (MA). The needs analysis consisted of literature, curriculum analysis, questionnaires and interviews. The curriculum analysis in five European countries emphasised the need to further address MA and demonstrated the potential for implementing digital games in teaching across all these countries. Based on the literature review, key design principles for such games include scaffolding, adaptive difficulty, narrative and storytelling elements, personalised feedback, and emotional regulation support, along with motivational gamification elements.

MA was widely recognized by teachers and parents, who identified a need for concrete tools, emotional support strategies, and stronger collaboration among school professionals. The enthusiasm of parents and teachers to participate in this study indicated that the topic is truly important. Digital games were seen as a promising complement to traditional teaching when designed with adaptivity, emotional safety, and motivational features. Although the current data are limited to Finland, they provide valuable direction for the game's co-design and related teacher training. As research expands across partner countries, it will further strengthen the foundation for an inclusive, research-informed intervention promoting mathematical learning and well-being.

Ethics declaration: This study did not require formal ethical clearance. However, all participating teachers, students, and parents were fully informed about the study and its purpose. Participants reviewed and accepted the data protection statement prior to participation. For students under the age of 15, written consent was obtained from their parents or legal guardians. We obtained research permission from the Department of Education of the City of Pori to conduct the study in schools within the region.

AI declaration: AI tools were used to support language editing, organize section titles, and identify repetition during manuscript preparation. SciSpace AI assisted in identifying literature sources, and ChatGPT was used selectively to refine text style, improve clarity, and structure ideas for the game mechanics section. All final content was critically reviewed and revised by the authors.

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Impact of Math Ludo on Skills in Students With Dyscalculia

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Abstract: Creative teaching approaches that incorporate game-based strategies and foster dynamic learning environments can greatly enhance the educational experience for students with diverse learning needs. This study examines the pedagogical effectiveness of Math Ludo, an original board game developed through a graduate-level educational games course, as an intervention tool for students with dyscalculia. The game mechanics incorporate dice-based navigation, numerical station challenges, and peer interaction dynamics to enhance core competencies in (1) basic arithmetic operations, (2) numerical magnitude understanding, (3) sustained attention, and (4) mathematical anxiety reduction. The study adopted a small-N, mixed-methods case study design rooted in special education research traditions. This design allowed for the integration of both quantitative and qualitative data streams to explore individualized instructional responses. Two first-grade participants with clinically diagnosed dyscalculia completed two one-hour gameplay sessions per week for seven weeks, following ethical research protocols. Quantitative assessment via the standardized KeyMath-3 test revealed score improvements of 42% and 58% for Student A and B, respectively, from baseline to post-intervention, with sustained progress observed at a two-week follow-up. Qualitative analysis of teacher-reported metrics demonstrated a 51% reduction in math-avoidance behaviors, a 60% increase in peer learning interactions, and a 65% improvement in task engagement duration. Mixed-methods analysis identified key success factors, including multi-modal reinforcement through tactile (dice), visual (game board), and verbal (peer negotiation) stimuli. These factors include error normalization via chance elements, which reduces performance anxiety, and progressive difficulty scaling matching participants' Zone of Proximal Development. Results suggest that games like Math Ludo, instructionally designed for specific learning objectives, can effectively bridge cognitive gaps in dyscalculia intervention by combining social-emotional learning components, strategic mathematical decision-making, and progressive task design. These results support the utility of well-designed educational games as tailored interventions for cognitive and emotional challenges associated with dyscalculia. Future research should evaluate scalability across broader and more diverse student populations. Top of Form

Keywords: Dyscalculia, Educational board game, Math learning skills, Math Ludo

1. Introduction

Dyscalculia a specific learning disorder, disrupts mathematical processing and performance, impacting approximately 3–7% of the global population (Mazzocco & Feigenson, 2011; Wall, 2022). This condition manifests in persistent difficulties with numerical tasks such as counting, number sequencing, and quantity comprehension, often leading to academic and functional challenges. Beyond cognitive impairments, dyscalculia frequently triggers emotional responses, including mathematics anxiety and avoidance behaviors, which further hinder learning (Carey et al., 2018; Rubinsten, 2022). Early intervention is critical to mitigate these effects and support long-term educational and professional success.

To understand the cognitive deficits associated with dyscalculia, the Cattell-Horn-Carroll (CHC) theory of cognitive abilities offers a psychometrically validated framework. This model organizes cognitive functions into domains such as Quantitative Knowledge (Gq), encompassing numerical processing and arithmetic operations, and Short-Term Memory (Gsm) and Processing Speed (Gs), vital for working memory and rapid numerical processing (McGrew, 2009). These domains are often impaired in dyscalculia, contributing to struggles in number sense and sustained attention (Schneider et al., 2017). Interventions targeting these abilities can address both cognitive and emotional barriers, paving the way for engaging, evidence-based solutions (Flanagan et al., 2010).

Traditional teaching methods, often text-based, fall short in engaging students with dyscalculia, who require personalized and interactive approaches (Conley, 2022). Cognitive training programs, such as brain-based interventions, have improved working memory but often lack motivational elements critical for sustained engagement. These limitations highlight the need for dynamic strategies that foster both cognitive growth and emotional resilience in learners with mathematical difficulties.

Game-based learning has emerged as a promising approach for students with learning disabilities, offering safe environments to practice skills while reducing the fear of failure. Digital games, such as those using augmented reality, have enhanced conceptual understanding in dyscalculia (Avila-Pesantez et al., 2017). Similarly, interactive board games have boosted arithmetic skills and interest (Torres-Carrión et al., 2018). These findings underscore the potential of games to transform mathematical learning experiences.

Despite these advances, gaps remain in the literature. Many studies focus on digital platforms or structured curricula, often neglecting peer collaboration and progressive challenges. Analog games, such as those designed for dyslexia, show promise for dyscalculia by fostering cooperative learning, yet rigorous evaluations using mixed-methods designs are scarce (Jiménez-Fanjul et al., 2021). This study seeks to address this gap by examining a custom-designed board game intervention tailored for dyscalculia.

Effective interventions for dyscalculia must integrate cognitive and socio-emotional support. Social learning theory suggests that observing and imitating peers can enhance both conceptual understanding and interpersonal skills (Bandura, 1977). In inclusive settings, where students with dyscalculia may feel isolated, collaborative environments can normalize mistakes and build confidence, fostering resilience and a positive approach to mathematics (Resnick, 2015; Wilkinson & Silliman, 2020).

To further ground this study, Self-Determination Theory (SDT) emphasizes autonomy, competence, and relatedness as drivers of intrinsic motivation (Deci & Ryan, 1985). In the context of dyscalculia, SDT-informed interventions can reduce anxiety and enhance engagement by offering choices, scaffolding challenges, and promoting peer interactions. Research on game-based learning supports this approach, showing improved self-efficacy and reduced anxiety in dyscalculic learners (Järvelä et al., 2023; Lin & Jiar, 2017). By combining SDT with CHC's cognitive framework, this study offers a robust lens for addressing both cognitive and emotional dimensions of learning.

This study investigates the effects of a novel board game intervention on arithmetic skills, number magnitude understanding, sustained attention, and mathematical anxiety in first-grade students with dyscalculia. Using a mixed-methods small-N case study design, it evaluates cognitive and socio-emotional outcomes, contributing to the growing body of evidence on game-based interventions for diverse learners (Kaufman & Kaufman, 2014).

2. Methodology

This study employed a mixed-methods small-N case study design, a robust approach in special education research for examining individualized interventions for neurodivergent learners, such as those with dyscalculia (Fu & Chin, 2021; Stovel, 2018). By integrating quantitative and qualitative data streams, this design enabled a triangulated analysis of cognitive and socio-emotional outcomes, aligning with the study's aim to evaluate the pedagogical efficacy of a tailored board game intervention in enhancing mathematical skills and reducing math-related anxiety. Grounded in the Cattell-Horn-Carroll (CHC) theory and Self-Determination Theory (SDT), the methodology targeted specific cognitive domains (e.g., Quantitative Knowledge, Short-Term Memory, Processing Speed) and motivational factors (autonomy, competence, relatedness) to address the multifaceted challenges of dyscalculia (McGrew, 2009; Deci & Ryan, 1985).

2.1 Participants

Two first-grade students (aged 6–7) with a clinical diagnosis of developmental dyscalculia (DD), confirmed by certified educational psychologists, were recruited from an inclusive elementary school in Tehran, Iran, through school counselors and special education services. Inclusion criteria required: a formal dyscalculia diagnosis; persistent difficulties in arithmetic computation and place value understanding; absence of neurological or sensory comorbidities; and a WISC-IV Index Score ≥ 85 (Wechsler, 2003; Abedi et al., 2015). Informed consent was secured from participants and their caregivers, adhering to the ethical guidelines of the American Psychological Association (2017) and local institutional review board policies.

2.2 Intervention Design

The intervention was implemented over seven weeks, with two one-hour sessions per week, totaling 14 sessions, conducted in a distraction-minimized classroom by educators trained in instructional game design. The board game was crafted to align with Universal Design for Learning (UDL) principles, promoting multimodal engagement through kinesthetic (dice manipulation), visual (color-coded board), and verbal-auditory (peer dialogue) elements (Meyer, Rose, & Gordon, 2014). Game mechanics, such as chance-based tasks and collaborative challenges, were designed to reduce math anxiety and foster social learning, targeting

CHC-defined cognitive abilities like Quantitative Knowledge (Gq) for arithmetic fluency and Short-Term Memory (Gsm) for active recall (Flanagan et al., 2010).

Instructional strategies drew on constructivist and Vygotskian principles, emphasizing the Zone of Proximal Development (ZPD) to scaffold tasks at developmentally appropriate levels (Vygotsky, 1978; Piaget, 1952). The intervention progressed from guided to independent gameplay, with task difficulty increasing gradually and facilitator support decreasing to encourage autonomous problem-solving. This approach supported SDT's motivational framework by fostering autonomy through strategic choices and competence through scaffolded challenges (Deci & Ryan, 1985).

2.3 Data Collection Procedures

A triangulated data collection model enhanced the study's internal validity, capturing both cognitive and socio-emotional dimensions of learning.

2.3.1 Quantitative assessment

Mathematical abilities were measured using the KeyMath-3 Diagnostic Assessment, a standardized tool for evaluating arithmetic skills and number sense, administered at three time points: pre-intervention, post-intervention, and a two-week follow-up to assess retention (Maricle & Vidovic, 2022).

2.3.2 Qualitative observations

Structured observation tools and peer-based feedback protocols, implemented within a school-wide behavioral monitoring framework, were used to assess student engagement indicators such as on-task behavior, peer collaboration, and avoidance responses (Ferrari & Lewon, 2025). These tools provided insights into socio-emotional changes during gameplay.

2.3.3 Fidelity monitoring

Intervention fidelity was ensured through detailed treatment logs and audio recordings, which verified consistent adherence to the game's instructional protocol and session structure.

Table1: Procedure of implementing Math Ludo

Session(s)	Phase	Focus and Activities	Instructional Strategies and Theoretical Basis
Session 1	Introduction and Familiarization	Introduce game rules, tools (dice, board); model gameplay; establish a low-anxiety environment	UDL Principles (Meyer et al., 2014); Multisensory engagement; Constructivism (Piaget, 1952); Active learning foundation
Sessions 2–3	Guided Gameplay & Basic Arithmetic	Solve basic arithmetic tasks within gameplay; promote cooperative peer play; encourage verbal strategy-sharing	ZPD Scaffolding (Vygotsky, 1978): Tailored tasks; Social Learning Theory (Bandura, 1977): Peer modeling and imitation
Sessions 4–5	Increasing Complexity & Reasoning	Scale task difficulty; encourage student-led play; emphasize collaborative reasoning	Error normalization via chance-based mechanics (Ashcraft & Krause, 2007); SDT (Deci & Ryan, 1985): Autonomy and competence
Session 6	Independent Gameplay and Strategy Mastery	Minimize facilitator support; focus on collaborative problem-solving; internalize strategies	Gradual scaffold withdrawal; SDT: Reinforce autonomy and resilience; Reflective discussions to consolidate learning

The six-phase structure was extended across seven weeks with two sessions per week, totaling 14 sessions, allowing repeated practice and skill reinforcement.

2.4 Data Analysis

Quantitative data were analyzed using descriptive statistics, with percentage change scores calculated to highlight learning gains (e.g., KeyMath-3 improvements). Qualitative data underwent thematic content analysis to identify patterns in engagement, peer interaction, and motivation (Braun & Clarke, 2006). The mixed-methods approach, integrating these data streams, provided methodological rigor, capturing the cognitive and socio-emotional impacts of the intervention with robust triangulation (Creswell & Plano Clark, 2018).

3. Findings

Analysis of data through the effect size method showed the performance of both participants improving significantly during their intervention phase. Results: On the KeyMath-3 tests, Student A showed a 42% increase in math skills from pre to post intervention, while Student B showed a 58% increase, and both sustained these gains at the 2-week follow-up.

Table 2: Descriptive Statistics and KeyMath-3 Scores Before and After Intervention

Participant	Baseline Range	Baseline Mean	Baseline Median	Intervention Range	Intervention Mean	Intervention Median
Student A	12–15	13.4	13	18–22	20.1	20
Student B	11–14	12.2	12	17–21	19.3	19

Analysis of effect size revealed that the non-overlap percentage data was 85% for Student A and 90% for Student B between both the baseline and intervention phases

Table 3: Behavioral Changes and Arithmetic Computation Performance

Behavior	Baseline (%)	Post-Intervention (%)	Improvement (%)	Baseline Mean (Computation)	Intervention Mean (Computation)
Math Avoidance	78	27	51	21	36
Peer Learning Interaction	22	82	60	22	39
Task Engagement Duration	35	100	65	22	37

Observed-behavior data analysis showed significant differences: the number of incidences of being unable to cope with the task decreased by 51%. Peer interaction during problem-solving tasks increased by 60%, and time-on-task duration increased by 65%, as measured by the average minutes spent working on math topics. These qualitative changes were also indexed through structured classroom observations following validated behavioral monitoring procedures (Burns & Spanjers, 2008).

Graphical methods also suggested the effectiveness of the intervention. As seen in Figures 1 and 2, the upward trend lines in both arithmetic operations and number magnitude understanding show gains over the weeks that build steadily as the 7-week period progresses.

The increases found were not only cognitive, but also socio-affective. During Math Ludo, students showed significant improvements in their willingness to try difficult tasks, make more effort after errors, and collaborate more with others. These results align with earlier research that indicated that multi-modal, socially embedded intervention is crucial for students with dyscalculia (Lavasani et al., 2011).

Additionally, fidelity logs' review confirmed that intervention sessions followed the instructional sequence and gaming procedures consistently, verifying the reliability of the results (Creswell & Plano Clark, 2018).

Table 4: Number Magnitude Transfer and Absolute Displacement Scores

Participant	Baseline First Score	Baseline Last Score	Baseline Absolute Change	Intervention First Score	Intervention Last Score	Intervention Absolute Change
Student A	6	7	+1	7	9	+2
Student B	7	9	+2	9	10	+1

The results of the analysis revealed a significant enhancement of number magnitude comprehension after the intervention. Students exhibited improvements in their understanding of the concept of number placement within a game-based context, moving from initial performances that were very low to significantly higher scores after intervention (Butterworth et al., 2011).

Table 5: Non-overlapping Data Percentages for Numeral Magnitude Transfer and Arithmetic Operations

Participant	Percentage of Non-overlapping Data (Magnitude Transfer)	Percentage of Overlapping Data (Magnitude Transfer)	Percentage of Non-overlapping Data (Arithmetic Operation)	Percentage of Overlapping Data (Arithmetic Operation)
Student A	100%	0%	87.5%	12.5%
Student B	87.5%	12.5%	87.5%	12.5%

Both participants demonstrated stronger performance in the intervention phase compared to the baseline, with Student A showing complete non-overlap and Student B showing near complete non-overlap with the baseline (Scruggs & Mastropieri, 1998).

Table 6: Descriptive Statistics for Addition and Subtraction Computation

Assessment	Baseline Mean	Baseline SD	Intervention Mean	Intervention SD
Student A	21	3	36	2
Student B	22	2	39	1

As with number magnitude transfer, large gains in students' knowledge of basic arithmetic facts were observed, including an overall increase in mean levels of performance and a decrease in the heterogeneity of the distribution of scores (Ashcraft & Krause, 2007).

Table 7: Data Percentage That Does Not Overlap in Arithmetic Operation

Assessment	Percentage of Non-overlapping Data	Percentage of Overlapping Data
Test 1	87.5%	12.5%
Test 2	87.5%	12.5%
Test 3	88.75%	11.25%
Test 4	86.25%	13.75%

These extremely high percentages, along with the non-contingency between test periods, underline the positive effects of the intervention on various mathematical skills areas (Torres-Carrión et al., 2018).

4. Visual Data Analysis Summary

When the sessional progress graphs were visually inspected, both the number magnitude transfer and basic arithmetic performance replicated the same upward direction:

- Student A made a 7-point gain in number magnitude and a 12-point gain in computation.
- Student B made a 10-point gain in number magnitude and a 14-point gain in computation.

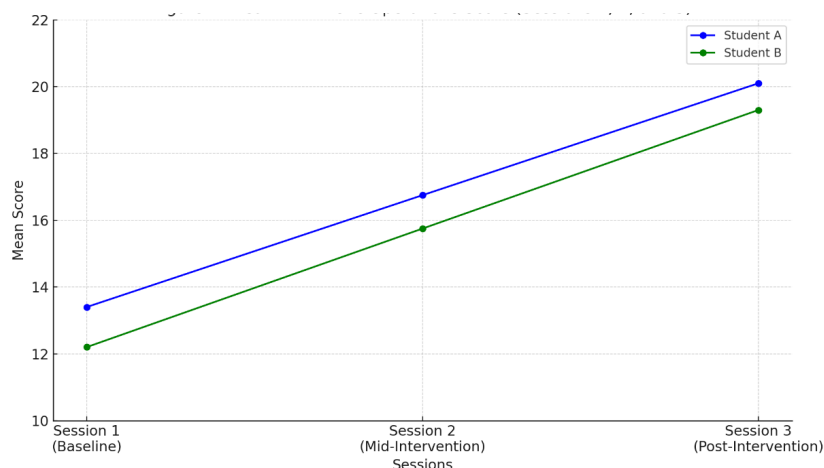


Figure 1: Mean Arithmetic Operations Score (Sessions 1, 2 and 3)

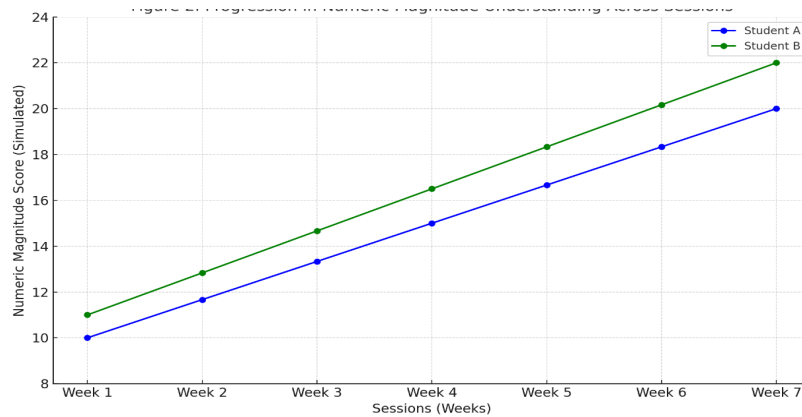


Figure 2: Progression in Numeric Magnitude Understanding Across Sessions

5. Discussion

This study examines the impact of Math Ludo, an educational board game, on students with dyscalculia. The results demonstrate its efficacy in improving arithmetic operations, number magnitude understanding, sustained attention, and socio-emotional resilience toward mathematics. These outcomes affirm that multisensory, game-based strategies can effectively address the learning challenges faced by dyscalculic students, as evidenced by significant quantitative gains in KeyMath-3 scores (42% for Student A and 58% for Student B) and qualitative improvements, including reduced avoidance behaviors and enhanced peer interactions.

The effectiveness of Math Ludo can be further elucidated through the Cattell-Horn-Carroll (CHC) theory of cognitive abilities, a psychometrically robust framework that categorizes cognitive functions into broad domains such as Quantitative Knowledge (Gq), Short-Term Memory (Gsm), and Processing Speed (Gs) (McGrew, 2009). These domains are directly relevant to the cognitive deficits observed in dyscalculia, such as difficulties in numerical processing and working memory (Schneider et al., 2017). Math Ludo's design, incorporating dice-based navigation, numerical station challenges, and peer interactions, targets Gq by reinforcing arithmetic fluency and number sense, while engaging Gsm and Gs through rapid decision-making and sustained attention during gameplay. For instance, the game's multisensory approach—combining tactile (dice), visual (game board), and verbal (peer negotiation) stimuli—facilitates active recall and processing, addressing cognitive bottlenecks in dyscalculia (Flanagan et al., 2010). This targeted design explains the observed improvements and highlights Math Ludo's novel contribution as a theoretically grounded intervention.

Furthermore, the behavioral shifts, such as the 51% reduction in math-avoidance behaviors and 60% increase in peer learning interactions, underscore Math Ludo's role in fostering both cognitive and emotional growth. This alignment with CHC domains reduces cognitive load on Gs and Gsm, alleviating frustration and promoting perseverance through chance-based error normalization (Schneider et al., 2017). These elements synergize with Self-Determination Theory (SDT), satisfying needs for autonomy, competence, and relatedness via strategic choices and collaborative play (Deci & Ryan, 1985). Such integration mitigates performance anxiety and enhances engagement, consistent with research on motivational dynamics in game-based learning for learning disabilities (Järvelä et al., 2023; Lin & Jiar, 2017).

The scaffolded progression in Math Ludo, mirroring Vygotsky's Zone of Proximal Development (1978), sustained learning gains and aligned with best practices in educational game design (Resnick, 2015). Visual data trends and absolute change scores further confirm its utility in building conceptual mathematical reasoning, echoing context-embedded instruction approaches (Butterworth et al., 2011). High intervention fidelity, verified through session logs, bolsters the reliability of these findings (Creswell & Plano Clark, 2018). Overall, Math Ludo cultivates a holistic profile of cognitive maturity and emotional resilience, extending prior evidence on the benefits of interactive games (Torres-Carrión et al., 2018; Kaufman & Kaufman, 2014).

6. Conclusion

The evidence from this study indicates that Math Ludo serves as an effective intervention for students with dyscalculia, integrating visual, tactile, and verbal elements in a socially interactive framework to remedy

deficits in calculations and number sense while boosting socio-emotional engagement in mathematics learning. By aligning with CHC theory—targeting domains like Gq, Gsm, and Gs—Math Ludo bridges cognitive gaps and creates a supportive, low-stakes environment that reduces anxiety, as reflected in the substantial reductions in avoidance behaviors (McGrew, 2009; Schneider et al., 2017; Flanagan et al., 2010). This novel blend of cognitive targeting and motivational support, informed by SDT, positions Math Ludo as a versatile tool adaptable to broader contexts, including digital platforms.

The notable gains across measured areas advocate for incorporating such game-focused techniques into special education curricula. With its progressive scaffolding and emphasis on peer collaboration, Math Ludo offers a scalable model that promotes inclusive practices for diverse learners. Future studies should explore larger samples, longitudinal effects, and comparisons with control groups to validate and expand these results. Despite its promising outcomes, this study has limitations, including the small sample size (N=2) and absence of a control group, which constrain generalizability. Nonetheless, it provides valuable insights into the potential of evidence-based, playful interventions to yield not only academic advancements but also emotional adaptability, paving the way for more equitable educational strategies.

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Ethical Declaration: Ethical approval was not required for this study, as it involved minimal risk and complied with institutional guidelines.

AI Declaration: Artificial intelligence was used in the creation of figures, tables, translation between Persian and English, and the formatting of references in Harvard style during the writing and editing of this article.

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Dialogic Teacher Facilitation of Esports Activities for Vulnerable Youth

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Abstract: The study is part of an on-going research project entitled “Esports as learning space and gateway for vulnerable youth” (2023-2026) funded by the Velux Foundation. In the project, researchers explore the esports programmes at three Specially Planned Youth Education schools (Særligt Tilrettelagt Ungdomsuddannelse or STU). STU is an offer to vulnerable youth unable to attend regular forms of youth education in Denmark. More than 30% of the STU students are diagnosed with disorders such as ADHD and autism and many have experienced school refusal and suffer from low well-being and/or stress, isolation and anxiety. The project explores the pedagogical approaches used by teachers in three esports programmes, where students (aged 16-25) play competitive multiplayer games, primarily *Counter-Strike 2 (CS2)* and *League of Legends*. This study analyses video observations from an esports class through the theoretical perspective of *dialogic space* to examine how a teacher facilitates dialogue in the classroom. We uncover how a dialogical approach to facilitating the esports programme is valuable for the teachers, especially because some students' gaming expertise exceeds the teachers' expertise, both in terms of game sense and understanding of game mechanics. The analysis shows how the students' dialogic participation is part of a teacher facilitated dialogic space, which is used as a starting point to create common goals for the programme and foci of students' collaboration. In this dialogical space students are invited to share game knowledge, strategic considerations, and analytical expertise about their gameplay. Further, the analysis will show how the teacher position himself differently in the classroom to facilitate students' reflections on taking different perspectives in the dialogic space. Finally, the study discusses how the aim of perspective taking, and communication for successful gameplay in CS2 aligns with the pedagogical aim for the vulnerable students in the esports programme.

Keywords: Esports, Special education, Vulnerable youth, Teacher facilitation, Dialogic education, Dialogic space

1. Introduction

Most studies on gaming in special education have been carried out using learning games (or “serious games”) designed to address specific learning aims – e.g. cognitive training of executive functions in relation to attention, working memory, and cognitive flexibility (Durkin et al. 2013; Rodriguez Timaná et al. 2024). Even though learning games may have clear benefits in addressing specific educational aims, they often lack the motivational and social aspects of the leisure games that children and young people play in their everyday life. In recent years, there has been a growing interest in studying how children with special needs may benefit from playing leisure games with others. Some studies have described the social, communicative and emotional benefits for children with autism and ADHD playing multiplayer games such as *Minecraft* (Ringland et al. 2016; Stone et al. 2023). These studies show how some of the challenges in video game play might be more manageable, more enjoyable and more rewarding, than other tasks that neurodiverse children have to tackle. This is similar to recent findings from our on-going project on esports education for young people at Specially Planned Youth Education (STU) (Jensen et al., 2024). These findings show how vulnerable youth benefit from strengthening their social relations and communicative skills by playing team-based multiplayer games such as *Counter-Strike 2 (CS2)* and *League of Legends*. Similar findings were identified in The School at Play project, which used the cooperative video game *Torchlight II* to promote motivation and social inclusion for vulnerable secondary students (Hanghøj et al. 2018). Despite these promising findings, there is a lack of knowledge on how teachers can or should facilitate interaction in and around multiplayer commercial games within special education. A review of earlier studies has shown that teachers need to play many different roles in game-based teaching (Kangas et al. 2018). This involves selecting specific games, planning their teaching, negotiating expectations with students, orienting students toward learning goals in and around the game, supporting students during gameplay, and evaluating outcomes of game sessions. However, most of the studies on game-based learning that focus on teachers' approaches are conducted within the context of general education. This context may differ significantly from special education in terms of teacher-student interaction. Further, mentoring practices among peers in online esports communities display dialogical aspects like shared goals and mutual engagement (Rusk et al. 2020). In the STU context, where students have varying levels of *gaming expertise* and some even surpass the teacher's,

co-construction of knowledge then becomes a potential viable teaching strategy. This brings us to the aim of the current study, which is to analyse the dialogue between a teacher and a group of STU students (age 16-25) ranging from expert to novice players of the game CS2. We explore the following research question: *How can we understand teachers' esports facilitation at STU as the framing of a dialogic space and what forms of participation does this enable for the students?* Methodologically, we will explore the question through an interaction analysis of video observations from the esports classroom. Our analysis is informed by a dialogic approach to game-based learning (Arnseth et al. 2018) as well as game research (Fanfarelli 2018).

2. Case: Esports Education at STU

Since 2007, Danish students who are unable to complete their education due to physical or psychological issues, have been offered an alternative, called Specially Planned Youth Education (STU). Some of the students have general learning difficulties, others also struggle with neurodivergent conditions, such as autism and ADHD in addition to other challenges such as anxiety, loneliness and/or depression (Ministry of Education, 2017). The students often have issues with school motivation, due to previous negative school experiences, as well as generally struggling to communicate with others. In a STU context, classroom interaction often differs from regular school, as students may struggle to participate or even show up to class. To address these issues, the STU observed in this study offers an esports programme to provide a space, where students have an incentive to directly communicate and participate. The objective of this esports programme established in 2017, is to enhance students' social competences in combination with developing their game expertise. This assumes that building up social skills and a sense of community around the games will have significant positive impact on the students' lives beyond the esports setting. In this study, we see how a specific STU utilizes esports to shape the classroom and build up a space for dialogue and communication with different viewpoints. The example explored is from an esports class that plays the game CS2, which is a first-person shooter where one team (the terrorists) must try to plant a bomb and plays against another team (the counter-terrorists), who must try to prevent the bomb from exploding. The game offers a realistic setting and a fast-paced gameplay in which precise communication of each team members' locations and actions are imperative. At this STU, the teachers often organize their classes in a particular three-part structure, consisting of a pre-game briefing, a game session, and a post-game debrief. In a briefing, the teacher will engage in discussion with the students about the focus of the current lesson. After the briefing comes the game session, consisting of one or more gameplay sessions. Afterwards, there is usually a debrief, which can involve feedback and discussions of the focus and the outcomes of the lesson. The teaching is therefore not only focused on the gameplay sessions themselves, but also creating a space for learning through both discussions and reflections in the briefing and debriefing sessions.

3. Gaming Expertise

This study seeks to explore how teachers and students take on a variety of different perspectives during esports facilitation. To do this we define what determines a players' understanding of- and their skills within, the game. We will focus on two aspects of gaming expertise that relates to *game sense* and *game mechanics* (Fanfarelli 2018). Game mechanics is the least ambiguous, simply referring to the mechanical ability of a player. When playing CS2, this includes the players' ability to aim, their ability to move and position themselves on and around the map, as well as their understanding of character abilities and synergies between different game elements. The game mechanics are therefore mostly concerned with motor skills and understanding of specific game elements and synergies. Game sense is more complex and abstract. It concerns the player's ability to quickly get an understanding of a situated game state and using this to make good game decisions. For making these snap-judgements, it is important for a player to understand how to survive and be able to anticipate and predict other players' actions, e.g. having an overview of their own and other players' economy, weapons and map placements. In multiplayer games this also concerns understanding which information to *communicate* to other team players, and how this leads to what Fanfarelli (2018) calls *thoughtfulness*. Thoughtfulness, in this context, refers to how players use the available information about the game state. This includes other players' positions, characters and their powers etc., to make thoughtful decisions, often quickly, with the goal of constantly getting a slightly better position to win the game. In this study we see varying levels of game expertise among the teacher and students, particularly in relation to game sense. Additionally, we will distinguish between an individual- and a team- player perspective. Game mechanics refers to both, including the individual's ability to aim, choose weapons and navigate the maps, but may also be related to how these choices synergize with the team's roles, choices of weapons, map locations etc. Game sense focusing on the overall game state, however, must include some level of team perspective, as it will include both the rest of a player's team as well as the

opposing team. This means that game sense expertise in CS2 inherently involves the ability to take on the team perspective and make thoughtful choices on behalf of the entire team.

4. A Dialogic Approach to Teacher Facilitation

In addition to identifying gaming expertise, we will also explore a dialogic approach to teaching and learning, which emphasizes interaction between participants, working with multiple point-of-views, and the co-construction of meaning (Wegerif 2020). In this way we view games as *dialogical tools* that can structure and mediate classroom interactions (Arnseth et al. 2018). Unlike traditional instructional tools, games invite students to engage with disciplinary content, pedagogical structures, in-game scenarios, and everyday knowledge practices in dynamic ways. Introducing commercial games into the school domain means introducing cultural phenomena from students' everyday lives, including pre-existing attitudes, motivations, and gaming identities into the classroom (Arnseth et al. 2018). This creates opportunities for both meaning making and tensions across domains with different validity criteria for what counts as valid knowledge. This potentially means that some students can play and/or understand the game at a higher skill level than the teachers. As one teacher notes: "[Student name] has 3000 hours in CS2, I'm in no position to argue with that knowledge." This highlights how disciplinary knowledge in this context is distributed among participants and is not necessarily provided by the teacher. This emphasizes the need for a dialogical approach to understand the classroom interaction.

Moreover, games may also be used as tools for creating *dialogic spaces*, where participants can enact and discuss multiple views on game-related aims, relations and topics (Arnseth et al. 2018). According to Wegerif (2013), teachers' facilitation of dialogic spaces can be examined in terms of how they *open*, *widen*, and *deepen* a dialogic space (Wegerif 2013). Opening the dialogic space involves inviting multiple opinions by asking open-ended questions such as "how?" or "why?". Widening the space occurs when diverse viewpoints are introduced, allowing students to explore different interpretations. Deepening the space involves critically reflecting on assumptions and reasoning processes (Wegerif 2020). Teachers can therefore be understood as facilitators of dialogic spaces that support peer learning and distributed authority, encouraging students to articulate reasoning, justify strategies, and reflect critically on each other's viewpoints.

5. Methods, Data and Analysis

This study is a part of a larger project that conduct video recordings, interviews with teachers and students, and document analysis to research the esports programmes at three STUs (Jensen et al. 2024). In this study, we focus particularly on one teacher's pedagogical approaches in the classroom through *focused ethnography* (Knoblauch 2005) to document and analyse classroom interactions in an esports class. Focused ethnography is a methodological approach that investigates specific social situations through short-term but intense field visits, often supported by video recordings. Unlike traditional ethnography, it relies on condensed, targeted observation and seeks to produce in-depth insights into how meaning is locally negotiated within complex, real-world settings (Knoblauch 2005). Across the three STU's we have recorded situations that show characteristics of dialogic spaces, where games, strategies, and player/student performances are discussed, and dialogue is being opened, widened and deepened, e.g. students sharing reflection on a particular strategy or debriefing with a student taking the lead reflecting on team performance. For this study, the example is a teacher that facilitate students' co-creation of knowledge concerning in-game roles in CS2. As the analysis show, this involves opening a dialogic space, widening the space by inviting different students and viewpoints to join the dialogue and using the students' perspectives to deepen the dialogue.

The data for this study consists of transcripts from a classroom observation captured by video. The situation is a teacher that opens a dialogic space to discuss in-game roles for students in CS2. We analysed the material by first viewing video recordings and then selecting sections for transcribing and analysis using Wegerifs theory of dialogic space (Wegerif 2013). Further we used the concepts of gaming expertise (Fanfarelli 2018) in combination with teacher interviews to understand the esports programmes subject domain as a compound of gaming expertise and individual/team perspective taking. These two theoretical perspectives were used in a deductive approach to code the data and interpret the students and the teacher's intentions and positions. The data presented is from a singular class and was selected because it shows how the teacher, a relative novice in CS2, navigates different student levels of expertise and his own perspective of creating a learning space. A further consideration for choosing the example was that the different aspects of dialogic space were identified in the same continues dialogue. This continuation has a communicative value that hopefully helps the reader to understand both the context and the significance of the example. Our methodological approach supports a detailed analysis of teacher facilitation and how the dialogue involves different student and teachers'

perspectives being: individual perspective, team perspective and teacher perspective that include varying levels of foci on game mechanics, game sense, and student learning.

6. Results

Here we present an analysis of dialogic interaction from a game session facilitated by an esports teacher. We show how it can be understood as a dialogic space and what student positions are enabled. The session is divided into several excerpts and presented below. Except for a few omissions due to repetition, the excerpts are taken from the same dialogic exchange, which only lasts a few minutes. The session is a morning pre-game briefing session facilitated by the teacher with five esports students and one IT student. The teachers focus for the session is to collaboratively create in-game roles to give the students a framework for peer feedback after gameplay. We use synonyms for all participants. T is the teacher.

The results presented in section 6.1 and 6.2 follow a classroom dialogue in which the teacher facilitates student co-construction of knowledge concerning in-game roles. From a novice gaming expertise position, the teacher opens a dialogic space that invites students to contribute with their own gaming expertise. As the dialogue unfolds, we identify different individual, team and 'student learning' perspectives that both align and create tensions. The analysis shows how we understand the teacher's navigation of these tensions as an aim to open and maintain a learning-oriented dialogic space.

6.1 The Teacher Opens the Dialogue and Invites Students to Join

The following situation takes place after a short break. The students are in the classroom, sitting at their desks, each with a full gaming setup. The teacher walks around the room, writing the roles on the whiteboard as the dialogue progresses. The teacher starts with:

01 T: This is where I need your help, because I don't know enough about CS2... My problem is, and this is where I need your help, that peeking is the only role I can come up with.

Here, the teacher tries to open an authentic dialogic space because he needs access to the students' input to define relevant roles in the game to make the ensuing feedback session meaningful for the players. the teacher's statement positions him as being dependent on the student's knowledge and their willingness to participate in identifying feedback roles. As a teacher, he is explicit about his novice position and limited gaming expertise as he only knows the role as "peeker" in CS2", which is to peek out from cover to find enemy positions. This is a dialogic move that *opens* a space for the students' voices and participation in the dialogue. This example shows how lacking gaming expertise as the teacher, especially game sense expertise, can be used to open this dialogue and allow for new perspectives.

Before the teacher's statement, a student from the IT program at the STU entered the class. He is supposed to repair a PC in the room. He pauses just within the door and listens to the teacher talk for about two minutes, raises his hand and is invited by the teacher to join the dialogue. He asks: "*what are you talking about?*". The teacher's answer is a summary of his intended focus for the briefing:

04 T: We are trying to add more layers to our feedback... we experienced last time that it was very difficult to find something concrete to improve, you know, 'where is it I need to practice in CS2?' ... So now we are trying to find more concrete roles, or areas of responsibility, that we can give feedback on.
08 T: And it might be because I don't know that much about CS. So now we're trying to identify some specific roles or areas of responsibility that we can then include in the feedback

Line 04-10 explains the teacher's stated purpose for the session and establishes the premise for the dialogue, which is to co-construct concrete game roles to practice peer feedback. The teacher opens a dialogue with the students to find focal points for feedback that the students can use to guide their input in the debriefing. The teacher again positions himself as a CS2 novice and frames the dialogue as a joint investigation inviting the identification of feedback points to be a shared endeavor. Following this the teacher exemplifies the feedback with the task of throwing a utility in CS2, (excluded lines 11-13) and widens the conversation to include the visiting IT-student, to invite possible new student opinions and knowledge:

14 T: ... So, if you have any input ... we'll gladly take it.
15 ITstudent: I'm just thinking about the bomb... It depends on what you plan to do... Whether you're planning to default or rush. And if you're rushing B, then it's the last guy who should have the bomb. Then he can plant after the site is clear, after

everyone else has run in. And if everyone else on-site dies, then he can just rotate.

In line 15-19 the IT-student contributes to the dialogue by questioning the premise of the conversation, hereby deepening the dialogue. The IT-student is deepening the conversation by questioning the premise for giving concrete feedback on throwing the utility, stating 'it depends' on what they intend to do with the bomb, and their overall game plan. The deepening in this way is rooted in the IT-student's game sense and intimate knowledge of the game. In relation to the dialogic space, the teacher's facilitation is focused on opening and widening the dialogic space, by inviting more viewpoints to participate. He invites multiple opinions and again positions himself as a novice concerning game expertise to invite the students to participate with theirs. This leads to the IT-student deepening the space, from a gaming expertise position showing an expert level of game sense. This, in the teacher's own words, is not possible for him as he does not know enough about the game to construct the roles needed to guide the feedback process. Next, the esports student M joins the dialogue and suggests the role of peeking (excluded lines 20-22) to which the teacher replies:

23 T: And I think there's a lot we can learn from all of this. I think, for me, it would improve learning to be the one who peeks because I might get a deeper sense of how the opponents move.

In line 23-25 the teacher tries to deepen the dialogue from a new perspective we call "student learning". In this way we can see two perspectives in the dialogue; the game sense expert that is focused on the optimal way of playing the game, and the teacher perspective that frames the gaming activities as learning opportunities. How these perspectives create tension in the dialogue is made clearer in the next excerpts where the teacher looks for more team roles to perform in-game.

6.2 Navigating Different Team Members' Perspectives

The next excerpts show the teacher navigating between the different foci and perspectives of the students.

26 T: I would really like to find a few more things (roles), if there are any... There must be. If we think a little creatively.
28 Student j: Those roles or whatever?
29 T: Yes, a few more things.
30 Student K: I mean, there is, well we basically already have it, but like a sniper.
31 T: Yes.
32 Student K: We have kind of unofficially already designated two people already for that.
33 Student M: There are three of us who can AWP.

In lines 26-31, the teacher invites the students to suggest more roles, and they bring up the Sniper role. Three of the esports' students, J, M, and K, join in the dialogue. In line 33, Student M suggests that three of the students 'can AWP' (AWP is a sniper weapon, so Student M suggests that three can take the sniper role). Which sparks a dialogue between two different perspectives, firstly the team as students in a school setting and secondly the team as an esports team.

34 Student J: Yeah, but there shouldn't be. There shouldn't be three who play AWP.
35 Student M: No no, but if needed, three of us can.
36 Student J: Sure sure, but the mindset shouldn't be that we have three AWP players.
37 Student M: No no, we just know there are three who can play it.
38 T: Well, I actually think that ...uh, we are a school, we are here to learn, so I think that we... Not that we should be five AWP players, but I think it's healthy that we all try out the sniper role once in a while... Then it might not go as well... But we are not in any competition either, we're practicing, so I think.
43 Student M: It also depends on which weapons people prefer.

Student M's suggestion that three people can take AWP is immediately rejected by Student J. An important context for this, is that Student J is a third-year student and one of only two students on the CS2 team that currently acts as the team leader role when playing the game. Relative to his teammates, Student J exhibits a high degree of gaming expertise in relation to both game sense and game mechanics. His perspective in lines 34 and 36 rejects the notion that having three AWP's is a valid approach to the game. Student J's statement reflects a team perspective as it does not strategically make sense to have three AWP's when playing as a team. Alternative to this, the teacher introduces the 'student learning' position and highlights the learning aspect of the situation, suggesting a learning benefit of more students trying the Sniper role. This is contrary to Student

M, who in line 40 maintains a more individual perspective, which assumes that the choice of weapons should depend on individual player preferences.

- 44 T: I thought that one, the sniper, that was a really cool one. Then you also must think... you also have to think a bit differently economically, I think. Because it is, as far as I know, pretty expensive.
- 47 Student J: Yeah, it is, but that's also why, if—for example—Student K picks up an AWP. That's when you think, okay, who plays AWP, who has the AWP role. And then he drops me the AWP, and I drop him an M4 or uh ...that one I dropped him last time, the SG or whatever it was.

In line 44-46, the teacher cautiously tries to deepen the dialogue with the economic aspect of the Sniper role. In line 47-50 this is further deepened by Student J, again with the team perspective, and that the AWP must go to the AWP player. In this way, Student J can understand the roles both from the team perspective; that having multiple AWP's is strategically unbeneficial, and from a teacher's perspective; that it makes sense to designate the AWP role to one student. He addresses the teacher's perspective of needing roles and deepens the conversation with game sense expertise explaining to drop items to the person with the AWP role to maintain game economy balance.

- 51 T: But I think we ...I would like us to go through all of these (*points to the roles on the board*) before we start a game. Like, who is the first, who is the second, who is the third, fourth, fifth. Yes, Student M?
- 54 Student M: Yeah, that thing about, uh, I'm also thinking that the sniper role also depends on which weapons people prefer. Because we can't just switch weapons around if we're not comfortable with them.
- 57 T: Think that's the...
- 58 Student J: That's exactly why we have roles.
- 59 T: I think that if you're given a task, sometimes ...I can't just sit down and say: Listen, I only play Desert Eagle, and I won't play anything else.
- 61 Student M: Exactly, but it also depends on what weapons people are...
- 62 T: So it might be, that if I have the sniper role today, well then I can choose between—isn't there two? So it might be that you're not used to playing sniper, or don't see yourself as a sniper, but I actually think it can be quite healthy to try it. Because then you also understand, okay, what it's like to be the sniper. Then we can better put ourselves in the position of being the sniper. Then we can better put ourselves in each other's shoes when we are in the middle of a game.

In lines 51-53, the teacher explains his envisioned organization of roles before each game. But Student M again states that the Sniper role should depend on individual preferences, clearly taking on more of an individual perspective, not considering that all players might want the same weapon, making for an unbalanced team. While Student M has enough game mechanics expertise to understand the different weapons and their connections to the different roles, he lacks game sense about the balance of the entire team. The different positions of individual or team perspectives seem to be related to the level of gaming expertise, respectively game mechanics and game sense expertise. Student J follows in line 58, framing the roles as a way of positioning the students according to their preference and what is best for the team in a fight. In line 59-60, the teacher however challenges this with a 'student learning' position, explaining that sometimes you can be given a task that you have to do. Here the dialogic space almost disintegrates as it seems difficult to keep the perspectives of the teacher; student learning, Student J; teamplay and Student M; individual preference in the same dialogue.

7. Discussion and Conclusion

As the results show the teacher and students' different levels of gaming expertise in terms of game mechanics and game sense, are intricately connected to how they participate in dialogic spaces in the esports class. Importantly, the results show that while the students' understanding of game mechanics can be exercised both from an individual perspective and from a team perspective, game sense cannot be fully understood in isolation from the other players. It requires the students to be attuned to each other's roles on the team. The example also illustrates a variation in skill level from novice to expert players, which we see across all three STU's. From a pedagogical point of view, the student's participation in the esports programmes allow them to shift from positioning themselves primarily as individual players to communicators and collaborators within a team context. Interestingly, shifting from understanding game mechanics to exercising game sense is both a pedagogical aim and a necessary progression for succeeding as a team in a competitive game such as CS2. This aligns with the broader aim of the STU esports programme: to cultivate social, communicative, and collaborative

competencies through the facilitated use of games. So, while gaming may appear to be an individualistic activity to the external views of parents or youth guidance counsellors, our analysis shows how dialogic facilitation reveals and enhances the inherently collaborative nature of successful gameplay in esports. Thus, being able to communicate effectively with teammates, participate in dialogues by assuming other players' perspectives, and being open to these, becomes an intrinsic goal for many esports students at the STU's. A goal they do not have possibilities to, or are able to, engage with in most (or any) other contexts in their life. This understanding of esports as an inherently social activity that necessitates communication and collaboration have broader implications for how the educational value of esports programmes as part of the STU education are perceived externally.

The student's transformation is enabled through dialogic teaching practices through which students potentially adopt and experiment with new perspectives. These practices rely on teachers using students' different levels of game expertise, especially game sense, as an essential resource for opening dialogic spaces and deepening them for in-game relevance. The example above would not exist were it not for the different students' input. Simultaneously, the distributed expertise challenges the teacher, who only has beginner level gaming expertise. Moreover, students' perspectives may reflect both individualistic and team-based perspectives, with varying alignment with the collective goals of the esports team as a learning situation. Student J for instance seem to value short term team success in the game over learning opportunities to become better as a team. This places the teacher in a complex position, where facilitating dialogue involves interpreting which perspectives genuinely support the development of the team both as players and as a learning community. This is seemingly a paradox as the teacher in this case might not know which game expertise perspective is most productive for the students as an esports team. However, this novice position also supports a dialogic approach: It allows the teacher to ask genuine questions and prompt reflection, rather than providing fixed answers. The teacher noted that this approach felt acknowledging for him and students, as it allowed the students to be recognized for their expert knowledge and provided a space to pass knowledge on to peers in a meaningful way. In this way, dialogic facilitation becomes both the means and the goal, supporting students in developing the collaborative awareness needed to function as a team, while also modelling how to engage meaningfully with others' perspectives. Still, such facilitation requires careful orchestration: the teacher must support students in recognizing when and how to contribute, ensure productive communicative ground rules, and help navigate moments of disagreement. The results show that a dialogic approach to teaching esports can be a valuable educational tool for beginner level gaming expertise teachers. How the dialogical approach could be implemented in future teacher training and align with curriculum goals is a promising path for future research.

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AI declaration: AI have been used for proofreading and as thesaurus.

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It's Going to be Amazing: Exploring Children's Game Play and Making

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Abstract: This paper reports on the results of a game-based learning study that had a twofold purpose: first we sought to find out what our study participants (ages 10-13) could tell us about their video game play habits at home and second to explore students use of *Super Mario Maker 2* software on the Nintendo Switch Lite to design their own games. The study took place in two schools, one middle school and one elementary school, in the suburbs of a medium-sized city on Canada's West coast. Two grade 6 classes participated in the study (n=44), and played *Super Mario Maker 2* over 9 days, in pairs. Overall, the study found that all students had prior gameplay experience, meaning that no students struggled with the controls, nor did they need much assistance to build their own games, even though only a handful of participants reported having prior coding and/or game design experience. We also found that gameplay was a common leisure activity for most participants, with girls demonstrating significant skill and familiarity with games, challenging previous gender disparities in game play. This short intervention demonstrates how a commercial off the shelf game can be used to support students' design-based thinking and making, with all participants managing to design a playable level by the end of the study.

Keywords: Nintendo Switch, Super Mario Maker2, Game making, Game-Based learning, Game pedagogy

1. Introduction

Even though gameplay patterns have shifted demonstrably since the pandemic (Donati et al, 2021; Lager & Corso, 2025; Smirni et al, 2021), there is a paucity of current research which examines gameplay choices and patterns of play among children (Lager et al, 2025; Gottfried et al, 2024). Indeed, much of the research on children and video games has been on the impact of video games and screen time on children, observing positive and negative correlated behaviours with use (Alanko, 2023; Lobel et al, 2017; Mupalla et al, 2023; Sauce et al, 2022), regardless of what they are choosing to play, overlooking the ways children engage with games (e.g., their preferences, social interactions, and time spent). The ways in which children engage with games, influenced by factors such as gender, socioeconomic status (SES), and race, has been generally omitted. Additionally, there is limited research about what games children are consistently playing, and the role video game playing has in their daily lives.

This study's purpose was to find out what our participants (children ages 10-13) could tell us about their video-gameplay habits at home, paying attention to whether and how the global COVID-19 pandemic may have shifted patterns of children's at-home video game play. Because of the large scale of surveys, overviews of play practices of children are usually just self-reported snapshots. We do not necessarily have a clear view of what school-age children are playing when they do play games, how often, and if their play is seen by them as overseen by a parent or guardian. Our hope is that this deeper dive into the play practices of young people in a small city in British Columbia might contribute to a more nuanced understanding of which young people are playing and why they say they are playing digital games.

2. Related Literature

Current research shows that more children are playing more often and for more hours than ever before (Donati et al, 2021; Smirni et al, 2021). According to a recent Pew Research report, 85% of U.S. teens report playing video games, and 41% say they play them at least once a day (2024). What that means is that video games occupy, for many young people, a very large part of their mediated world, especially outside of schools. Games and learning literature has for decades, made a strong connection between games and learning. (Barab et al, 2012; Barr 2016; Carrisoli & Villani, 2019; Cassie, 2012; Foster et al, 2011). Used in classrooms to teach a variety of subjects (Tobias & Fletcher, 2012; Young, et al., 2012), games have become a tool that educators call on to introduce concepts or practice new skills (Barab et al, 2012; Cole et al, 2023; Dishon & Kafai, 2020). When used in classroom settings, some video games have been used to address different curricular expectations (Barr 2016; Hébert et al, 2018). When examined through the lens of the British Columbia Core Competencies (BC Government, 2015), which are quite wide-open curriculum expectations, many of these studies directly address

the key skills that educators are working on to bring to their classrooms in the province (Carmen et al, 2012, Cassie 2012; Cole et al, 2023; Foster et al, 2011). This more specifically includes the Applied Design, Skills, and Technologies curriculum, which emphasizes iterative learning processes, visual programming, design thinking, and strategies for identifying and troubleshooting problems with regards to technology (BC Government, 2015).

2.1 Gameplayers

As the aforementioned Pew study discussed, most teen boys and girls play video games, but more boys play every day (61% vs. 22%) (Gottfried et al, 2024). This gender discrepancy in everyday play practices is seen in smaller qualitative studies as well (Almusharraf et al, 2023; Girón-Gamero & Franco-Mariscal, 2023; Jenson & de Castell, 2023; Nguyen et al, 2022). There are few, if any, more recent qualitative studies which examine these game play differences with respect to gender since the COVID-19 pandemic. This study reexamines these gendered play differences post-pandemic and, in a school-based setting.

2.2 What is Being Played?

There have many studies who ask students to play video games within school contexts, and which examine the educational affordances of video games (c.f. Beavis, 2014; Nash & Brady, 2022; Zucker & Anderson, 2021). However, there are limited studies of at-home play patterns of children generally breaking down the percentage of people who play (Donati et al, 2021), and they do not address who is playing what. This omission is potentially crucial in understanding play patterns within the class, as what they play at home is foundational to their game understanding within the classroom. None of the located studies include outside the classroom or previous video-game play experience as an examined variable when incorporating video games into the classroom.

3. Research Design

This qualitative study looked to understand young people's game play, in and outside of school. Two grade six classes (ages 12-13) participated in the study in the suburbs of a small city on Canada's West coast. The middle school where the study took place occupies a building that is over a century old and scheduled for demolition at the conclusion of the 2025 academic year. Currently, a new facility is under construction directly in front of the existing structure. The students in the middle school are from varied social-economic backgrounds. Two of the authors of this paper (Jenson and Perry) ran the study for 9 days, which took place an hour a day with supervision from the classroom teacher. Data collection included video and audio recording of all play sessions, teacher interviews, short 5-to-10-minute interviews with all students (usually in their game play pairs), scans of game design notebooks that students planned their games in, and a short questionnaire on at home and in school game play. Both authors also took field notes over the two weeks of game play, and two GoPro captured ongoing audio-visual data.

Participants included two classes of grade 6 students (n=44) and their two teachers. The classes were not especially diverse linguistically, as just two children were English language learners, which meant that they received additional English language support. There were 19 female-identifying, and 15 male-identifying student participants. All but two students who were in the classes during the study consented to participate.

During the 9-day study, participants were provided Nintendo Switch consoles on which to play and to create levels within the game *Super Mario Maker 2* in pairs. Researchers taught basic game design terms, and asked participants to then create their own "playable" levels within *Mario Maker 2*, which would be shared with the class on the last day of the study. The study concluded with the students playing each other's levels on a projector, so that each pair was given a chance to showcase their level to the whole class. These levels were first drawn by participants in sketchbooks that we provided, then constructed within the game and edited to create a level on the Switch. We continually emphasized during the two weeks that the participants' goal was to create a 'playable level' – that is one that they (and others) could complete. Participants were not trained on any of the technical skills or more complex blocks that users can utilize when building in *Super Mario Maker 2*. Instead, participants were introduced to the "Tutorials" section of the game, where different skills are broken into digestible steps and in-game logic is explained. All mechanics that they incorporated they taught themselves to use, including levels that made use of conditionals, creating levels that offer a depth of in-game knowledge that surprised us.

3.1 Data Analysis

With so much data from participants with respect to their gameplay and game making, a thematic analysis approach was selected to sort the interviews and provide inductive codes on at-home play. Following Braun et al's definition of themes as "reflecting a pattern of shared meaning, organized around a core concept or idea, a

central organizing concept,” (p. 3, 2019) themes were created from coding the interviews and checking those against the responses on the questionnaire with respect to at-home gameplay. Preliminary inductive codes were created from the interview data, the gameplay footage, and from the interview with the teacher. These inductive codes were based on expressed game-play time, devices, and preferences that participants shared. By examining the images of their play and sketchbooks with the inductive codes from the interviews and observing how students visually represented their play and design processes, details were revealed that may not have been fully articulated in interviews, such as which participants had constructed their own game levels before.

4. Prior Video Game Experience

4.1 At-Home Game Play Experiences

All participants had experience playing on a Nintendo Switch console prior to the study. This is in contrast to previous studies in libraries or classrooms that have noted that boys tended to report having more prior gameplay experiences than girls (Cunningham, 2018; Hébert, et al., 2018). That all students in this study reported prior experiences playing on a Nintendo Switch is noteworthy. For example, while studies have shown that most households have a game console (Donati et al., 2021), having a group of participants that all had prior play experiences on a Switch changed how we approached using the console and teaching with it. Additionally, when introducing the console to the class, we affirmed that students were comfortable with the location of the buttons on the Switch and their actions without needing guidance. That all students had prior gameplay experience meant that all students started from a somewhat level playing field, meaning that they all had familiarity with Nintendo Switch, and did not need to be taught how to use the controls.

When asked in the interviews, all participants said they had prior gameplay experience, and all students had played or regularly played at home. All students had access to at least two technologies with which to play, with 12 of the participants having regular access to three or more game play technology options. These options included traditional game consoles like Nintendo Switches and PlayStations, but also more general-purpose options like computers, phones, and tablets. The most common technology option for play was a phone (n=32), with Nintendo Switch as the second-most common (n=24) and any model of computer third (n=21). Participants also listed having access to PlayStation and Xbox consoles (respectively, n=19, n=11), and tablets (n=8) at home to a lesser extent. Interestingly, the teacher’s perception of participants’ SES did not seem to correlate to the number of devices they had access to at home. In other words, even lower income households had two or more devices on which participants reported playing games.

At home, 18 student participants reported playing every day, for at least an hour, ranging to four hours a day, five of those identifying as girls. The other 24 students ranged from playing every other day to two to three times a month. The average student in the class reported playing **five days a week, for two hours per play session** for those who offered an estimate for how long they played (n=29). When asked how they know their play session is done, the participants who answered (n=27) were split, either they stopped playing when bored, or they were told to stop or were limited by their parents.

In terms of what the participants reported playing, the most popular titles were *Fortnite* (n=19), *Minecraft* (n=25), and several titles from the *Mario* franchise (*MarioKart*, *Super Mario Galaxy*, *Super Mario Odyssey*) (n=23). Only five students reported that they did not play with others, either in person or online. While of the other 39, 34 reported playing both online and in person with friends or strangers in online lobbies. Not all participants mentioned playing in gaming lobbies directly, and many of those who did not mention lobbies still discussed playing games such as *Fortnite* or *Roblox*, which exist almost exclusively as online multiplayer games that utilize lobbies and play with randomly grouped strangers. Therefore, most of our participants (87%) are reporting playing with friends or strangers in lobbies, whether they recognize it or not. This is notable as it reflects the significant role video games have as a socializing tool for these young people.

4.2 Perceptions of Gaming Outside of School

Playing video games, we learned, was a way for some participants to connect with each other outside of school. As the interviews were conducted in pairs, several of the pairs named each other first when sharing who they connected with outside of school, whether it was through playing video games together, calling, or texting. Games were considered a common form of interaction between friends, with several of the participants (n=13) offering that they went home to immediately log on, playing with local friends from school or, as two participants mentioned explicitly, calling close friends who live far away and playing together. Digital games are often used for socializing, and participants mentioned that even when they were not in physical proximity, they would use two kinds of virtual connections to play together. For example, participants would put each other on FaceTime,

SnapChat, or a phone call while playing games like Roblox together regularly. For many of the participants, games are a primary medium for connecting with friends outside of school.

For some of these students, games were also their main source of activity and entertainment outside of school, describing how they play digital games with family, immediate and extended. Even before working with the participants directly, their teacher had named several participants who were vocal about their gameplay at home, with each other or around games. For example, one of the teachers mentioned a specific participant who often did not show enthusiasm for schoolwork but would share his game progress with her when talking about his at-home activities. This participant was one who was immediately excited to discuss video games with the researchers, naming many games he interacted with and how he enjoyed their difficulty.

4.3 Learning from Games

Due to the rudimentary coding mechanics that *Super Mario Maker 2* employs, participants were asked about previous educational coding and gameplay experiences. Twenty-one out of the 23 participants had played or made games using coding software/building games like *Scratch*, *Roblox*, or *Minecraft*. Many of these players had mentioned learning with *Scratch* (a rudimentary coding and game-maker, free online) in school (n=30); however, only one person chose to build in *Scratch* outside of these classroom based-experiences. Additionally, many students (n=24) mentioned playing *Roblox* at home, and only nine students said they chose to build their own game in the program. The ratio of students whose knowledge of building games came from school compared to those who sought out similar experiences on their own time was notable because of the expressed enthusiasm within the class for creating the levels. Many proponents of educational video games encourage the use of games like *Roblox* or *Minecraft* for the coding opportunities embedded in certain game functions (Han et al, 2023). Within this study, the classroom setting offered a structured environment where participants were excited to engage with the coding affordances of the game.

5. Findings: Play at Home Impacts Engagement in Game Play in Classroom

When planning the study, one of the most interesting and pressing questions was how at-home gameplay and experience may be impacting participants' in-school play. This was timely as well, because the teacher initially expressed concern that while some of her students were avid gamers, some may be unfamiliar and therefore disengaged. This perceived unfamiliarity was immediately addressed when all of her students reported playing video games at home in some capacity. To address any lingering imbalances in the participants' game play ability, the class was given a five-minute introduction to the game mechanics in *Super Mario Maker 2*. While participants were familiar with the gameplay and the mechanics with which they were interacting, they did treat this as an academic experience, focusing on the designated level-building tasks they were given.

As previously stated, participants played in pairs during the study, paired with someone whom their teacher thought that they could collaborate with while still staying focused. We were consistently impressed with the engagement of the class. In video and photo data, student pairs diligently constructed levels, both in their notebooks in the ideation phase, and in the *Super Mario Maker 2* game in building mode. Engagement for this group required very little teacher feedback, as the group were given directions on the order of building their level and then time to work, while observed by the research team. As their teachers commented multiple times in their exit interviews, every student participated actively and enthusiastically.

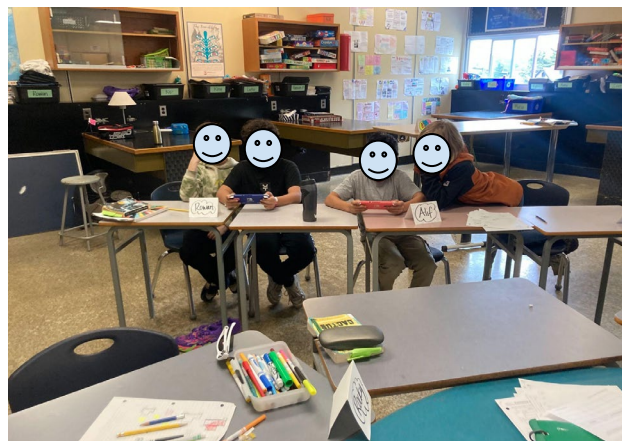


Figure 1: Players collaborating in their pairs, close body language

For example, Ms. R characterized student learning during the study as immersive, expressing her “shock” at how engaged some of her girl students were when they did not talk previously about their game play habits to her. Their obvious prior play experiences were seen through their comfort with the game, as well as the collaborative ways in which they constructed their own levels. How well the participants all engaged together was reiterated during the 9 days of the study, as well as the teacher interviews post-study.

That doesn’t mean we didn’t observe some frustration during level-building, particularly in the playtesting stage. After participants had constructed the levels they had designed in their sketchbooks, they played their own levels and each other’s to test out the feasibility of completing the level in its original design. The challenge was to offer kind but critical feedback to other pairs in their level, so that they could take the level and adjust it for the final showcase. This was an iterative process, a cycle of testing, offering feedback, reworking, and testing again. Frustration was also seen when building progress was lost, as some groups forgot to save their levels and therefore lost their work.



Image 2: Pairs playtesting each other’s levels, exchanging Nintendo Switches with each other

5.1 Social and Physical Proximity

Sociality between and among students was crucial to this project’s success. The two teachers had a strong understanding of their classes, providing the researchers insights into how different pairs would collaborate successfully. In previous iterations of this study, there have been classes where partnerships had been changed to support the focus of the pair or minimize their disruption to the class. These classes worked more in tandem, within groups that surprised the teachers, and collaborated without teacher input to show each other their levels, playtest, and offer ideas in each other’s notebooks. As seen in the above images, the students were physically close as well as sharing verbally with each other.



Image 3: Final class where the participants played each other’s levels

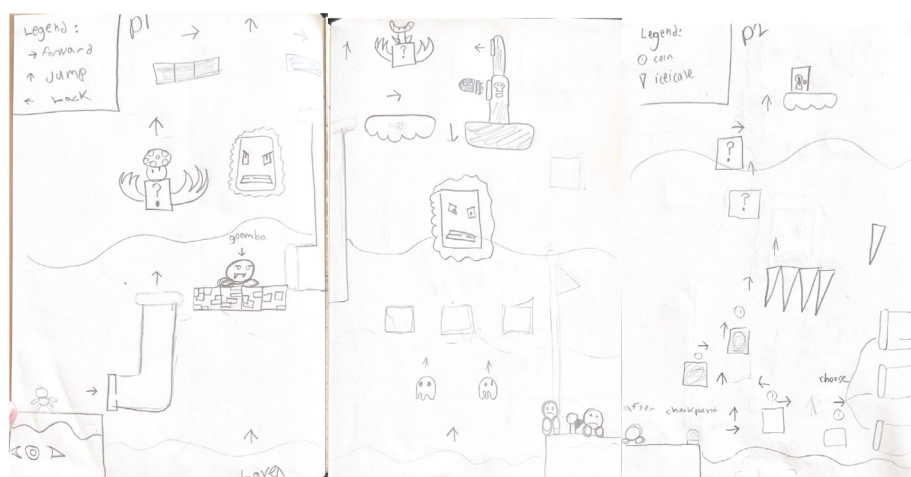
5.2 Design Thinking Through Game Making

As stated previously, participants were encouraged to plan their levels by sketching them in their notebooks after they had experimented with play to familiarize themselves with the usable game elements. Many of their initial drawings featured levels that were impossible to complete, featured too many enemies that the player had to fight, and sometimes missed including a floor for the player to walk on. These initial drawings showed a familiarity with the characters and concepts of the game but lacked the deeper knowledge of how to create a level that was playable. Often, there were several iterative drawings of these levels, changing how the blocks were arranged for players to run on, and altering the mechanics needed to win the game (e.g., adding a door where a key needs to be retrieved).



Images 4-6: Examples of a single participant's initial notebook sketches that are infeasible due to the number of enemies

Through iterations, whether altered by feedback or their building understanding of the game, most participants created playable levels. Their sketches showed their experimentation process, with the development of levels that show an understanding of the players' movement through their designed space, as well as the actions needed to progress. This is seen in the above images 4-6, in which the participant employed so many enemies that they could not play their own level to completion. Over time, they redesigned their level so that the final product was playable, yet looked similar in structure to the images above. Many of the students started including arrows in their drawn designs, tracking where the Mario avatar would need to traverse to get to the flagpole that signaled the end of the level.



Images 7-9: An exemplary created level, with the inclusion of legends to show what selected symbols meant

This theme of game-design thinking encompasses much of the planning, strategy, and iterative problem-solving seen in participants' work. Both their sketchbooks and the levels developed from the sketches show this movement from initial creative development to producing playable levels, with the audience in mind.

6. Study Limitations

This qualitative study is limited to the population that we examined, one middle school, in one small city in British Columbia, Canada. While it can't account for all children's play habits at home, nor how they might exhibit their game play skills in a classroom setting, we do think it gives some important insights into play habits and preferences for children who were significantly impacted by the global COVID-19 pandemic.

7. Conclusion

This study offers an examination of video game play in and out of the classroom. The variety and sheer amount of data, help to create an in-depth picture of what and how often children are playing video games. Indeed, the reported number of hours participants reported playing weekly (five hours on average) was startling to us as researchers, as many of these students are replacing in-person play or hanging out with playing video games together, especially while calling or FaceTiming. This change to an online existence is made more distinct by the use of video games to socialize.

For example, the self-reported gaming habits of participants revealed that all students in the class regularly engaged with video games at home. This was startling to one of their teachers but was seen in the easy engagement of all the participants during level creation and gameplay. As Ms. R had noted previously, she expected less engagement from some of the girls in her class, but across the class, we saw the girl participants playing collaboratively and engaging deeply in their game-development process. Their participation in game play was enthusiastic, and they were open to engage with a problem-solving process. The interviews offered insight into participant attitudes around video game play, whether they were excited to play or hesitant to show enthusiasm. The comfort and ability to socialize around games translated to what can best be described as an engaged, enthusiastic classroom for all participants, regardless of gender.

Finally, and to repeat, all students engaged collaboratively in their level construction and sharing their levels with the class. This formal-learning setting offered a space for personal interests in games to bridge into the class, fostering an enthusiasm that surprised their teachers. Student participants less invested in the more traditional lessons were offered a space to creatively engage and showcase a passion that they have at home. All participants reported spending a large proportion of their time outside of school on screens, and integrating more screen time into a school setting increases those hours. This study shows that while having the requisite skills to navigate playing video games in classrooms might have been a barrier for some students to participate fully in in class video game play, that skills gap has, at least in this study, been closed, in a large part due to the purchasing of game consoles by families to have indoor activities for young people to do during stay at home orders during the pandemic. Moving forward, we hope to conduct the study a second time within the same school to see what similarities and differences there might be within this age range.

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

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Abstract: This paper reports on mixed-method action research implementing and evaluating a battery of creative writing games for reading (CWGR) progressing from more open games (freewriting-based) to closed games (recombinant). The goal of the study was to investigate how the movement from open to closed games affected creativity (divergence), engagement, and play. It was hypothesized that the restrictive nature of closed forms would render them less engaging overall, particularly for students identifying as creative; however, it was also hypothesized that their rule-based nature would make the creative process clear, accessible, and inclusive, and thus would engage students who *did not* self-identify as creative. Surprisingly, the most recombinatory game was identified by both engaged and disengaged students as *more* creative than the others; more surprisingly, it was rated one of the most engaging games overall. Contrary to the secondary hypothesis, however, the high level of perceived creativity coincided with *lowered* engagement for students who identified as less creative. Other notable results include the following: while highly engaging, freewriting measured low in creativity (divergence) and play; the most engaging games were also the most disengaging for a relatively equal number of students; and finally, in *every* game, students responding in their native language scored *lower* on creativity (divergence). Overall, while results varied by game, most students found that *at least one* game raised divergent awareness. This is a surprising measure of success given the novelty of the games and the short time students were exposed to them. This points to the potential for recombinatory writing games (RWGs) to develop student creative skills (divergent thinking) in reading and writing. This investigation is important in terms of the larger conversation concerning open vs. closed game structures, for example, the effectiveness of open-world exploration and building versus closed, solution-based games. In this case, more closed, recombinatory games were surprisingly effective in terms of both creativity and engagement.

Keywords: Recombinatory games, Creativity, Divergent thinking, Engagement, Writing, Reading

1. Introduction

In response to the radical drop in reading levels in Norway (PISA 2022), the perennial problem of engaging upper-secondary students in reading and writing, and the central place of creativity in 1. the Norwegian curriculum (LK20); 2. the Organization for Economic Co-operation and Development's (OECD) measure of student skills "essential for full participation in modern societies" (PISA); and 3. overall success (Caughron et al, 2011), this study investigates upper-secondary students' engagement and creativity in a series of recombinatory writing games (RWGs). As this project brings together multiple fields, the research context is broken into sections. For a more in-depth treatment of creativity and engagement see Jones (2023), and for literary studies, see Jones (2024).

2. Literary Studies

Language as a game has a significant history in both literary studies and philosophy (Gunn, 2022); the twentieth-century experimental tradition has investigated games and processed-based tools for creative writing (Jones 2024); and the narrative-story debate in electronic literature has established a theoretical discussion treating game-based narratives (Aarseth, 2014); however, investigation into the practical use of literary games as tools for critical reading and interpretation has been limited. The key theoretical background in literary studies is McGann's (2001) "critical deformation", also called "algorithmic criticism" (Ramsay, 2011) and comparable to "decomposition" in creativity studies (Smith, 1998). While these approaches have seen success in literary interpretation and creativity training, they have not been pursued through game-based learning. This study focuses on a game-based approach to "critical deformation" and follows the lead of recent work done by Mills (2022), who explores game-based methods for framing the writing process as collaborative, creative play.

3. Creativity Studies

Creativity, generally defined as both novelty and usefulness in an idea or solution, is fundamental to success in the 21st century (McWilliam & Dawson, 2008; Caughron et al, 2011). It is also trainable and teachable (Ma 2006; Rose & Lin, 1984; Torrance, 1972) particularly idea production (Scott, Leritz, & Mumford 2004); however, its complexity makes research and implementation difficult. It can be measured in terms of a cognitive process, a personal characteristic, a creative product, or a facilitating context (Rhodes, 1961; Zeng et al, 2011), and it

includes seven separate approaches (Hennessey & Amabile, 2010), fourteen theories, and eighty-two processes (Bull et al, 1995). As this complexity makes measurement a challenge (Corazza et al, 2022), most studies focus on divergent thinking and use it interchangeably with creativity (Baer, 1993; Sternberg & Grigorenko, 2001). Therefore, this paper focuses on creativity as divergent thinking.

Divergent thinking is the ability to produce multiple ideas/solutions to a problem, convergent thinking is the ability to select the single best solution, and the creative process is the recursive movement between the two (Eyman et al, 2024; Basadur et al, 1982). The present study measures this process using the most commonly accepted methods (Amabile, 1983; Cortes et al, 2019): as a *process* through observation and as reported by students, as a *product* through game product analysis, and as an *ability* through the most commonly used tests (Cortes et al, 2019): for divergence, an Alternative Uses Task (novel uses for an object); for convergence, a Remote Associates Task (connect 3 words thematically). Game product measurement is complex, as each game has different rules/parameters, therefore, measurements were based upon the most commonly used scoring categories (Guilford, 1967): 1. **fluency**: the ability to produce *multiple* ideas; 2. **flexibility**: the ability to produce *differing* ideas; 3. **originality**: the ability to produce *unique* ideas; 4. **elaboration**: the ability to deepen or *develop* an idea. In creative writing games, this amounts to a quantification of “literal” (significant) narrative turns (Acar & Runco, 2019).

4. The Importance of Measuring Self-Efficacy and Self-Identification

Self-efficacy is a major factor in student engagement, development, and overall success (Hidi et al, 2006; Karwowski & Lebuda, 2017); it also affects effort, how long students will work on something, and anxiety surrounding a subject (Usher & Pajares, 2008). Self-efficacy is particularly at issue when studying creativity, as many people believe that creativity is innate, unteachable, impractical, and impossible to assess (Amabile, 2018; Guilford, 1950; Rhodes, 1961; Treffinger, Isaksen, and Dorval, 2000; Waitman & Plucker, 2009), and the creative impulse is often considered disruptive in the classroom (Beghetto, 2007; Amabile, 2018). Low self-efficacy in creativity was confirmed by the Organization for Economic Co-operation and Development’s (OECD), who found that students believing they can improve their creativity outscore those who don’t, but that this is only one in two students (PISA, 2022). Creative self-efficacy is particularly a challenge in creative writing, as most students do not consider themselves writers in the first place (Waitman, 2009; Runco, 2014). Finally, writing functions as an assessment method across the entire curriculum, a relationship that does not open the free, playful space necessary to develop creativity (Boscolo and Hidi, 2007). This challenging context for self-efficacy in creativity and writing makes it a key factor to investigate and develop.

5. Game-Based Learning

Game-based learning has coined the term “microworld”: “a small, but complete, version of some domain of interest” (Rieber, 1996: 46). Rieber gives the example of a sandbox as a microworld for a child. With a little imagination, the child can build endless worlds to wander, and in terms of learning domains, he or she can experiment with the physics of sandcastle building. There are two important keys to a microworld: 1. “it presents the learner with a simple case of the domain” (46). In other words, while the user can build with increasing complexity, the world contains only the basic building blocks in that field of knowledge. 2. microworlds “match the learner’s cognitive and affective states” (46). Put simply, no directions are needed. We arrive on a Minecraft beach with a hammer, and we simply figure out that the goal is to break and place blocks. While the notion of textual games as open worlds akin to Minecraft has been discussed elsewhere (Jones, 2024), here the notion of microworlds serves to clarify the idea that writing can be materialized in a game-based sandbox so that words, through recombinatory mechanics, serve as domain-specific building blocks for student/player experiment.

6. Relevant Studies

Relevant studies exist, but none has used a data-driven, game-based approach. Preliminary studies on Norwegian creativity (Jones, 2023) and recombinatory game theory (Jones, 2024) laid the foundation for this paper. Littlemore & Law (2006) investigate metaphors in EFL but focus on mastery not generation. Figgins (2007) explores Surrealist games but does not collect data. Bundy (2017) studies creative writing role-playing games, and Lee (2019) studies narrative-based games and engagement in EFL; however, neither examines recombinatory approaches. Frye et al (2015) examines the use of riddles, but in a different domain (science) and focused on information retention. Loffredo & Manuela Perteghella (2014) examine similar notions of textual transformation but without the game-based element. Motivation’s relationship to creativity (Amabile, 2001) sets up the relationship in this study, and the usefulness of random information in convergent processes has been demonstrated (Mastria et al, 2022) but without a game-based approach. Disney (2014) studies the use of

surprising poetic juxtapositions in L2 classrooms; however, his investigation focuses on traditional creative writing processes. McCallum (2012: 74) proposes the concept of L2 “re-creativity” (“manipulation of source material to bring something new into being”), which is very in line with “critical deformation”; however, McCallum also uses a non-game-based approach.

7. The Study

A within-subject research design compared the change in student engagement and creativity as games moved from open (freewriting) to closed (recombinant). The study consisted of a teaching intervention introducing divergent thinking, followed by seven questionnaires administered by the researcher and two Norwegian teachers over 4 weeks to 100 students, ages 16-19 ($n = 1, 49, 44, 6$), from two upper-secondary schools in Norway. The surveys included choice-based and open feedback questionnaires as well as guided gameplay. The data consists of the questionnaires, gameplay results, and teacher/researcher observations. The pre-survey included a divergent thinking test and information on creative self-efficacy, personality, and relationship to creative writing, reading, and games. Post-game questions focused on engagement and divergent awareness.

The games were creative writing games for reading (CWGR) chosen to compare more open (less recombination) to more convergent, recombinatory writing games (RWGs). The goal was to investigate engagement as games became increasingly closed/recombinatory and thus closer to the “critical deformations” that have proven useful as advanced critical reading tools (McGann, 2001). The games were simplified to clearly represent differing levels of recombination. While it was assumed this would reduce engagement when compared to testing fully developed games, this approach allowed the study to more precisely assess a sequential increase in recombination. Secondly, the goal was to investigate whether or not the rule-driven nature of recombinatory games would appeal more to self-identifying non-creatives. This connects to the larger project of proceduralizing/gamifying creativity to engage a larger group of students/users.

8. DROP Exploratory Analysis Framework

To add more analytical capability to the conclusions, the games were analyzed using a simplified version of the DROP framework (Jones, 2024):

- **Divergence (D):** the level of divergent writing (vs. convergent). This was measured using Guilford’s original categories modified to match each game’s particular design parameters.
- **Recombination (R):** to what extent the game uses a recombination of the curricular text.
- **Openness (O):** while this can mean open world (Jones, 2024), here it was simplified and put in contrast to recombinatory, rule-based, and solution-based game mechanics.
- **Play (P):** play refers to any of the following: competition, chance, vertigo, make-believe, role-playing, spontaneous play, rule-based play (Callois, 1958), ludic activities (Salen & Zimmerman, 2004), performance play (Sutton-Smith, 1998), and narrative play (Aarseth, 2014; Ryan, 2009). Due to the subjectivity of the play experience, the resulting variation in its measurement, and because engagement is a key factor in the definition of play, engagement was used as a baseline from which to measure.

9. The Games in Detail

The games had two stages: a battery of skill-building freewriting exercises and then more developed games that moved toward increasing recombination (see Figure 1). The freewriting versions taught students to track the recursive movement between divergent and convergent thinking so they could more accurately track this in the developed games. After freewriting, each game used an increasing amount of recombination (words from the curricular reading text). This is clearly the case with cut-up story (**cu**), which *only* uses the reading text; however, it is arguable whether three words (**3w**) or metaphor riddle (**mr**) is more combinatory, as they both use 2-3 words from the reading text. The leap from this low level to a game that is completely recombinatory (**cu**) reveals the need for future design and research on a game design that can offer more recombination than **3w** and **mr** but less than **cu**; at the same time, the engagement and effectiveness of **cu** reveal real promise for extreme levels of recombination.

fw	open freewriting	students write without stopping
bfw	blind freewriting	freewrite with eyes closed
sfw	senseless freewriting	freewrite without making sense
wb	word bomb	textual words called out must be incorporated
cp	catch phrase	freewrite until stuck then write “I remember” and continue
sa	silly argument	list most possible arguments for “clowns should rule the world because...”
3w	three random words	choose three random words from text and find most possible connections
mr	metaphor riddle	five-clue, student-designed riddle comparing two textual terms
cu	cut-up story	use any 30 words from story to write a new ending

Developing skills in creativity

Increasing recombination

Figure 1: Games in order of play (skill building → increased recombination)

10. Results

Data and results were extensive. Included here are the most interesting and important results on overall engagement, engagement in creative vs. non-creative self-identifying students, divergence in L1 vs. L2 students, and the overall relationship between divergence (D), recombination (R), openness (O), and play (P).

11. Engagement

While **fw** was by far the most popular in the post-study measure (table 1), student familiarity may have positively affected the score; however, it also had a negative effect, as demonstrated in the qualitative feedback where some students found the familiarity “boring” and that the lack of constraints lead to less creativity and surprise or “shock”, as one student put it.

Table 1: Post-game/post-study engagement percents, rounded up; (n) varied due to absences.

post-game	wb: 62 (81)	cu: 61 (62)	cp: 52 (94)	mr: 51 (67)	3w: 48 (91)	sa: 36 (89)
post-study	fw: 73 (62)	wb: 58 (62)	3w: 58 (62)	bfw: 55 (62)	mr: 55 (62)	cu: 55 (62)

Note that the freewriting variations (**fw**, **bfw**, **sfw**) did not include post-game measures as creative divergence is lessened by assessment (Amabile 1982, 2018), and the study wanted to establish a preliminary exploration of divergence under optimal conditions, as it served not just for data collected but as a teaching intervention.

Despite its top position on the post-study Likert scale, **fw** is a completely open game with no recombination (O: 100/R: 0) and thus not useful as a critical deformation. We might assume this openness means it is high in play (P) and divergence (D), but in practice, it is typically low, a fact confirmed by this study. In freewriting, play and divergence are not structured and thus mirror the previously developed expertise of the student; thus, it is typically low when the sample is untrained in creative writing. While a free, unjudged space is key to divergent creativity, a complete lack of guidance leaves untrained students writing what one called “the same story”. In addition, zero recombination (R) means no relation to the curricular reading text. While this means freewriting is not very useful as a critical deformation, incredibly high engagement makes it a promising mechanic to integrate alongside recombination.

Wb was in the top post-game position on the Likert scale, the second post-study rating after **fw**, and in the “strongly like” category, it scored more than double the next game in the post-game scale. Additionally, when asked post-game if they liked **wb** better than **fw**, 48% agreed and only 16% disagreed (n=81). The qualitative data also revealed that in the two classes where the researcher did not administer the survey, some students felt **wb** contained difficult vocabulary words (qualitative data supported by game product data). This kind of word difficulty lowers divergent “fluency”, as the cognitive load of integration obstructs the flow of writing. Students also pointed out that the words were, in some cases, called too quickly. Both of these results points to a higher score for **wb** with correct administration. This is important as **wb**’s recombination, while low (typically R = 5-7 words), is higher than **fw**. So, while engagement is high for both **fw** and **wb**, **wb** functions better on the recombinatory scale in DROP, making it a promising mechanic for future studies and design.

In addition to the post-game and post-study Likert scale, the post-study questionnaire included a “favorite” game question. This was important in terms of examining what games had the most effect over time.

Table 2: “Favorite” game percents; rounded up at .05; partial results list (n = 62)

favorite	cu: 20.1	fw: 17.7	bfw: 14.5	mr: 14.5	wb: 14.5	3w: 10
least	cu: 29	bfw: 17.7	mr: 11.3	fw: 8.1	3w: 6.5	--

Interestingly, **wb** dropped to fifth place when students assessed favorite game overall (table 2). Note, however, that the four games scoring better than **wb** are both most *and* least favorite (**cu**, **bfw**, **fw**, **mr**). One conclusion is that no single game can speak to all students. This seems to go without saying, but it is interesting to see how radically the data supports a diverse set of games/mechanics. While **wb** does drop to the fifth spot, it is also in the last spot for “least favorite”, signalling a low barrier for initial acceptance. This makes **wb** a very promising set of mechanics for future development particularly in early stages of student use.

Due to observed difficulty in a previous study (Jones, 2023), **cu** was modified in this study to increase engagement: shorter recombination (50 to 30 words), a competitive element (students could not use what others chose), and a performative element of sharing the stories they made (P: performative play). Qualitative data supported performative play as a factor: *“It was kind of boring, but sharing the stories was fun”*. The positive engagement data here is important, as **cu** is the most recombinatory game. Surprisingly, while the sample was overwhelmingly positive about competition in games, here the competitive aspect had a negative effect for some students according to the qualitative feedback.

12. Divergent Awareness

In overall divergent awareness (table 3), **3w** and **cu** are in the top position (39%), though **wb** is virtually identical (38%). It is not surprising that **cu** was rated highly, as every word of the game puts a player through the divergent-to-convergent process: in other words, every word chosen draws the writer away from the narrative (divergence) and then must be integrated back (convergence); however, the words are chosen by the student, and thus there is the potential to choose convergent terms. Data results were mixed on this with a significant number of students creating radically divergent texts, far more divergent than **wb**. **3w** included both a clearly divergent and a clearly convergent level, which highlighted the two parts of the process: this may account for its high rating in divergent awareness. More research is needed to test this hypothesis.

Table 3: Top post-game divergent awareness percents; rounded up

Post-game div/conv	3w : 39/n=91	cu : 39/n=62	wb : 38/n=81	mr : 25/n=67
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While we might assume that an emphasis on divergence is the key to increased creativity, the results from **wb** showed the key role of convergence. In **wb**, the word “bombed” into the free space of a **fw** acts first as a divergent force (the player’s mind must race to a very random word), and then a convergent force (the player must try to incorporate the word into their narrative). The qualitative data showed that for some students, it was the convergent impulse/movement that most developed their creativity: *“I wanted the text to make sense even though it was really hard. I got really creative when trying to do this”*. Interestingly, while this particular student did not identify as creative, according to the pre-game divergence test, the student was in the 63rd percentile of creativity according to the initial creativity test. At the same time, the **wb** game product reveals this student in the lowest scoring group in terms of actual divergence or significant (“literal”) narrative turns: significant turns are ones that take the narrative in a new direction rather than simply being integrated into the same convergent narrative (Acar & Runco, 2019). This means that while the convergent movement made the student *aware* of the creative process, it did not actually *increase* creativity within the timeframe of the study; however, considering the positive relationship of creative awareness and self-efficacy to the development of creativity, it can be assumed that a game producing an awareness of success in creativity will improve the skill itself over time. Qualitative results speak to this, one student pointing out that the internal progression of **wb** increased divergent skills: *“Each time a word got dropped in, it got easier to think divergent.”*

13. “Creative” vs. “Non-Creative”

The pre-test questionnaire asked students to self-identify as creative/non-creative. A second question asked them to report liking/not liking creative writing. 22 marked non-creative and 29 marked disliking creative writing. Interestingly, the same group of female students marked both. The 7 new students (an increase of nearly one third) who marked themselves as creative but not liking creative writing were all male. This result may point to males associating creativity with non-writing activities more than females. More research is needed to confirm this. This is important as it can develop our understanding of the relationship between general notions of

creativity and creativity as it pertains specifically to reading and writing. If we can confirm that other types of creativity are more accepted by certain student groups, integrating these kinds of creativity into textual creativity can serve as an evidence-based method for increasing engagement.

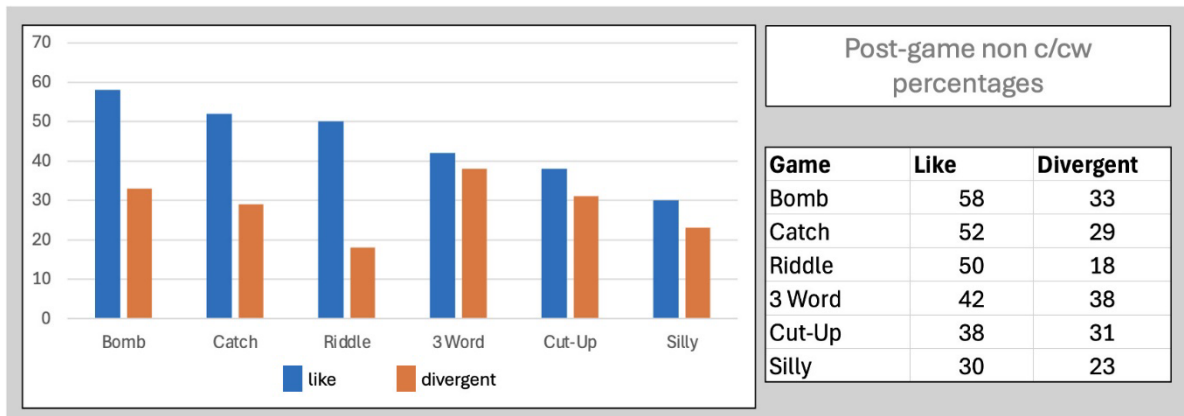


Figure 2: Top post-game percentages (Likert/divergent awareness) for non c/cw students, rounded up

The study revealed that not only was **wb** the most liked game, it was also the most liked by the group identifying as non-creative/disliking creative writing (non c/cw) (figure 2). In the measure of divergent awareness, though **3w** scored better (38%), **wb** was second (33%). This makes a convincing argument that **wb** is the most effective overall, if we take into account the goals of both engagement and awareness of creative skill usage. It is important to notice that while **3w** was in fourth place in terms of the Likert scale, it was rated highest in terms of making non c/cw students aware of divergent-convergent processes. This is significant as students had very brief exposure to creativity concepts. Continued awareness over time would presumably positively affect both divergent skills and engagement.

The qualitative data gives a more thorough picture of the relationship between divergent awareness and engagement. Students actually pointed to their awareness of divergent-convergent processes itself as a key engager for **wb**, one student pointing out that it was precisely the movement away from logical thinking that served as an effective engager: “It’s fun and you don’t have to think too much. Just do it.” This implies a possible value in developing this meta-awareness as a game mechanic. For non c/cw students, qualitative feedback on **wb** engagement added factors including “humor”, “writing fast”, “more concrete”, “gives a direction to write in” (convergent), and “random stuff happens” (divergent). The first three factors fall outside divergent awareness and could be considered on their own in future studies. One student who reported not liking the game pointed out that it “makes it easier to write without stopping”. This implies that the game can be productive even for students who do not find it enjoyable.

14. Divergence and Play on the Openness-Recombination Spectrum

The researcher expected completely recombinatory games to have lower engagement than more open games. The case turned out to be more complicated. In fact, there was a high level of divergence, play, and engagement when recombination was *most* pronounced (figure 3). This is surprising and promising for future game design that incorporates high levels of recombination; at the same time, it is important to note that *disengagement* was also the highest in the most recombinatory game. This implies that the entry threshold is higher and means either designing with this in mind or leveling games so that full recombination comes when the player has already developed skills and confidence. There is also an issue of L1 and L2 to consider (see below).

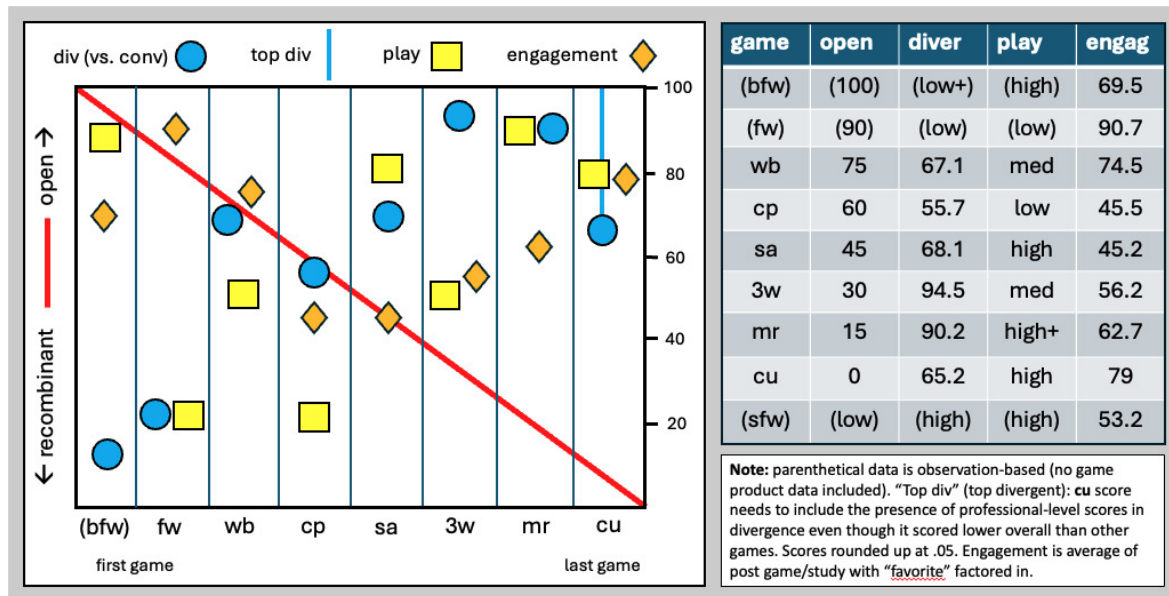


Figure 3: Divergence (d), recombination (r), openness (o), play (p), and overall engagement percents

15. L1 vs. L2 Students

Probably the most unexpected result was the difference in actual game-product divergence for L1 and L2 (figure 4). While divergence measures are complex, in every game, scores for significant narrative turns were higher for L2. Less surprising, and perhaps a partial explanation for the high disengagement numbers for cu overall, students responding in L1 overwhelmingly picked cu as their favorite game, whereas L2 students were far more likely to dislike it or choose it as their least favorite. This points to high disengagement resulting from the difficulty of high recombination in L2. Further research is needed to verify this.

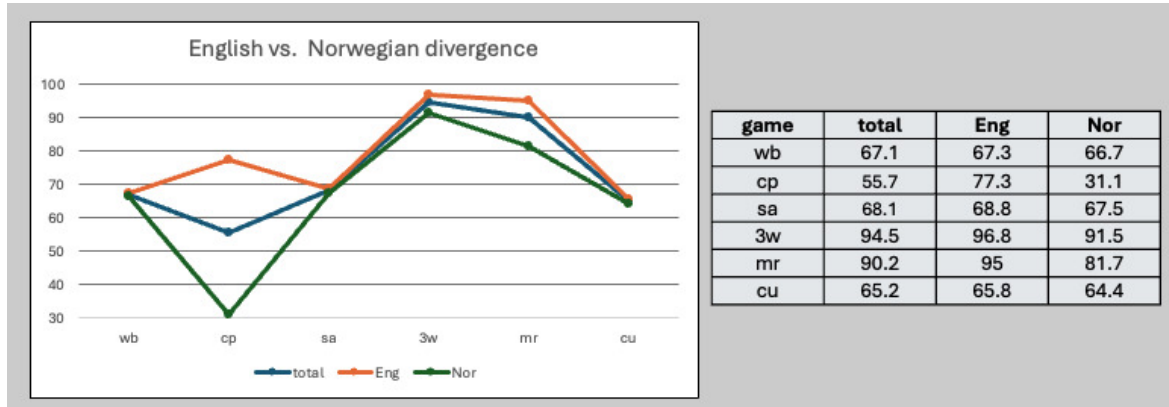


Figure 4: Divergence in game products for students answering in Norwegian vs. English

16. Conclusion

This paper has found that open freewriting is engaging but not effective creativity training, that recombination can engage both self-identifying creatives and non-creatives, that the most engaging games are also the most challenging for an equivalent group of students (L1 vs. L2 playing a factor), that non-creative students did *not* find the more recombinatory game more accessible (in fact students saw it as *more* creative overall), and finally, that across the board students allowed to respond in their native language scored *lower* on divergence. Interestingly, **cu** produced the highest level of creative writing. For example, one student wrote: "When the coyotes slept, they could see stars, liquor and smoke". This is exceptional work by professional creative standards in terms of its surprising, divergent juxtapositions and the way in which it combines thematic elements from the curricular text. Overall, the mechanics in **cu** and **wb** stand out as most effective in the most categories analyzed here.

Ethics declaration: No personal data was collected except a coded list of first names which was de-coded (destroyed) immediately after the study took place. The process was cleared with the Norwegian Ministry of Education and Research (Sikt).

AI declaration: No AI used for this paper.

Conflict Of interest: No conflicts of interest reported.

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Who Learns from City Games? Examining the Role of Motivation, Personality, and Experience

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Abstract: Unlike traditional escape rooms, city games shift from a confined space to an open environment, allowing for greater exploration that incorporates elements of local art, history, and culture into the gameplay. Because of this, city games are often designed to promote learning about specific themes within a city. However, research on players, gameplay, and learning opportunities in city games remains limited. This experimental study examined how individual differences, such as personality, motivation, prior gaming experience, and interest in the game's subject matter, correlated with self-reported experiences and learning outcomes. A total of 23 adult participants, all visitors to Stockholm, Sweden, engaged in a custom-designed city game focused on sustainability and urban planning. Participants completed pre- and post-game surveys to assess their learning. Results showed that participants with higher levels of prior gaming experience reported significantly greater learning. Engagement with the game's supplementary "Did You Know" informational content was strongly associated with reported learning gains. Measures of motivation and personality significantly predicted predispositions toward teamwork and enjoyment during gameplay, but they were not significant predictors of learning outcomes. These findings have implications for pedagogy and learning through play, particularly in game design and education. The study underscores both the potential and limitations of city games in creating inclusive learning experiences.

Keywords: Games, Learning, Pedagogy, Motivation, City games, Education

1. Introduction

The growing popularity of escape rooms has led to the emergence of various adaptations of the escape game concept (The Economist, 2019). One such variation is the city game, which extends the escape game format by distributing puzzles throughout an urban environment. While city games share core mechanics with escape rooms, such as puzzle-solving, teamwork, and time constraints, they differ in key ways (Veldkamp et al., 2020). Unlike traditional escape rooms, which take place in a controlled, enclosed setting, city games integrate real-world locations into their design, encouraging players to navigate and interact with their surroundings as part of the experience. This shift from a confined space to an open environment allows for greater exploration and immersion, often incorporating elements of local history, culture, or education into the gameplay. In this way, city games can be seen as an evolution of escape rooms, blending structured play with the dynamic and unpredictable nature of urban spaces. Because of this, city games are often designed to promote learning about specific themes within a city. However, research on players, gameplay, and learning opportunities in city games remains limited.

1.1 City Games: Escaping the Room

An escape room is a live, team-based game in which players collaborate to solve puzzles and complete storyline-driven missions within a limited time, typically while confined to an indoor setting. In contrast, city games extend the escape game format to a series of puzzles distributed throughout a larger city environment. Players follow a storyline as they solve challenges sequentially. However, while escape rooms are confined to a single space, focusing on puzzles, hidden clues, and time-limited collaborative problem-solving, city games

span urban environments, ranging from exploring a city block to traveling across an entire city. City games combine physical activity with digital or location-based technologies to prioritize exploration, navigation, and real-world interaction. Players progress through the storyline, delivered via an app or physical kit, and solve puzzles collaboratively with friends or family. Some popular city adaptations include *Questo*, *Mystery City Games*, *Amaze Games*, and *Clued Upp*.

City gaming as through the lens of game-based learning leverages the environment of a city as a platform for learning goals (Huizenga et al., 2009; Hanney, 2024; Tan, 2016; De Lange, 2009). In this approach, urban spaces are transformed into interactive learning environments where learners can engage in activities that promote exploration, problem-solving, and critical thinking within real-world contexts. City gaming can encompass a range of activities, from scavenger hunts to location-based challenges that require participants to navigate and interact with their surroundings (Tan, 2016). There is a great deal of variety in the commercial and educational escape and city-gaming space. It is not the intent of our paper to document the breadth and theoretical implications of this diversity, but to highlight the distinction between escape room games and city-games as game categories.

For educational applications, increased immersion in a story through non-fiction can be beneficial for the players by directly involving players in a story or problem, inviting active engagement and participation (Veldkamp et al., 2022). The immersive nature of city gaming helps learners connect educational content with tangible experiences, enhancing retention and understanding (Yang, 2012). City gaming aligns closely with contemporary educational theories that emphasize the importance of situated learning and experiential education that may provide more accessibility to learning (Kolb, 1984). These theories advocate for learning experiences grounded in authentic, real-world contexts; thus, allowing learners to apply knowledge and skills in meaningful ways. City gaming, through utilizing the urban landscape as a classroom, provides such opportunities, making learning both relevant and impactful.

With increased popularity, there has been a rise in research pertaining to the learning outcomes associated with escape rooms as well as how these games may be applied for educational purposes (López-Pernas et al., 2019; Veldkamp et al., 2022; Yang, 2012). While city games are similar in principle and approach to escape rooms, they currently are not as often utilized. One reason may be because while an escape room takes place in a confined and carefully designed indoor space, city games may be subject to greater environmental constraints due to increased variability of a more uncontrolled environment. For example, factors such as weather, construction, or public events could potentially alter a game experience. Nonetheless, city games offer a unique opportunity for players to learn about real-life cultural landmarks and city environments. It may be that these types of games may have more broad appeal and learning outcomes for individuals who struggle in more traditional classroom learning environments (Huizenga et al., 2009). However, because city games reflect a new approach to the 'escape game' concept, there is a lack of research regarding the learning associated with participation in city games.

1.2 Interest, Motivation, and Learning

Central to the effectiveness of learning experiences are motivation and interest, two interrelated factors that play pivotal roles in shaping learner attitude and behavior. Past literature has established this intricate and interconnected relationship between interest, motivation, and learning outcomes. Schiefele and Csikszentmihalyi (1995) characterizes interest as a precursor to intrinsic motivation. In their framework, interest acts as a foundational underpinning to intrinsic motivation, serving as the initial spark that ignites enthusiasm and curiosity for a particular subject or task. In other research, interest has been identified to have a crucial role in educational contexts, acting as a catalyst for involvement, enjoyment, concentration, and activation (Hidi & Renninger, 2006).

Interest leads to involvement by capturing individuals' attention and stimulating curiosity (Hidi & Renninger, 2006). Hidi and Renninger (2017) propose that interest activates cognitive processes by stimulating individual thinking and problem-solving skills. When individuals are interested in a topic, they are more likely to engage in critical thinking, analysis, and synthesis of information. When individuals find topics and subjects personally relevant or intellectually stimulating, their likelihood to actively seek out information and engage in exploration and discovery heightens. This active involvement fosters deeper, more meaningful learning experiences and motivates one to invest more time and effort to furthering knowledge. Moreover, interest promotes enjoyment by creating a positive emotional experience associated with learning. When individuals find themselves interested in what they are learning, they experience feelings of enjoyment, satisfaction, and

fulfillment. This positive affective state enhances the overall learning experience and also reinforces motivation to continue learning and exploring the topic further.

1.3 Individual Personality

Apart from designing for immersion and considering factors related to motivation and interest, it is still possible that individuals themselves may bring with them their own differences to a game. Personality is one such individual difference that may act as a predictor of behavior in a game, and as such has important implications for game engagement and learning outcomes. For example, one study found that low neuroticism and high openness to experience predicted more cooperation in games (Lönnqvist, Verkasalo, & Walkowitz, 2011). In escape room settings, personality traits can shape social interactions and individual problem-solving strategies, similar to game-based assessments (GBA; de Hesselde et al., 2021). Personality may predict behavior and influence both game experience and learning outcomes. The Big Five personality traits, in particular, have been linked to the use of self-regulated learning (SRL) strategies, which include goal setting, time management, task strategies, and help-seeking. Research shows conscientiousness is the strongest predictor of SRL, while agreeableness also plays a mediating role (Bruso, 2019). Additionally, personality influences goal-attainment strategies: agreeableness and conscientiousness are closely tied to mastery-approach goals, whereas neuroticism correlates with avoidance and performance goals (McCabe et al., 2013). Given these associations, the Big Five traits are likely to shape individuals' experiences in city games through their impact on behavior.

1.4 Current Study

Data on players, gameplay, and learning opportunities in city games remains limited. This experimental study examined how individual differences, such as personality, motivation, prior gaming experience, and interest in the game's subject matter correlated with self-reported experiences and learning outcomes. Understanding individual interest and motivation is essential in educational contexts, as it plays a critical role in shaping learners' engagement, persistence, and learning outcomes. Participants completed a pre-game and post-game survey to assess their learning during a custom-developed city game using the *Questo* mobile app.

We predict that participants with higher prior gaming experience, stronger interest in the game's subject matter, and greater engagement with informational content will report higher learning outcomes in a city game. Additionally, individual differences in motivation and personality will predict enjoyment, teamwork, and learning gains.

2. Method

2.1 Participants

Female undergraduate participants who were on a study abroad program ($N = 23$) in Stockholm, Sweden, were recruited using convenience sampling methods through flyers, in-person requests, and a campus app. The entirety of the sample identifies as female. Demography consisted of 4% Asian or Asian American ($n = 1$), 4% Black or African American ($n = 1$), 74% White ($n = 17$), 4% Hispanic or Latino ($n = 1$), and 13% "Other" ($n = 3$). Participant's university attendance was as follows: 13% attend public universities ($n = 3$), 43% attend private universities ($n = 10$), and 43% attend liberal arts colleges ($n = 10$). All participants were visitors to Stockholm, Sweden, and had not been in Stockholm for more than 8 weeks.

Participants were grouped based on availability indicated in a recruitment survey. Researchers formed groups of 2–4 and assigned them randomly within those availability windows. Access to a smartphone was required to engage with the city game. Although exclusion was possible due to weather or feasibility of outdoor play, no participants were excluded. All participants gave written consent after receiving study information verbally and in writing. Each received a €10 gift voucher for participation. Participants were recruited using convenience sampling, as the study targeted adult visitors to Stockholm who were available and willing to participate during the game's scheduled sessions. Inclusion criteria required that participants be over 18 years of age and proficient in English; no additional exclusion criteria were applied. The small sample size reflects the exploratory nature of the study and the logistical constraints of running a live, location-based game.

The study's methods and protocol were conducted in accordance with the standards specified in the 1964 Declaration of Helsinki and were approved by the local ethics committee of Uppsala University and the Swedish Ethical Review Authority (2022-03420-02).

2.2 Materials

2.2.1 Pre-survey

Consistent of the following questions:

- Have you ever played a city game before?
- Have you ever done an escape room before?
- Do you enjoy escape rooms?
- What games do you like to play? Select all that apply.
- [Ten Item Personality Measure (TIPI)]
- [The General Motivation Scale (GMS-28)]

2.2.2 Ten item personality measure (TIPI)

Personality was assessed using the Ten Item Personality Measure (TIPI; Gosling, Rentfrow, & Swann, 2003), a brief instrument designed to measure the Big Five personality dimensions: Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Openness to Experience. Participants rated themselves on 10 items using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The TIPI is widely used in research contexts requiring a short, time-efficient assessment of personality.

2.2.3 The general motivation scale (GMS-28)

Motivation was measured using the General Motivation Scale (GMS-28; Howard et al., 2021), which assesses different types of motivation based on Self-Determination Theory. The scale includes 28 items covering intrinsic motivation, identified regulation, introjected regulation, external regulation, and amotivation. Participants responded using a 7-point Likert scale ranging from 1 (not at all true) to 7 (very true). The GMS-28 is a validated tool for capturing a broad spectrum of motivational orientations across contexts.

2.2.4 Questo game storyline description

Participants used *Questo*, a mobile app that delivers location-based, gamified urban exploration through narrative-driven tasks, clues, and puzzles requiring physical navigation to specific sites. Each quest follows a thematic storyline, often historical, cultural, or fictional, encouraging interaction with the environment.

In this study, participants completed a custom-designed *Questo* quest (*Sabotage! Prevent sustainability sabotage with the Planet Protectors*) set in a predefined area of Stockholm, themed around sustainability and urban planning. They used their personal smartphones to download and access the app. Before starting, participants received instructions on app usage and were asked to enable GPS. No additional guidance was provided during the quest to maintain naturalistic engagement.

The custom developed *Questo* contained the following storyline, provided to participants at the start of the game: "Agent Green, You are a covert operative with the Planet Protectors, a secret United Nations agency charged with protecting Earth's environment. You're a spy on behalf of the planet. Your goal is to ensure a livable planet for future generations. Today's mission: secure the sustainability assets at the Stockholm Royal Seaport (SRS), one of Europe's most important sustainable development sites. A UN delegation of world leaders will visit SRS tomorrow. Use any means necessary to ensure the tour is a success."

1.1.5 Game and city map

See Figure 2.

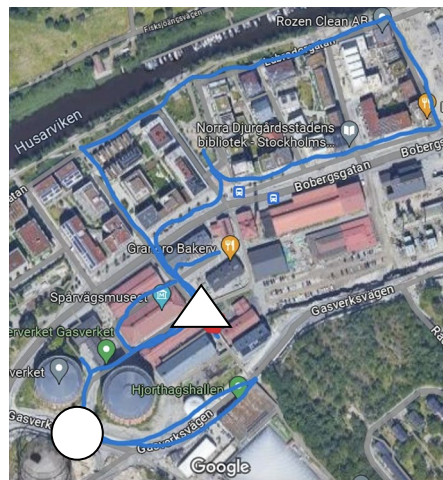


Figure 2: The bottom circle marks where participants started, the triangle is where participants ended. The drawn line is where participants would have to walk or the typical path they'd take to complete the game

2.2.5 Puzzles

A total of 14 puzzles were completed across the game map. The puzzles could not be accessed after completion or when not on location. See Table 1 for a list of the puzzle types.

Table 1: The order of puzzles with a brief description of the task and the learning mechanisms that task used to solve the puzzle

Puzzle Order	Puzzle Description & Learning Type
Puzzle #1	<i>How many steel vertical supports?</i> Matching visual elements to real-world contexts.
Puzzle #2	<i>Look around and find the name of the threatening organization.</i> Word puzzle, matching visual elements to real-world contexts.
Puzzle #3	<i>Find the SDG that speaks to teaching and learning, and report the code number.</i> Location task and reporting.
Puzzle #4	<i>What is the reading on the large and small gauge?</i> Location task and reporting.
Puzzle #5	<i>Heat and electric ducts, find which post holds a password, alphanumeric code.</i> Locating in a physical environment and reporting.
Puzzle #6	<i>Walk through the drainage system path and order images provided.</i> Matching visual elements to real-world contexts.
Puzzle #7	<i>Inspecting construction of the building, which image shows the renewable source from which this building was made?</i> Image recognition and matching.
Puzzle #8	<i>Locate statue pictured, confirm the security of this social value space by documenting which UN SDG spaces like this contribute to.</i> Visual search and analysis.
Puzzle #9	<i>From your position at the location in the image you can see a number of sustainability assets. Use a</i>

Puzzle Order	Puzzle Description & Learning Type
	<i>checklist to identify which SDG goals are observable at location.</i> Systematic observation and recording.
Puzzle #10	<i>Compare the given image to real signs and order the modifications.</i> Visual comparison.
Puzzle #11	<i>Waste management: order the number of images of the color-coded receptacles so they match the order of the symbols in the image.</i> Pattern recognition and sequencing skills.
Puzzle #12	<i>Find playground equipment visible in the images, which UN SDG do they refer to and report code from the checklist.</i> Observational and reporting.
Puzzle #13	<i>Blue and white markers with numbers/ symbols/ letters, find 7 symbols and use them to decode message.</i> Pattern analysis, visual search, logical reasoning, and problem solving.
Puzzle #14	<i>Look below (letters on floor) and decode the message.</i> Spatial skills, lateral thinking.

2.2.6 Post-survey

Immediately following the completion of the game, participants completed the following questions:

- Describe anything you learned during the game. Please be as specific as possible.
- Did you read the "Did you know?"
- My team worked together on every puzzle.
- Which role did you take during the game?
- I participated (e.g., read/listen to the questions, think through a possible solution, work together, etc.) throughout the whole game?
- I liked the game and had an enjoyable time playing it.
- Describe anything you learned during the game.
- Did you experience any difficulties or technical issues during the game?

2.3 Assessments

2.3.1 Personality

To determine personality information, each participant answered the Ten Item Personality Measure (TIPI; Gosling, Rentfrow, & Swann, 2003) as part of the pre-survey. Respondents indicated on a seven-point scale how well each item resonated with them (from 1 = "disagree strongly" to 7 = "agree strongly"). The TIPI measure comprised 10 survey items. Each item is delineated by the five personality domains, established by the Five Factor Model (Costa & McCrae, 1992). These include (1) extraversion, being sociable and active, (2) agreeableness, being soft-hearted and trusting, (3) conscientiousness, being organized and reliable, (4) emotional stability, being calm and relaxed, and (5) openness, being curious and creative.

2.3.2 Motivation

The Global Motivation Scale (GMS-28), completed during the pre-survey, was employed to assess motivations for participating in city games (Guay, Mageau, & Vallerand, 2003). The scale assesses behavior shaping motivation using 7 constructs: (1) intrinsic motivation, (2) motivation toward knowledge, (3) accomplishment and stimulation, extrinsic motivation subclassified, (4) identified, (5) introjected, (6) external regulation, and (7) amotivation. Participants responded to 28 items on a 7-point scale (from 1 = "does not correspond accordingly" to 7 = "corresponds accordingly").

2.3.3 Experience

Prior experience of participants was measured in the pre-survey and answers were recorded on a 5 point likert scale (ranging from 1 = "No, never" to "Yes, more than 10 times"). These questions included the following: (1) have you ever played a city game before and (2) have you ever done an escape room before.

2.3.4 Interest

Participant interest was measured in the pre-survey. Answers to the first interest question were recorded on a 5 point likert scale (ranging from 1 = "No, never" to "Yes, more than 10 times"). This question asked: "Do you enjoy escape rooms?" The second question measuring interest was a multi-select question, asking: "What games do you like to play? Select all that apply."

2.4 Procedure

Participants were contacted prior to arrival and given details about the game starting point, where they met the researcher(s). Upon arrival, the researcher(s) explained the study instructions and obtained written participant consent. Participants were guided through downloading the city games app, *Questo*, and locating the game within the app. They then completed a pre-survey. The researcher instructed the group to begin and left the group. The participants followed in-app instructions to complete 14 puzzles around the Stockholm Royal Seaport neighbourhood. Once the participants finished the game, they met the researcher to complete a post-survey. Player progress and performance statistics were tracked in the app.

2.5 Study Design

This study was a within groups quasi-experimental design. All participants experienced the game in groups of 2-4 for a duration of roughly an hour. Quasi-independent variables included personality, motivation, prior experience, and interest. The quasi-dependent variable in this experiment was self-reported game-based learning.

2.6 Analysis Approach

Data were analyzed using SPSS (v.31) to explore relationships between individual difference variables and game-related experiences. Pearson correlation analyses were conducted to examine associations between personality traits (as measured by the TIPI), motivational constructs (as measured by the GMS-28), and key game-related variables, including teamwork, enjoyment, prior escape room experience, and engagement with in-game content. These analyses were used to identify potential patterns and predictors relevant to participants' subjective experiences during the city game.

In addition to correlational analyses, independent samples t-tests were used to compare group differences in reported participation based on whether participants indicated that they had learned something from the game. A one-way analysis of variance (ANOVA) was also conducted to assess differences in reading engagement across groups categorized by the type of content participants reported learning. Effect sizes and confidence intervals were reported where appropriate to contextualize the strength and reliability of findings. All significance thresholds were set at $p < .05$.

3. Results

Pearson correlation analyses were conducted to examine the relationships between motivational constructs, personality traits, and game-related experiences. Intrinsic motivation was negatively correlated with teamwork, $r = -.467$, $p < .05$, and positively correlated with openness to experiences, $r = .525$, $p < .05$ (see figure 3). Intrinsic motivation was also positively associated with escape room enjoyment, $r = .44$, $p < .05$. These findings suggest that individuals with higher intrinsic motivation may report lower levels of teamwork, but greater openness and enjoyment during the escape room activity.

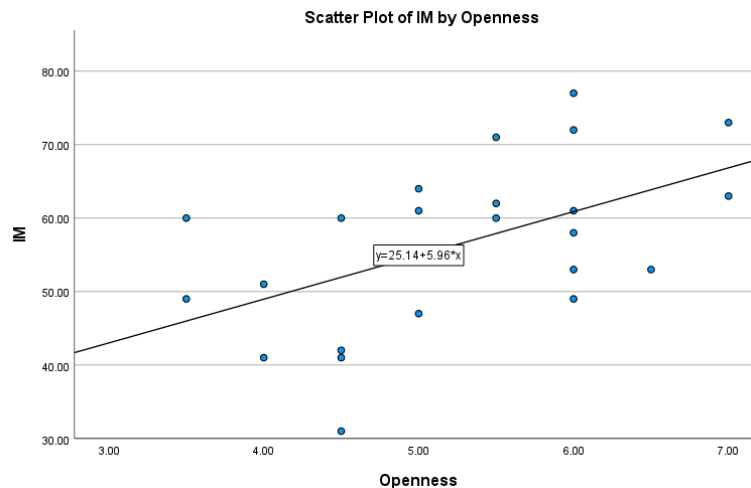


Figure 3: Depicts positive correlation between the personality trait “openness to experiences” and intrinsic motivation (IM)

A significant negative correlation was found between teamwork and openness to experiences, $r = -.550$, $p < .01$, indicating that participants who scored higher in openness were less likely to engage collaboratively with others.

Additional correlations revealed that amotivation ($r = .628$, $p < .01$) and introjected extrinsic motivation ($r = .503$, $p < .05$) were both positively associated with time spent reading game content. This suggests that participants with either amotivated or introjected motivational styles were more likely to engage with the game's reading components.

Further analyses showed that prior experience with escape rooms was positively associated with escape room enjoyment ($r = .505$, $p < .05$), but negatively associated with teamwork ($r = -.505$, $p < .05$).

An independent samples t-test was conducted to compare participation levels between participants who reported learning something from the game and those who did not. Results indicated a significant difference, $t(19) = -2.288$, $p < .001$, $F(1, 19) = 14.672$, with higher participation reported by those who indicated learning.

A one-way analysis of variance (ANOVA) was also performed to assess whether reading behavior differed based on the topics participants reported learning. The results demonstrated a significant effect, $F(3, 17) = 9.359$, $p < .001$, $\eta^2 = .623$, 95% CI [.199, .741], indicating that reading engagement varied meaningfully depending on the content learned. Figure 4 shows the distribution of reading effort on learning.

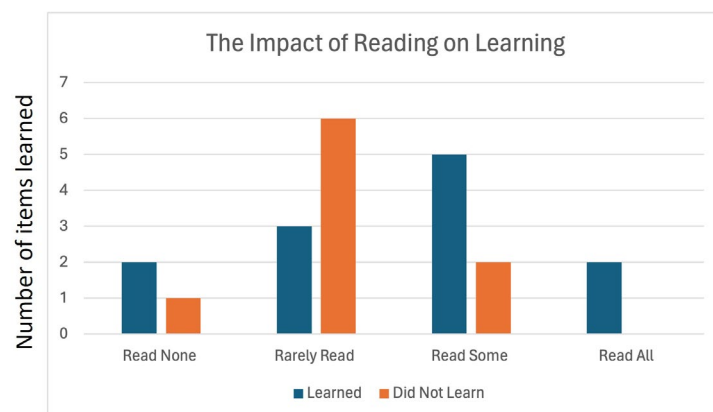


Figure 4: Depicts the distribution of reading effort on learning

4. Discussion

The central research question guiding this study was: to what extent does learning occur through participation in city games? More specifically, we examined whether factors such as participation, reading behavior,

personality traits, and motivational orientations predict learning outcomes in game-based contexts. We proposed two hypotheses: first, that participation in city games would lead to self-reported learning, and second, that individual differences, including personality, motivation, prior experience, and interest, would influence the quality of learning derived from gameplay.

Those who reported learning something, especially about sustainability or urban planning, also reported higher participation, supporting the hypothesis that engagement enhances learning and the absorption of educational content. A notable and unexpected finding was the negative correlation between intrinsic motivation and teamwork. This challenges the assumption that intrinsic motivation universally enhances collaboration, suggesting instead that intrinsically motivated individuals may prefer independent problem-solving. A similar pattern was observed for openness to experience, which was also negatively associated with teamwork. Contrary to prior research linking openness with collaboration, this suggests that, in exploratory games, openness may reflect a preference for individual exploration (Juhász, 2010).

Another key finding was the positive relationship between intrinsic motivation and enjoyment of the city-based escape game. This highlights the intrinsic rewards of gameplay and suggests that individuals driven by personal growth and achievement also derive enjoyment from such experiences. Further research into the interplay between intrinsic motivation and enjoyment could inform the design of immersive games that enhance engagement and satisfaction. Analysis of participants' prior escape room experience revealed that experienced players reported higher enjoyment but lower teamwork engagement. This suggests experienced players may prefer autonomy over collaboration. Designing games that account for varying skill levels can better accommodate both novice and experienced players, improving overall enjoyment and team dynamics.

A unique feature of the study was the inclusion of optional "Did you know?" sections, offering educational content on sustainability and urban development in the Stockholm Royal Seaport. These segments paused the in-game timer to promote stress-free reading. Interestingly, reading engagement positively correlated with both amotivation and introjected extrinsic motivation. Although typically associated with low engagement (Hulaj et al., 2020), these motivations may have been influenced by more engaged teammates, indicating group dynamics at play. These findings suggest a need to explore how less productive motivational styles can still support educational engagement in games.

4.1 Limitations

It is important to acknowledge several limitations of this study. The relatively small sample size ($n = 23$) limits the generalizability of the findings, and the sample's homogeneity, composed exclusively of women, most of whom were white, restricts the ability to explore how gender, race, or other demographic differences may influence experiences and learning outcomes in city games. Additionally, the small group size limited the exploration of group dynamics, which are particularly relevant in collaborative, team-based gameplay. The reliance on self-reported measures for constructs such as motivation, personality traits, and learning also introduces potential response biases, which may affect the accuracy of the results.

One important limitation of this study is the reliance on self-reported learning outcomes, which may be subject to biases such as social desirability, memory recall, or personal interpretation of what constitutes "learning." Without objective assessments to validate these reports, the findings should be interpreted with caution. Future research would benefit from incorporating independent or performance-based measures to more robustly evaluate learning outcomes in city game contexts.

4.2 Conclusions

City games, by incorporating engaging, hands-on learning activities, may support learners who are intrinsically motivated and prefer self-directed exploration, as well as those with lower intrinsic motivation who benefit from group influence to engage with reading materials and factual content. The negative correlation between intrinsic motivation and teamwork found in this study suggests that independent exploration may be more rewarding for some learners. This insight can inform city game design by allowing for independent tasks or optional collaborative elements, which could increase accessibility for learners who thrive on autonomous learning, such as introverts or students with social anxiety. Tailoring game design to accommodate such individual preferences could broaden participation in educational activities, fostering an inclusive learning environment for students with diverse engagement needs.

The study highlights how reading sections embedded within city games can support information retention and learning for certain types of players; Those with higher amotivation or introjected extrinsic motivation were

more likely to engage with these sections. This insight underscores the potential of city games to create multiple pathways to engagement and learning, allowing players to acquire knowledge through different modalities, which may especially benefit students who process information more effectively through reading than interactive play alone. Given these findings, city games could be designed with an understanding of diverse motivation styles, creating opportunities for knowledge acquisition through both self-driven and group-facilitated interactions. Embracing such flexible design strategies would allow city games to be more accessible, providing meaningful educational experiences to students with varying personality traits, learning preferences, and motivational profiles.

The findings of this study can be meaningfully interpreted through the lens of Self-Determination Theory (SDT; Deci & Ryan, 1985), which differentiates intrinsic motivation, engaging in an activity for inherent satisfaction, from extrinsic motivation, driven by external rewards or pressures. Our results show that intrinsic motivation was positively associated with openness to experience and enjoyment during the game, but negatively correlated with teamwork. This may suggest that intrinsically motivated individuals value personal exploration and autonomy, which aligns with SDT's emphasis on autonomy as a fundamental psychological need. Conversely, extrinsic motivational styles, such as introjected regulation, were linked to greater engagement with the game's informational content, indicating that external or internal pressures can also drive participants to seek knowledge, albeit through different motivational pathways. These distinctions show the importance of designing city games that support intrinsic motivation to enhance enjoyment and foster meaningful engagement, while recognizing that extrinsic motivators can play a role in promoting specific learning behaviors.

This study's contributions to games-based learning opens the door to further research on the educational potential of city-based escape games, particularly in relation to long-term knowledge retention, transfer, and real-world application. Future investigations might also examine how instructional strategies, such as debriefing sessions and scaffolding techniques (Friedrich et al., 2019), can be optimized to support learning outcomes in these environments. By expanding on the insights gained here, researchers can continue to refine our understanding of how game-based experiences shape learning and contribute to the design of more effective and engaging educational tools.

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Ethics declaration: The methods and protocol of the study were conducted in accordance with the standards specified in the 1964 Declaration of Helsinki and were approved by the local ethics committee of Uppsala University, The Swedish Ethical Review Authority (2022-03420-02).

AI declaration: No generative AI tools were used in the preparation, writing, editing, or analysis of this paper. All content reflects the original work and intellectual contributions of the authors.

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Gamification for Enhanced Recycling Engagement in Circular Economies

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Abstract: Global waste generation continues to rise, with current estimates ranging between 7 and 10 billion tons annually (Alvarez-Risco et al., 2022). Although Germany operates one of the most advanced recycling systems worldwide, its complexity - characterized by strict multi-bin separation rules, regional sorting variations, and the growing use of mixed-material packaging - presents significant challenges for residents. Additionally, public motivation to sort waste correctly is declining. The Transformers project addresses these challenges by developing a gamified, web-based application designed to promote correct recycling behaviour through interactive, educational, and motivational elements. This digital tool is part of a broader initiative to boost material recycling through digital innovation and encouraging active public involvement. By combining proven learning strategies with immersive gamification elements, the application significantly improves knowledge retention and fosters deeper user engagement in recycling activities. The gamification strategy and learning modules were developed based on interviews with experts from the recycling industry. A mixed methods approach also encompassed a design sprint with citizens and representatives of public authorities. Key features of the application include sorting simulations, knowledge quizzes, challenge-based activities, a personalised dashboard, weekly leaderboards, and progress summaries. Educational content is delivered through structured modules, gamified tasks, interactive games, and an integrated Recycling News Hub. A point-based rewards system further incentivises participation, enabling users to redeem their points for sustainable rewards. Future developments will integrate artificial intelligence to offer personalised recommendations, adaptive learning pathways, real-time chatbot assistance, and natural language processing-based summaries of recycling news.

Keywords: Digital engagement, Game-Based learning, AI-Enhanced learning, Public participation in recycling, Sustainability, Behavioural change

1. Triggering Action in an Era of Growing Waste

Recycling represents a central pillar of sustainable urban development and circular economies. As global consumption rises, recycling offers substantial opportunities for reducing raw material use and lowering carbon emissions. Despite Germany's advanced infrastructure with multi-bin systems and regulations, participation rates remain low, and recycling infrastructures are underdeveloped in many regions (Konstantinidou *et al.*, 2024). Research studies show that barriers to effective recycling systems are primarily behavioural, including knowledge gaps, operational complexity, and motivational challenges (Timlett and Williams, 2008a). Germany provides an advanced recycling infrastructure with a multi-bin separation system, regional logistics, and adequate regulations. However, inconsistencies in sorting rules and the growing prevalence of mixed-material packaging cause incorrect waste separation (Dahlén and Lagerkvist, 2010) which leads to an increased contamination of recyclable materials, lower recycling rates, and declining participation rates (Konstantinidou *et al.*, 2024). Especially the dwindling acceptance is crucial, as effective recycling systems rely on more than only high-quality infrastructure; they require sustained public engagement. As Timlett and Williams argue, participation declines without ongoing guidance, personalised feedback, or motivational incentives (Timlett and Williams, 2008a). Sustained engagement demands continuous behavioural reinforcement. Behavioural research identifies psychological and social factors hindering recycling participation, e.g. invisible impact, lack of social recognition, inconsistent sorting instructions, and insufficient feedback mechanisms (Timlett and Williams, 2008a; Konstantinidou *et al.*, 2024). These barriers are especially relevant among diverse urban populations, including international residents unfamiliar with local rules. Regarding that, digital participation solutions offer a variety of new ideas and approaches, particularly those using advanced motivational mechanisms like gamification. Game elements such as challenges transform mundane tasks into interactive and rewarding experiences. In terms of personal feedback and adaptive content, AI solutions offer a variety of new possibilities. As Vegesna highlights, future digital sustainability solutions will integrate AI-powered features for real-time personalised support, predictive feedback, and context-aware engagement (Vegesna, 2023). Building on these foundations, this research investigates how a gamified platform can foster correct recycling behaviour through interactive learning modules, challenge-based participation, real-time feedback, and social incentives. In the

Transformers project funded by the Ministry of Culture and Science of North Rhine-Westphalia in Germany we developed the Transformers-App through a participatory design approach involving municipal experts, recycling professionals, and citizens. The app aims to create sustainability knowledge in a broadly diverse population and transfer it into measurable action. The approach builds on the principles of circular economies. By aligning gamified learning with adaptive engagement strategies, this study contributes to the field of sustainability education and digital behaviour change bridging the gap between recycling knowledge and consistent action.

2. Gamification, Behaviour Change, and Engagement in Recycling Systems

Education for Sustainable Development (ESD), as defined by UNESCO, aims to equip learners with the knowledge, skills, values, and attitudes necessary to make informed decisions and take responsible actions for environmental integrity, economic viability, and social equity, both for present and future generations (UNESCO, 2020). Digital strategies especially gamification, play a critical role in transforming passive awareness into sustained recycling behaviour by combining informational support with motivational mechanisms. In the following chapters the conceptual basis of our work is laid.

2.1 Conceptual Foundations: Gamification, Serious Games, and Behaviour Change Approaches

Gamification has become an established approach for enhancing user engagement and activating sustainable behaviours. It applies game-design elements such as points, badges, challenges, feedback loops, and leaderboards in non-game contexts to increase engagement and behavioural persistence (Deterding et al., 2011). In sustainability education, gamification has demonstrated measurable effects on learning retention, behavioural activation, and habit formation (Hoffmann and Pfeiffer, 2021; Novo et al., 2024). It can be implemented across multiple layers of design, including surface-level interface elements, underlying game mechanics, heuristic principles for user interaction, and deeper conceptual frameworks that guide system behaviour (Deterding et al., 2011). In sustainability education, gamification bridges the gap between environmental knowledge and consistent behavioural application. Hoffmann and Pfeiffer (2021) found that scenario-based challenges, iterative feedback, and reinforcement improved waste-sorting knowledge retention and the real-world application of sorting rules (Hoffmann and Pfeiffer, 2021). These results show that solutions with motivational design enhance not only cognitive understanding but also lead to behavioural changes. Closely related to gamification are serious games. These represent fully developed game environments created for educational, behavioural, or training purposes. As Bopp (2009) outlines, serious games can be categorised into educational, health, corporate training, and persuasive games, depending on their thematic objectives and targeted outcomes (Bopp, 2009). In sustainability contexts, serious games allow users for instance to engage with simulated decision-making scenarios and experience the environmental consequences of their choices within risk-free, immersive settings (Dudok and Pigniczki-Kovács, 2024). Such simulations support experimental learning, often facilitate a deeper understanding of complex environmental systems and trigger behavioural changes. Behaviour change strategies in sustainability education are based on psychological theories that explain human motivation and action. Self-Determination Theory identifies autonomy, competence, and social relatedness as fundamental psychological needs for intrinsic motivation and long-term engagement (Deci and Ryan, 1985). This theory has been applied in environmental contexts to guide the design of interventions that encourage sustainable behaviour through intrinsic triggers rather than external enforcement. Thus, Hsu developed a framework with key behavioural triggers such as challenge, feedback, perceived impact, and reward mechanisms to maintain user attention and commitment in environmental settings (Hsu, 2025). By aligning game design with motivational theory, Hsu's work offers an evidence-based structure for developing gamified sustainability interventions that go beyond surface engagement to support lasting behavioural change.

2.2 Behavioural Engagement Strategies in Sustainability Education

Effective recycling education integrates knowledge transfer with motivational feedback and scalable digital learning environments for flexible, individualized learning in daily life (Rof, Bikfalvi and Marques, 2024). In digital learning environments gamification plays a vital role (Timlett and Williams, 2008b; Konstantinidou et al., 2024; Hoffmann and Pfeiffer, 2021). Social mechanisms like leaderboards and community challenges foster shared responsibility and enhance participation in recycling systems (Briones et al., 2018). Projects like GoBeEco demonstrate how gamified elements combined with real-world actions improve sustainable behaviour (Novo et al., 2024). Timlett and Williams emphasise that the most effective recycling tools combine educational content, personalised feedback, challenge progression, and local adaptability (Timlett and Williams, 2008b).

2.3 Overview on Existing Digital Solutions for Recycling Engagement

Numerous digital initiatives have been exploring the potential of gamification and behavioural engagement strategies to encourage sustainable practices and participation in recycling. However, most focus on isolated engagement aspects rather than offering an integrated platform. The GoBeEco project for instance used gamification for general sustainability habits (Novo et al., 2024) but lacked operational recycling guidance. RecycleMich, an Austrian recycling app, was developed to assist users in correctly separating plastic, metal, and beverage carton packaging in accordance with European recycling targets. RecycleMich incorporates barcode scanning recycling challenges and offers discounts or vouchers for sustainable behaviour (Denovo · RecycleMich App, no date). Nevertheless, its educational dimension remains limited. In contrast, apps like JouleBug promote sustainable behaviours through social competitions, digital rewards, eco-friendly challenges and rewards (Make Sustainability Second Nature - JouleBug, no date) but lacks localised recycling guidance. The TerraCycle-system as another example enables recycling of hard-to-recycle materials via mail-in programs (Wikipedia contributors, 2025), but its digital engagement focuses on logistics rather than daily behaviours. Sensoneo delivers smart waste management solutions for municipalities, focusing on real-time bin monitoring, waste tracking, and collection route optimisation (Smart Waste Management Company | SENSONEO, no date). Although the platform enhances waste system efficiency on a municipal scale, its citizen-facing engagement features are minimal, lacking gamification or educational modules to foster recycling literacy and sustained behavioural change. While each project demonstrates strengths, there remains a gap for solutions combining modular learning, real-time behaviour tracking, personalised feedback, and gamified engagement within one platform. A novel solution shall overcome this gap by offering structured educational modules, challenge-based participation, real-time feedback, and sustainability rewards, translating behaviour change theories into a coherent digital intervention. By aligning educational content with behaviourally supportive game mechanics, the Transformers-App offers a novel contribution to digital sustainability education, supporting users in translating knowledge into consistent and measurable recycling action.

3. Research Approach and Participatory Development

In this research, a Design Science Research (DSR) methodology was used to guide the development and evaluation of the Transformers-App, a digital gamification solution to promote sustainable recycling engagement and behaviour change. DSR has been chosen for its systematic approach for solving real-world problems through the creation and evaluation of innovative artefacts particularly in complex socio-technical contexts where theory-driven design and iterative stakeholder feedback are essential (Hevner and T. March, 2004). The Transformers-App operates at the intersection of behavioural science, digital sustainability education, and user-centred interface design aligning with DSR's objective of producing practically relevant and rigorously evaluated solutions (vom Brocke, Hevner and Maedche, 2020). The methodology facilitated an iterative refinement of the app in response to real-world user feedback while contributing to the broader scientific understanding of digital behavioural intervention. Applying the DSR process allowed the project to systematically address key behavioural barriers in recycling through the design, testing, and improvement of an educational and motivational app. The research followed four main phases: (1) Problem exploration and state-of-the-art analysis, (2) Expert interviews and participatory stakeholder engagement, (3) Co-design sprint and student involvement, and (4) evaluation and usability testing.

3.1 Problem Exploration and State-of-the-Art Conclusions

The research began by exploring behavioural barriers in recycling participation and identifying effective design strategies in sustainability education. A literature review was conducted to analyse existing research on behavioural engagement strategies, gamification approaches, and recycling practices. The most promising analysis results for supporting behaviour change were beside feedback loops, rewards and scenario-based learning (Deterding et al., 2011; Hoffmann and Pfeiffer, 2021) serious games to foster experiential learning and reflection (Bopp, 2009). In the conceptual design of the app, we also emphasised the importance of motivational triggers and personalised engagement (Hsu, 2025). The analysis of existing recycling engagement projects came to the main result that most of the projects lacked an integration of modular learning, real-time behaviour tracking, and user-centred feedback mechanisms. These gaps shaped the conceptualisation of the Transformers-App as a holistic platform combining education, feedback, challenge engagement, and behavioural analytics. Our approach focuses on translating theoretical insights from gamification and behaviour change research into a participatory digital intervention for recycling engagement.

3.2 Expert Interviews and Participatory Stakeholder Engagement

To align the app development with practical needs, in a second research phase semi-structured expert interviews were conducted with municipal waste representatives and stakeholders from recycling industry. The results of the first phase were incorporated into this phase and thus discussions focused on operational challenges in waste management, user behaviour barriers in recycling participation, specific problems related to plastic waste, and digital opportunities for behavioural support. Experts highlighted that beside user confusion due to regional variation sorting rules, a lack of feedback on recycling behaviour and missing personalized support can be seen as the main factors contributing to sorting errors and disengagement. Motivational systems were seen as insufficient, especially for international users unfamiliar with local recycling practices. Plastic waste management emerged as a major concern exacerbated by contamination and mixed materials. Experts highlighted the need for digital solutions offering targeted guidance, feedback, and real-time support. Further on they emphasized that user-centred tools should combine education with real-time behavioural reinforcement to improve recycling outcomes. The experts' findings were used as input in a half-day co-design sprint with 10 participants, comprising municipal partners, UX designers, recycling experts and scientific researchers, to develop a first design concept. The sprint was based on the design sprint by Knapp et al. (2016). The original two-day group work phase was shortened to half a working day to save time, as the workshop participants were volunteers who did not receive any financial compensation. Results of the sprint included several aspects: camera-based identification of materials, explanation of material separation and presentation of the results/effect of correct collection/separation.

3.3 Student Involvement in App Development and Evaluation

In a third phase master's students of computer science participated in two ways. First, through the co-design sprint in an early stage of the project. From a user perspective they identified requirements and generated innovative ideas. In a later phase students project groups developed digital recycling-related prototypes (e.g. an informative campus-oriented app prototype combining recycling guidance with campus services like Mensa menus, course schedules or a waste-bin sorting smartphone game). Although not directly interrelated with Transformers-App development, these projects provided valuable insights into user engagement, interface design, and gamified educational strategies. For instance, it has been demonstrated that recycling can be communicated in a more subtle way through a visually sophisticated mobile sorting game with engaging gameplay, rather than through text-based knowledge transfer.

3.4 Evaluation

Project results were evaluated in group workshops and individual sessions. One municipal waste representative and four stakeholders from recycling industry tested core features such as onboarding, challenge-based participation, progress dashboard, and educational modules. Feedback focused on usability, clarity, content relevance, and motivational mechanisms. In particular, experts discussed data protection aspects (e.g. clear names and activity tracking) and the question of whether there should be a difference in user motivation between non-profit and commercially collected materials. Continuous expert input ensured the app met user needs, improving its support for recycling behaviour.

4. Transformers-App: A Gamified Platform for Behavioural Changes in Recycling Processes

Building on the theoretical foundations outlined in Chapter 2, the app integrates key behavioural strategies such as motivational triggers, challenge-based engagement, feedback mechanisms, and social incentives. The app's architecture was designed to overcome limitations identified in existing recycling applications, including the lack of integrated educational content, minimal operational guidance, and absence of personalised feedback. This chapter presents the conceptual motivations, technical features, and modular infrastructure of the app, highlighting how it translates state-of-the-art knowledge into applied behavioural change design.

4.1 Conceptual Foundations and Design Motivation

The Transformers-App was developed to address behavioural barriers in recycling through gamification, participatory design, and modular education. The app's design is grounded in Self-Determination Theory (L. Deci and M. Ryan, 1985), embedding autonomy is supported through user-defined goals, competence via feedback and progress dashboards, and relatedness through leaderboards and community challenges. These principles combined with behavioural triggers from Chapter 2, guided the functional development.

4.2 Gamified Architecture and Core Interface

The Transformers-App is structured around a personalised progress dashboard. While users do not receive an immediate overview upon logging in, the dashboard becomes the central space for tracking recycling-related activities once engagement begins. As shown in Figure 1, the interface provides access to the user's accumulated points, weekly activity, current level, progress graphs, material distribution charts, and a community leaderboard. These metrics are also used on the homepage. To support the onboarding and initial engagement process, a dedicated help icon is accessible from the dashboard, which leads to an introductory section explaining the purpose and key features of the app to guide users in a transparent and accessible manner. Points are earned by completing challenges, engaging with educational modules, and scanning recyclable items (via packaging barcodes). Scanned items are matched with public databases to determine the material and product information for the metrics. Users can also adjust the information (e. g. material, weight) themselves. Accumulated points contribute to level progression, reinforcing participation and recognising effort. In contrast to existing solutions (Section 2.3), which focus on badges, Transformers emphasises tracking of cumulative performance to encourage ongoing engagement. The dashboard features visual feedback tools such as a weekly activity and material distribution chart to help users to contextualise their recycling efforts within a broader sustainability framework. These tools support effective learning and encourage sustainable changes in recycling behaviour. The leaderboard encourages social comparison and collective engagement by ranking users based on their recycling activities. This drives long-term motivation by encouraging shared responsibility and constructive competition. By combining the tracking of personal progress with visibility in the community, the dashboard supports both self-regulated behaviour and social interaction in a gamified system.

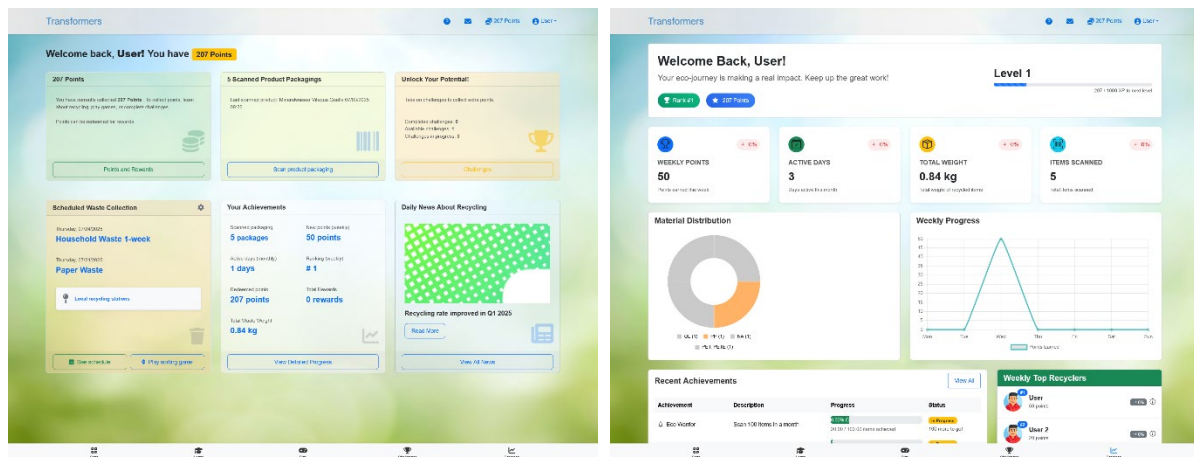


Figure 1: Transformers-App Home (left) and Progress Dashboard (right) with user rank, recycling data, achievements, leaderboard, and engagement metrics

4.3 Educational Integration and Learning Flow

A key feature of the Transformers-App is the educational component, which aims to close knowledge gaps through interactive micro-learning modules (Figure 2). These modules cover topics such as waste sorting, e-waste disposal and common household sorting mistakes and combine clear objectives with scenario-based stories. Each module ends with a short quiz that reinforces learning through immediate feedback and encourages the application of recycling behaviour in real life. External resources from organisations such as the European Commission and Recolight lend credibility to the content, while the Eco Games Hub supports further practice through interactive sorting games. The app ensures that learning outcomes are translated into measurable recycling actions by embedding modular learning into a game-based system, encouraging long-term sustainable habits. For example, the learning modules communicate information on separating materials or mishthrows, which in turn improves performance in sorting games and collection challenges.

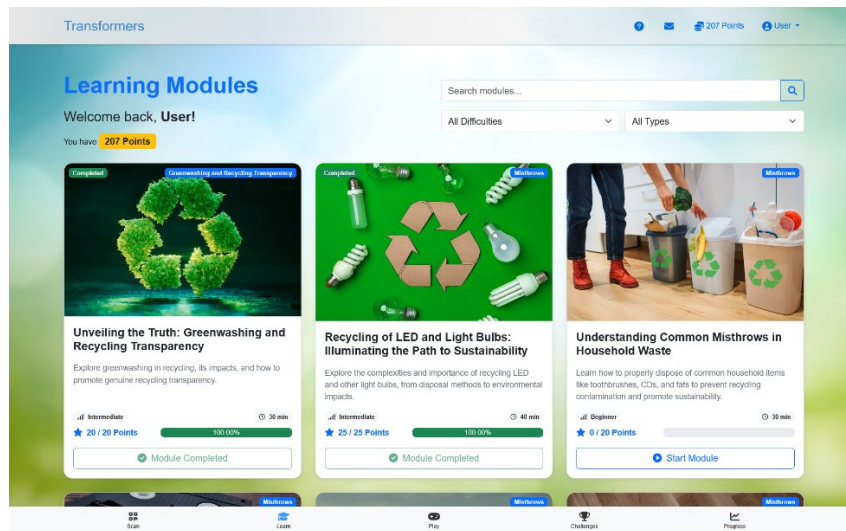


Figure 2: Learning module introduction page outlining key objectives and trusted resources

4.4 Challenges and Motivational Progression

The developed solution features a progressive challenge system designed to activate and sustain recycling behaviours. These challenges are structured around specific, measurable goals, beginning with simple tasks like scanning recyclables items and advancing to more complex tasks such as weekly plastic consumption challenges. Each challenge is time-bound to maintain momentum and follows an incremental difficulty structure, allowing users to gradually build recycling habits through achievable milestones. This progression logic draws on behaviour change strategies discussed in Section 2.2, which emphasise the importance of reinforcement through incremental achievements. Successful challenge completion contributes to multiple engagement layers: users receive points, digital badges, leaderboard advancement, and access to exclusive rewards. These multi-layered incentives foster motivation by recognising both short-term efforts and long-term behavioural commitment. A distinctive feature of the system is its flexibility: external partners, such as municipalities and companies, are encouraged to design and publish their own challenges, allowing the app to be tailored to local recycling needs and sustainability goals. This adaptability allows the app to tailor content to local recycling rules, community needs, and sustainability initiatives. By linking individual participation to broader collective efforts, the app transforms recycling from a routine task into a goal-driven and habit-forming civic engagement activity.

4.5 Social Incentives and Tangible Rewards

The Transformers-App integrates social incentives and a modular reward system to connect digital engagement with real-world sustainability outcomes. A community leaderboard promotes social comparison, recognition, and shared environmental responsibility. Furthermore, users can accumulate points, which can be redeemed to rewards. The user-friendly rewards interface helps users to track progress and recognise the environmental value of their actions. In the participatory design workshop, we developed conceptual reward ideas including custom 3D-printed items with environmental impact certificates, access to recycling seminars and workshops, and local events with sponsored gifts. Participants discussed the possibility of enabling external partners sponsoring challenges or offering branded rewards. Though conceptual, this flexible reward structure demonstrates the app's potential to scale partnerships and engage diverse stakeholders in sustainability campaigns. By combining digital recognition, tangible rewards, and scalable partnerships, the app fosters sustained, community-driven recycling behaviours.

4.6 Technical Infrastructure and Analytics Architecture

Transformers technical infrastructure is a modular, scalable system designed for adaptability and integration with recycling and sustainability initiatives. It showcases core engagement mechanisms while supporting future expansion. The architecture comprises three main layers: user interface, application logic, analytics/administration layer. These layers interact via defined interfaces, ensuring modularity. Components like the educational module and the reward mechanism can be adapted for other platforms without major changes. The frontend, built with Bootstrap, offers a responsive, device-independent interface with personalised progress tracking, educational content, and community features adaptable to diverse audiences. The backend, implemented with Node.js, manages user interactions in an event-driven environment, with Firebase enabling

real-time data handling, authentication, and cloud-based database services. The analytics layer supports personalised feedback, and behaviour monitoring, while an administration dashboard allows system administrators to create and configure challenges, monitor engagement, and adjust educational content based on behavioural data. Hosted on Microsoft Azure, the system ensures reliability and scalability. This modular prototype provides a flexible foundation for behavioural change across varied settings supporting future enhancements like AI-driven personalization, predictive analytics, and adaptive learning, and integration into broader sustainability ecosystems.

5. Artificial Intelligence for Smart Recycling Guidance

The future integration of Artificial Intelligence (AI) can enhance the recycling app that provides real-time recycling statistics, visual feedback, and gamified learning modules in a variety of ways. This is summarised in the following figure:

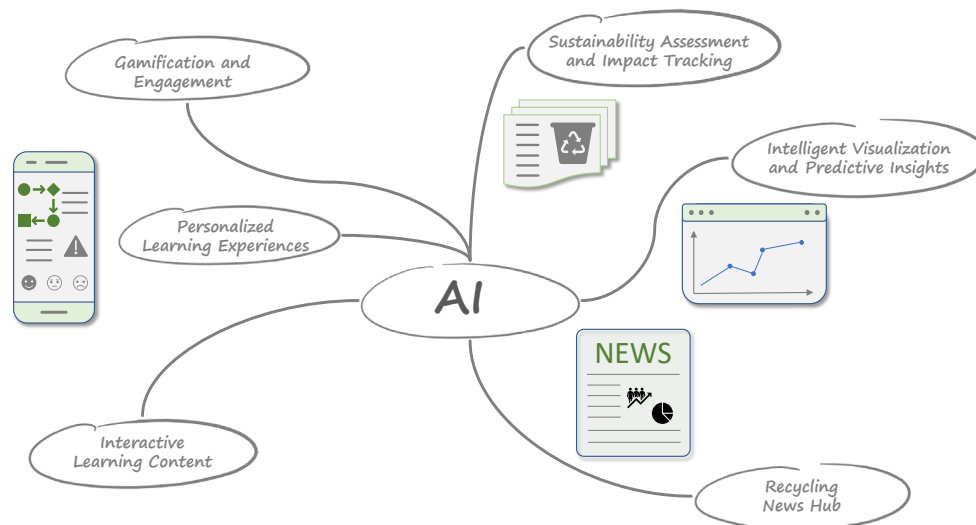


Figure 3: Integrating Artificial Intelligence for Smart Recycling Guidance

By analysing user behavior, the integration of AI enables the creation of personal learning paths. The selection and content of different modules can be customized to the individual user by using AI, guiding them on their individual learning path. AI can support users to design the learning path individually and interactively: the users are motivated to change their behaviour through customized goals and levels of the game-based tasks which are generated individually for them. Balanced feedback e.g. suggestions or predictions helps to achieve this (see e.g. Sajja et al., 2024). AI-generated analyses of individual learning progress and the consequences of users' recycling behaviour help users to adapt their behaviour where necessary (see e.g. Yayzy Footprint Calculator) and make it possible to calculate and visualize the individual impact of users' behaviour on the environment. This makes it very clear to users how useful it is to engage in recycling and thus support the goals of the circular economy. AI can thus play the role of a virtual and personal tutor that provides feedback in real time, interacts with the user, generates customized learning content, offers tips and tricks and motivates the user, e.g. through quizzes (see also Chen et al., 2023; Goel, 2020). Natural language processing (NLP) can summarize the latest recycling news, allowing users to quickly access information and better understand recycling habits and their impact. Future AI integration in the Transformers app will offer personalized learning, enhanced engagement through games and quizzes, and insights into user behaviour impact.

6. Discussion

The evaluation of the project results combined expert workshops and usability testing, providing comprehensive insights into its effectiveness in fostering recycling engagement. Experts from municipal waste management, recycling companies, and sustainability education institutions participated in structured feedback sessions. These sessions assessed app clarity, behavioural guidance mechanisms, and the motivational logic of gamified challenges. Feedback highlighted strengths such as real-time feedback integration, challenge-based engagement, and adaptive support for diverse user profiles. The app's gamified structure — point systems, progress tracking, and community leaderboards — was perceived effective in initiating and reinforcing behavioural changes. Experts highlighted the flexibility of the challenge system and the role of analytics in enabling personalised feedback and behavioural reflection. Whereas the overall evaluation was successful, some

improvement suggestions concerning clarity, the quality of feedback messages, and an enhanced visual presentation of behaviour tracking were made. A major strength of the research was its participatory development methodology, ensuring iterative improvement based on both institutional expertise and user perspectives. However, limitations must be acknowledged: testing occurred primarily within a university setting among users already interested in environmental issues. Broader evaluations are necessary to assess adaptability and long-term impact across diverse demographic and infrastructural contexts. Overall, our findings affirm that gamified digital tools can bridge the gap between environmental knowledge and consistent behaviour, particularly when supported by interactive feedback and community engagement. Future work should explore how localised content, adaptive learning paths, and cross-sector partnerships can strengthen behavioural outcomes. As a modular platform, the developed solution presents a promising basis for scalable, collaborative recycling education within the circular economy transition.

7. Conclusion and Path Forward

This research addressed the challenge of promoting correct recycling behaviour through digital solutions that integrate education, motivation, and engagement. Within the framework of ESD, the study demonstrated how gamification and interactive learning can support behavioural change and foster sustainable practices in everyday life. The development of the Transformers-App offered valuable insights into translating recycling knowledge into measurable action through a user-centred design approach. It contributes to the field of digital sustainability education by combining structured learning modules, challenge-based engagement, and personalised feedback mechanisms. Developed through a participatory process, the app addresses key barriers such as sorting complexity, lack of guidance, and low motivation. By embedding behavioural theory into gamified strategies, the app illustrates how digital tools can bridge the gap between environmental awareness and consistent action. Building on this foundation, future research should explore the app's adaptability across diverse infrastructural contexts and evaluate its long-term behavioural impact. Emphasis should be placed on pilot testing to assess usability and effectiveness in different scenarios and conditions. Moreover, future development can benefit from integrating AI-driven personalisation, municipal system interoperability, and deeper social networking features.

Ethics Declaration: The ethical clearance was not required for the research.

AI Usage Declaration: No AI tools were used in the development the Transformers-App. For the paper, AI-based tools were minimally employed to paraphrase or enhance the wording of some sentences, but they did not contribute to the overall content creation, data analysis, or structure. All core intellectual contributions were human-driven, and AI use was limited to minor stylistic improvements.

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Designing AI-Enhanced Educational Digital Escape Room Games (EDERGs): A Framework for Teacher Implementation

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Abstract: In recent years, educational digital escape room games (EDERGs) have become a dynamic method for fostering problem-solving, collaboration, and engagement in learning environments. Simultaneously, artificial intelligence (AI) has emerged as a powerful tool to enhance personalization, adaptivity, and real-time feedback in educational contexts. While both domains hold significant pedagogical potential, teachers often lack accessible guidance on how to meaningfully integrate AI into the design of educational games. This study addresses this gap by proposing a design and development research (DDR) project aimed at constructing a step-by-step framework to support teachers in designing AI-enhanced EDERGs. The research explores the question: How can teachers design AI-enhanced EDERGs? Drawing on insights from previous professional development sessions with in-service teachers, this study adopts a qualitative approach to capture educators' experiences, needs, and reflections. Through iterative cycles of analysis, design, evaluation, and refinement, we develop a practical and theoretically grounded framework that combines game-based learning principles with AI-enhanced instructional strategies. The proposed framework outlines key design steps, including setting pedagogical goals, crafting meaningful narratives, designing puzzles aligned with learning outcomes, and integrating AI components such as adaptive hints, automated feedback, and learner analytics. Teacher feedback collected through interviews and reflection journals informs the refinement of the model, ensuring its usability and relevance in real classroom settings. This paper presents the initial version of the framework along with examples of how it can be applied by teachers with varying levels of technical expertise. By bridging the gap between game-based learning and AI integration, the framework aims to empower educators to create more engaging and responsive learning experiences. The study contributes to the field by offering both a practical design guide for educators and a foundation for future research on AI-supported educational game development.

Keywords: Educational digital escape room games, Game-Based learning, Artificial intelligence in education, Technology integration in education, Instructional framework

1. Introduction

In today's technology-rich classrooms, educators are constantly seeking new ways to foster student engagement, collaboration, and critical thinking. Educational digital escape room games (EDERGs) have emerged as a powerful strategy in this regard, transforming learning environments into interactive problem-solving adventures (Fotaris and Mastoras 2019). Simultaneously, AI has revolutionized educational possibilities by enabling real-time feedback, personalized pathways, and adaptive learning experiences (Luckin, Griffiths and Forcier, 2016).

While both game-based learning and AI offer unique pedagogical benefits, the meaningful integration of these two domains remains a significant challenge for educators. Teachers often lack structured, practical guidance on how to design AI-supported educational games—particularly when it comes to balancing pedagogical goals with technical implementation (Chassignol et al, 2018). This gap is even more pronounced when considering non-technical educators who may not have access to specialized development tools or AI expertise.

Despite the growing research on AI in education and the increasing use of educational games, few studies offer a comprehensive framework that supports teachers in designing AI-enhanced EDERGs. Most existing approaches focus either on game mechanics or AI functionalities, without offering a unified and teacher-friendly model that brings these elements together in a meaningful instructional design.

This study addresses this gap by asking: How can teachers design AI-enhanced educational digital escape room games? Using a design and development research (DDR) approach, the study draws on qualitative data collected during professional development sessions with teachers. The result is a practical and theoretically grounded framework that guides educators step-by-step through the process of integrating AI into EDERG design. By doing so, this study aims to bridge the gap between innovation and implementation, offering a solution that is both visionary and grounded in classroom realities.

2. Literature Review

To develop a meaningful framework for designing AI-enhanced educational digital escape room games, it is essential to examine existing literature across three key domains: game-based learning, artificial intelligence in education, and technology integration models. Each area provides a foundation for understanding the opportunities and challenges of combining pedagogy, technology, and instructional design in innovative ways. This review begins by exploring the pedagogical value and design principles of EDERGs, followed by an overview of the roles AI can play in educational contexts. Finally, the review discusses existing technology integration frameworks that inform the structure and scaffolding of the proposed model.

2.1 Educational Digital Escape Room Games (EDERGs)

Educational digital escape room games are gamified learning experiences in which students solve puzzles, interpret clues, and complete tasks within a narrative structure to achieve a specific learning goal. These games are typically time-bound, collaborative, and designed to promote problem-solving, critical thinking, and content mastery (Fotaris and Mastoras, 2019). As digital adaptations of physical escape rooms, EDERGs allow for greater flexibility in classroom use, especially when implemented through platforms such as Google Forms, Sites or Genially.

Recent studies have shown that EDERGs foster learner motivation and engagement, particularly when designed around meaningful challenges and authentic scenarios (Veldkamp et al, 2020). Their collaborative structure also aligns with social constructivist perspectives on learning, in which knowledge is co-constructed through dialogue and shared activity. Despite their growing popularity, many teachers face difficulties in designing EDERGs, especially when required to align gameplay with curricular goals and integrate digital tools. While template-based solutions exist, they often do not provide pedagogical or strategic support for meaningful instructional design (Borrego et al, 2017). Moreover, as noted in Kara (2021), there is a growing need for structured guidance that enables teachers to design these experiences independently, even without advanced technical expertise.

The integration of AI into escape rooms is a relatively new and underexplored area. Early experiments have shown that AI can support real-time scaffolding, adaptive hint systems, and data-informed personalization within game environments (Khine, 2024). However, most existing AI-enhanced escape rooms have been developed by researchers or developers—not teachers—highlighting the need for a framework that enables classroom educators to access and utilize such technologies in a pedagogically grounded way.

2.2 Artificial Intelligence in Education

Artificial intelligence (AI) has emerged as one of the most influential technologies shaping the future of education. In recent years, AI applications have expanded rapidly, enabling systems that can provide real-time feedback, personalize learning pathways, detect learner emotions, and assist in both assessment and content creation (Luckin, Griffiths and Forcier, 2016; Holmes, Bialik and Fadel, 2019). These technologies hold promise for making learning more adaptive, data-driven, and responsive to student needs.

AI-enhanced learning environments can support differentiated instruction by automatically adjusting the level of challenge or providing timely hints based on learner behaviour (Das and Ray, 2025). Moreover, intelligent tutoring systems and learning analytics platforms have been shown to improve student outcomes by identifying gaps in understanding and tailoring instruction accordingly (Baker and Inventado, 2014). In addition to cognitive support, AI has also been applied in the affective domain—for instance, by recognising learner frustration or disengagement and responding appropriately (Woolf, 2010).

Despite these advances, integrating AI into classroom practice remains complex. Many teachers lack both the technical knowledge and conceptual understanding needed to effectively implement AI tools (Zawacki-Richter et al, 2019). Concerns around ethics, data privacy, and transparency further complicate adoption, particularly in K–12 settings where student data sensitivity is a major consideration. Furthermore, much of the existing research and development in AI for education is geared towards system developers, not end-users such as teachers (Chassignol et al, 2018).

In the context of game-based learning, the potential of AI is only beginning to be explored. AI can enhance educational games by offering real-time scaffolding, tracking progress, and generating content dynamically (Khine, 2024). However, few frameworks exist to help educators integrate these tools meaningfully and pedagogically. As AI continues to evolve, there is a pressing need to develop practical, teacher-friendly

frameworks that align AI capabilities with instructional goals—especially in innovative formats like educational digital escape room games.

2.3 Technology Integration Models as Design Inspiration

Successfully integrating artificial intelligence into educational practices requires more than access to tools—it demands pedagogical frameworks that help educators make informed, purposeful design choices. Over the past two decades, several models have been proposed to guide technology integration in teaching and learning. Among the most influential are the TPACK framework, the SAMR model, and the Technology Integration Matrix (TIM). These models provide valuable conceptual foundations for designing a framework that supports teachers in creating AI-enhanced educational digital escape room games.

The Technological Pedagogical Content Knowledge (TPACK) framework emphasizes the intersection of content, pedagogy, and technology knowledge, suggesting that effective educational technology use arises when these domains are thoughtfully aligned (Mishra and Koehler, 2006). In the context of AI-enhanced EDERGs, TPACK offers a lens through which teachers can reflect on how AI tools support both disciplinary learning and instructional strategy within the game environment.

The SAMR model, developed by Puentedura (2006), provides a four-tier continuum of technology use in education: Substitution, Augmentation, Modification, and Redefinition. SAMR encourages educators to move beyond simple tool replacement and toward transformative practices. In game-based learning contexts, AI may begin as an augmentative tool (e.g., auto-generating clues) but has the potential to redefine the learning experience through adaptive gameplay and intelligent scaffolding.

The Technology Integration Matrix (TIM), developed by the Florida Center for Instructional Technology (2011), categorizes technology use across five levels of integration (Entry to Transformation) and five learning characteristics (active, collaborative, constructive, authentic, and goal-directed). TIM's focus on learning experience and student agency aligns well with the immersive and participatory nature of escape room games, and provides inspiration for how AI can be mapped onto different types of learning engagement.

Together, these models offer conceptual tools for building a framework that is not only technically grounded but also pedagogically meaningful and accessible to teachers. By drawing from these traditions, the proposed framework aims to help educators make thoughtful decisions about where, when, and how to integrate AI into the design of EDERGs.

3. Method

3.1 Research Design

This study adopts a design and development research approach, as outlined by Richey and Klein (2014), to systematically create and refine a framework for designing AI-enhanced educational digital escape room games. DDR is particularly suited to studies that aim to produce practical, usable educational interventions while grounding them in theoretical and empirical research (Richey, Klein and Nelson, 2003). The methodology involves iterative cycles of analysis, design, implementation and evaluation, enabling close collaboration with end-users - in this case, pre-service teachers - throughout the development process. A high-quality design and development study aligns instructional design practices with clearly defined research goals. The process typically follows an iterative cycle encompassing stages such as analysis, development, implementation, and evaluation. Throughout this cycle, researchers collaborate with participants to co-develop a product that holds scholarly value and contributes to the broader literature. The study not only assesses the effectiveness and practical relevance of the developed designs but also considers the time frame required for implementation. Additionally, a variety of research methods—each tailored to the specific phase of the design process—are employed and examined in detail (Design Based Research Collective, 2003; Kuzu, Çankaya and Mısırlı, 2011).

3.2 Participants

Participants were selected using purposeful sampling, focusing on teachers working in schools implementing game-based learning. Four workshops were held in this context. Information on the participants in these four workshops is given in Table 1.

Table 1: Participants

Workshop	Female	Male
First Session	15	5
Second Session	12	9
Third Session	10	8
Four Session	13	11

3.3 Data Collection Tools

To gain a comprehensive understanding of teachers' perspectives and experiences during the development of the AI-enhanced EDERG framework, multiple qualitative data sources were utilized. Semi-structured interviews were conducted at the beginning and conclusion of each design cycle to explore participants' initial expectations, their evolving design practices, and their reflections on the integration of AI elements into educational escape room games. In addition, observation notes were systematically gathered by the research team throughout the professional development workshops. These notes focused on teacher interactions, collaboration patterns, design-related decision-making, and engagement with AI tools. Together, semi-structured interviews and systematic observation notes provided rich, triangulated insights into the instructional design process and informed iterative improvements to the proposed framework.

3.4 Data Collection and Analysis

To explore how teachers engaged in the design of AI-enhanced EDERGs, qualitative data were primarily collected through systematic observation notes recorded during professional development workshops. The observations focused on key aspects of the design process, including narrative construction, puzzle development, time management, and the use of AI tools.

Following Creswell's (2016) guidelines for observation-based qualitative analysis, observation notes were systematically reviewed to identify recurring challenges, patterns of behaviour, and responses to AI integration. Findings were organized according to major components of the framework, ensuring that the analysis remained closely aligned with the practical design issues encountered by teachers. Triangulation was strengthened by combining observations with informal participant feedback collected during and after the workshops.

4. Findings

The findings of this study are organized around the key challenges, developments, and observations that emerged during the teacher workshops on designing AI-enhanced educational digital escape room games.

4.1 Initial Challenges in Game Design

Teachers generally demonstrated a good command of constructing narratives, likely due to their familiarity with student interests. However, despite this advantage, narrative construction was still reported as a time-consuming task. One of the most prominent challenges identified was the difficulty teachers experienced in creating meaningful connections between the storyline and the embedded puzzles. While storylines were developed, the clues and tasks often remained disconnected from the narrative, diminishing the overall coherence of the games. Additionally, participants faced significant issues with time management. Although designing an EDERG could theoretically be completed within a few hours, many teachers found themselves unable to finalize their games over several days, often leading to frustration and, ultimately, abandonment of the design process.

4.2 Revisions to Training Based on Feedback

In response to the identified challenges, the training program underwent several targeted revisions. Initially, detailed templates were introduced to guide teachers through each step of the design process. Hands-on demonstrations were incorporated to model the use of these templates. Subsequent feedback indicated a need for further support, particularly in aligning narratives with clues. As a result, examples of AI-generated

story and puzzle connections were shared, along with sample prompts that teachers could adapt. Additionally, sample games designed by the researcher were integrated into later workshops, allowing teachers to experience complete, well-structured EDERGs and better internalize the design principles.

These ongoing revisions based on direct feedback proved crucial in shaping the final instructional framework. By closely aligning training content with the evolving needs and challenges of teachers, the development process ensured that the framework was both practical and highly responsive to real-world classroom conditions. The iterative refinement of training materials not only enhanced participants' design competencies but also provided a solid empirical foundation for the structure and components of the final framework. Consequently, the framework evolved as a user-centered model, deeply rooted in authentic teacher experiences and validated through multiple cycles of observation, feedback, and revision.

4.3 Teacher Perceptions of AI-Supported Content Generation:

Participants were asked about their opinions regarding the use of AI tools for supporting the creation of storylines and puzzles during the design of educational digital escape room games. Their initial reactions and reflections on how AI-assisted design influenced their work were collected through interviews and workshop observations.

Teachers expressed overwhelmingly positive views toward AI-supported content generation. They noted that using AI tools made it possible to design games much faster and more efficiently. Several participants highlighted that the use of AI significantly reduced the time burden of game creation, which had previously been a major obstacle.

Teacher 1: "Now we can design many games very quickly."

Teacher 2: "I have already started creating games on my phone."

Following the introduction of AI tools into the training sessions, it was observed that the design process accelerated noticeably. In earlier workshops, participants struggled to complete their games within the allotted time; however, after the integration of AI tools, teachers were able to finalize their games more quickly and even had time to playtest them during the same session. Observations also indicated that teachers showed increased engagement and enthusiasm when using AI tools, as they appeared more motivated and confident in their ability to complete their projects.

4.4 Improvements Observed in Teachers' Design Practices

By the conclusion of the training cycles, significant improvements were observed in teachers' time management and design coherence. Teachers developed more consistent and engaging narratives and demonstrated a greater ability to create puzzles that were meaningfully integrated into the storyline. Furthermore, their ability to use AI tools, particularly in generating prompts and refining content, improved notably over time. Teachers became increasingly adept at crafting targeted and effective prompts to guide AI-generated outputs, enhancing the quality and relevance of their games.

4.5 Perceived Value of the Framework

Teachers reported that the final framework significantly accelerated their design process, enabling them to develop educational digital escape room games far more efficiently. They emphasized that, with the support of the framework and AI tools, game design became a feasible and time-efficient task. Importantly, participants highlighted that the framework addressed one of their primary concerns: minimizing the time burden associated with designing high-quality educational games, thus making the practice more sustainable and appealing for busy educators.

4.6 Visual Representation of the AI-Enhanced EDERG Framework

In order to clearly synthesize the findings obtained through teacher training sessions and to present the iterative structure of the framework developed in this study, a visual model of the AI-Enhanced EDERG Framework was designed. This visual representation emphasizes the continuous development cycle inherent in the framework and provides an accessible overview for educators aiming to design AI-supported educational escape room games. The circular design and the directional arrow at the bottom of the figure symbolize the ongoing, cyclical nature of the design process, highlighting that each implementation should lead to further reflection, revision, and enhancement.

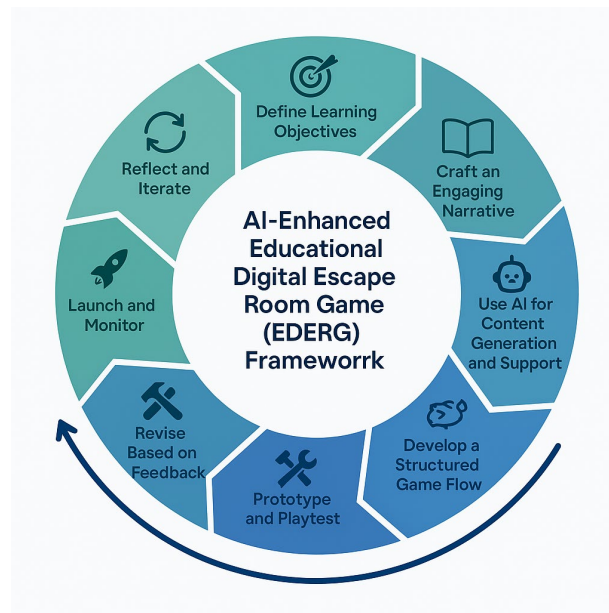


Figure 1: AI-Enhanced Educational Digital Escape Room Game Framework

The framework begins with defining clear and measurable learning objectives that are aligned with curriculum goals. This is followed by crafting an engaging narrative that features a coherent beginning, middle, and end structure tailored to students' interests and developmental levels. Teachers then design puzzles that are meaningfully integrated into the storyline, ensuring that each clue advances both the narrative and the learning outcomes. Artificial intelligence tools are utilized at this stage to support the generation of story ideas, puzzles, and adaptive hint systems, enhancing the creativity, personalization, and efficiency of the design process. A structured game flow is developed to organize the progression of gameplay and manage time effectively. Optionally, AI-enhanced features such as automated feedback, adaptive hints, and basic learning analytics are embedded to further enrich the learning experience. After initial prototyping and small-scale playtesting, teachers revise their designs based on participant feedback and observed challenges. The completed game is then launched in real classroom environments, where student engagement, collaboration, and learning are closely monitored. Finally, teachers engage in reflection and iteration, using insights gained from classroom implementation to refine and improve the design in future applications.

This visual framework not only encapsulates the iterative and user-centered approach emphasized throughout this study but also serves as a practical tool to support teachers in overcoming common challenges in AI-enhanced educational game design. By making the design process more structured, efficient, and adaptable, the framework contributes to bridging the gap between innovative pedagogical concepts and real-world classroom practices.

5. Discussion and Conclusion

The findings of this study highlight the transformative potential of integrating AI into the design of EDERGs to create more dynamic, adaptive, and engaging learning experiences. Teachers demonstrated strong capabilities in crafting narratives but faced challenges in aligning puzzles with storylines and managing time effectively during the design process. The introduction of AI tools notably addressed these challenges by streamlining content generation and enhancing the coherence between game narratives and learning objectives. Furthermore, participants' positive perceptions of AI-supported design suggest that, when provided with appropriate scaffolding, teachers can confidently and effectively leverage AI technologies within game-based instructional contexts.

These results align closely with existing research on EDERGs and AI in education. Previous studies, such as Fotaris and Mastoras (2019), emphasized that EDERGs foster learner motivation and engagement, particularly when designed around authentic and meaningful challenges. Similarly, Veldkamp et al (2020) underscored the importance of narrative coherence and the integration of puzzles into authentic scenarios for maximizing educational impact. The difficulties teachers faced in creating cohesive links between storylines and puzzles in the early stages of this study reflect the same challenges highlighted in prior literature. However, by

introducing AI support, this study extended previous findings by demonstrating how technological scaffolding can directly address narrative-puzzle alignment issues, an area that had been underexplored.

In terms of AI integration, the results corroborate previous observations by Luckin et al (2016) and Holmes, Bialik and Fadel (2019), who identified AI's potential to offer personalized feedback, adaptivity, and real-time support in educational settings. Moreover, Khine (2024) emphasized the role of AI in enhancing adaptive learning environments, particularly through real-time scaffolding—a role mirrored in this study, where AI tools helped teachers generate differentiated content and adaptive hints more efficiently. However, this study also echoes the concerns raised by Chassignol et al (2018) and Zawacki-Richter et al (2019) regarding the challenges non-technical educators face when adopting AI-based tools. Initially, several teachers expressed uncertainty or hesitation toward AI use, highlighting the ongoing need for accessible, teacher-friendly AI integration strategies.

The development of the AI-enhanced EDERG framework represents a meaningful contribution to the field by synthesizing insights from game-based learning, AI in education, and technology integration models such as TPACK (Mishra & Koehler, 2006) and SAMR (Puentedura, 2006). By emphasizing iterative reflection, adaptation, and practical design scaffolding, the framework provides a tangible, actionable guide for teachers seeking to meaningfully integrate AI into educational game development. Unlike prior template-based EDERG design models (Borrego et al, 2017), this framework centers not only on game mechanics but also on pedagogical alignment and technological augmentation, thereby bridging the gap between innovation and classroom reality.

In conclusion, this study demonstrates that when appropriately supported, teachers can successfully integrate AI technologies into educational digital escape room game design, leading to more efficient, coherent, and engaging learning experiences. The AI-enhanced EDERG framework offers a practical pathway for educators to incorporate AI into instructional design without requiring advanced technical expertise. Future research should further explore the longitudinal impacts of AI-enhanced EDERGs on student learning outcomes across diverse educational settings. Moreover, investigating the integration of emerging AI capabilities, such as generative AI and adaptive learning analytics, into the framework could unlock new possibilities for personalized and transformative educational experiences.

6. Limitations and Future Research Directions

This study provides valuable insights into the design of AI-enhanced educational digital escape room games, but several limitations must be noted. First, the participant group mainly included teachers who were already interested in game-based learning, which may limit the generalizability of the findings. Second, the study focused on short-term workshop outcomes and did not assess the long-term sustainability of the framework's application in everyday classrooms.

Future research could experimentally investigate the impact of EDERGs designed using this framework on student motivation, engagement, and academic performance. Additionally, applying the framework across multiple teacher training sessions, gathering further feedback, and iteratively refining the framework could strengthen its adaptability and effectiveness for broader educational contexts.

Ethics Declaration: The confidentiality and anonymity of all participants were strictly maintained. All collected data were stored securely and used solely for research purposes. No identifiable personal information was disclosed.

AI Declaration: As of the version dated 26.04.2025, this paper was prepared with the assistance of Chatgpt-4.0, which was employed to proofread, edit, and refine the text, enhancing clarity and coherence. The AI tool was used as a supplementary editorial aid, complementing the human editorial process by refining language while preserving the author's original analysis and intent.

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Fostering Data Literacy Through the Delta i Data! Game Package: Teacher Insights

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Abstract: As digital technologies and data-driven systems are integrated into our daily social, study, and work life, fostering critical awareness of data collection becomes increasingly essential. K-12 teachers play a key role in building students' data literacy through engaging and inclusive activities. Analogue games have proved valuable for active learning and group interaction. Seeking insight into how analogue game-based learning can support teachers in fostering students' data literacy, this paper presents a case study examining how 20 upper-secondary teachers experienced using *the Delta i Data! Game Package*. Containing two analogue data literacy learning games and additional teaching resources, the game package was developed as part of a University-County Council collaboration and distributed to 42 upper-secondary schools in Norway at the beginning of the 2024 school year. An online qualitative survey conducted two months later investigated how upper-secondary teachers implemented the games in their classroom practices. Thematic analysis revealed four key findings: First, the teachers' use of the games differed. Second, the games contributed to student engagement and social interaction. Third, the games fostered data awareness by providing a good starting point for discussions on privacy concerns, data trails, and the role of digital data in everyday practices. Fourth, some teachers found it challenging to facilitate digital data reflections, while others chose to use the games solely for relationship building and did not address data literacy with their students.

Keywords: Educational games, Analogue games, Data literacy, Social interaction, Teachers' experiences

1. Introduction

Digital technologies have profoundly transformed the way we create and share information, as well as how we interact socially. Tracking technologies embedded in digital environments are used to collect large amounts of data, promising effectiveness, content tailoring, and personalisation (Pangrazio & Selwyn, 2023). While offering numerous affordances, these developments also pose risks. For instance, gamified algorithms designed to keep users' attention can lead to increased use, which in some cases can be linked to higher stress in adolescents (Smahel et al., 2025). Furthermore, increasing use of digital technology has not automatically led to higher levels of digital competencies or data awareness (Datatilsynet, 2024; Fraillon, 2024). *Data literacy* involves understanding how and in what contexts digital data is generated, collected, and used, and is essential for navigating current data infrastructures and implementing future datafication processes responsibly (Pangrazio & Selwyn, 2023). Gaining data literacy early in life is a significant advantage in today's digital world, and teachers play an important role in supporting all K-12 education students in developing digital skills, including competencies that extend beyond the practical use of digital tools (Vermeire et al., 2025).

The growing presence of generative AI systems, algorithmic, and data-driven technologies has led to a stronger international emphasis on using and understanding data as key competencies for active and responsible participation in society (Van Audenhove et al., 2024). In Norway, governmental initiatives have prompted action at both the school and school owner levels to support teachers and students in navigating the responsible use of AI (UDIR, 2024). In this context, there is a need to provide inclusive and engaging data literacy learning opportunities that reach across diverse student groups.

The Delta i Data! (DiD!) Game Package is a game-based learning initiative for data literacy, developed in collaboration with Vestland County Council in Norway as part of a broader initiative to support teachers' work with AI-related topics. In August 2024, 147 *DiD! Game Packages* were distributed to all public upper secondary schools in the county with the aim of promoting data literacy through playful classroom interaction. Each package contained a class set of two analogue learning games, and additional teaching resources were made available through a website.

This paper presents a case study aimed at understanding how analogue game-based learning resources can be used by teachers to foster students' data literacy. An online qualitative survey was conducted among upper-secondary schools two months after they had received *the DiD! Game Package*, to investigate teachers'

experiences with the resources. The paper presents findings from a thematic analysis of responses from 20 teachers from 14 different schools who had used the games in their classes, involving a total of 628 students.

1.1 Background

Educational games can be valuable tools for supporting critical reflection and awareness of digital data (Castañeda et al., 2024; De La Hera et al., 2024), due to their immersive and motivating qualities and potential for active learning (Arnab, 2020). Analogue games, including tabletop, card, and board games with little or no digital gameplay, are often designed for ‘face-to-face gameplay’ in social settings (Bayeck, 2020), and have shown potential for meaningful learning through group interaction and communication (Sousa et al., 2023).

According to a review by Bado (2022), teachers pedagogically frame the use of games in teaching and learning situations through structured activities *pre-game* (e.g., gameplay training, lectures and handouts), *during game* (e.g., scaffolding content, classroom management and technical support), and *post-game debriefing* (e.g., guided discussion and reflection). Despite the importance of post-game debriefing for learning, the review showed that this phase received the least attention in studies of teachers’ instructional practices when using games (Bado, 2022).

Previous studies on games for digital literacy have demonstrated its relevance for learning about privacy and online safety (Henriksen-Bulmer et al., 2024), internet cookies (Diez & Melcer, 2020), fake news and cybersecurity (De La Hera et al., 2024), and artificial intelligence literacy (Du & Wang, 2023). While the field of research tends to focus primarily on digital games, some studies have addressed the educational potential of analogue games for computational thinking (Bayeck, 2020), digital literacy (DeJong, 2023), and data literacy (Lameras et al., 2024).

2. The Delta i Data! Game Package

The DiD! Game Package (Figure 1) is a ready-to-use teaching resource designed to promote data literacy. It was developed and designed by researchers as part of the EduTrustAI project at the Centre for the Science of Learning and Technology (SLATE), University of Bergen, and adapted for upper secondary education contexts in dialogue with Vestland County Council in Norway, as part of a broader set of initiatives aimed at supporting schools’ work with generative AI.



Figure 1: The DiD! Game Package

The game package includes two physical analogue games: *DataDelta* and *Data Iceberg* designed with the aim of fostering a basic understanding of digital data and raising awareness of (1) that we constantly create *data footprints* when we interact with digital devices, and (2) that there are different visible and invisible *data types* (SLATE, 2024). The original versions of these games were developed within the EU Erasmus+ project Data Literacy for Citizenship (DALI, 2023) as part of a toolkit of 11 games designed to support adult learners’ data literacy (Castañeda et al., 2024). Two of the DALI games (Game of Phones and Data Iceberg) were further developed, piloted, and playtested for use in Norwegian upper secondary education, resulting in *the DiD! Game Package* versions *DataDelta* and *Data Iceberg* described in the following (Figure 2).

DataDelta is a card game that prompts players to use their phones to look up and share online content. While practising skills relating to the use, access, and communication of digital materials retrieved from online sources (DALI, 2023), the players also engage in social interaction and get to know each other. The aim of the game is to provide a foundation for post-play reflection on how all digital actions generate data footprints.

Data Iceberg is a memory game where players uncover and categorise everyday scenarios to reflect upon and increase awareness of how visible and invisible types of digital data are generated (SLATE, 2024).



Figure 2: Game impressions for *DataDelta* and *Data Iceberg*

Including the two games in the game package was intentional. While *DataDelta* creates engagement, curiosity, and prompts concrete digital actions ideal for post-game reflections, *Data Iceberg* introduces defined concepts about data types. These two games complement each other: the first game sets the stage for reflection, while the second helps students develop a conceptual understanding. In this way, the games function as pre-play and post-play activities for each other (Klykken, 2025).

The box is supported by a website with free supporting materials (SLATE, 2024), which had 4,891 unique pageviews and 646 downloads between August 2024 and July 2025. It offers digital and printable games, a teacher's guide, ready-to-use presentation slides, and a suggested lesson plan. The objective of the 2 x 45-minute lesson plan (Figure 3) is to support students' basic understanding of digital data through play, reflection, and discussion, by combining gameplay with pre-play teacher-led instruction, and post-gameplay group activities.



Figure 3: Suggested lesson structure using *the DiD! Game Package*

Before the autumn semester of 2024, a total of 147 physical *DiD! Game Packages* (pictured in Figure 1) were distributed to 42 upper-secondary schools in the county. Targeting over 8200 first-year students, each box contained both games and enough materials for 32 players. In collaboration with the County Council, the game package was promoted to support not only data literacy, but also social relations. This dual emphasis was chosen to appeal to a broad range of teachers, including those who are mainly looking for activities for building a socially constructive class environment. While teachers were encouraged to use the game package for data literacy and relationship building during the introductory week, they were free to use it as they saw fit.

3. Methodological Approach

The overall objective of this study was to explore how teachers can utilise analogue game-based learning to foster students' data literacy. Specifically, we investigated this through a case study examining teachers' experiences when integrating *the DiD! Game Package* in their classroom teaching, and their reflections on how its use contributed to students' data literacy as well as to the social environment. The study is guided by the following research question:

RQ1: How do upper-secondary teachers experience using the Delta i Data! Game Package as part of their teaching?

We employed a case study design, suitable for exploring a single case in depth while capturing the complex context of the specific initiative. (Simons, 2009), and an appropriate approach since the teachers' experiences were deeply embedded in the application of specific games during a particular time.

An online questionnaire was designed, containing both quantitative and qualitative, open-ended questions, allowing for rich responses, descriptions, and reflections on their actual use (Braun et al., 2021). The questionnaire asked teachers to evaluate the game package on a five-point Likert scale regarding their perception of the games' usability and impact in terms of fun and engagement, relationship building, and learning about digital data. The questionnaire also asked how many students and with what intention the games had been used. In the open-ended questions, the teachers were invited to provide in-depth descriptions and examples of their experiences, including how the games were integrated into their teaching (e.g., what did and what did not work), as well as assessing their educational value.

The game packages were distributed to schools for the start of the term in August 2024. Two months later, we sent out the survey to the 42 upper secondary schools that had received the games, asking school administrators to share it with teachers and other relevant staff who had direct experience with using the games. We employed a purposeful sampling strategy (Simons, 2009), inviting only teachers who had used the games, while targeting multiple schools. This approach aimed to provide relevant insights into the specific case, while capturing geographical broadness in terms of how teachers at different schools across the county experienced the package.

For the analysis of the open-ended responses, we employed a thematic approach, searching for patterns and contrasts, and constructing themes to represent the recurring and varied ways the games were used and experienced (Braun et al., 2021).

The research followed ethics guidelines, including the principle of informed consent (Roberts & Allen, 2015). The email invitation and survey provided potential participants with information concerning the study's purpose, the estimated time to complete the survey, that participation was voluntary and anonymous, and that no identifiable information would be collected or shared.

4. Findings

Twenty teachers (including two department leaders) from 14 different schools responded to the survey. Together, they reported using the *DiD! Game Package* with a total of 628 students across both general study and vocational programmes. We constructed four themes during the thematic analysis: 1) *Variation in use*, 2) *Contributing to engagement and relationship building*, 3) *Fostering data awareness through discussions*, and 4) *Challenges in facilitating digital data reflections*.

4.1 Variation in use

The survey responses revealed variations in how teachers used the game package. Regarding the number of games, we found that 60% of the teachers used only *DataDelta*, whilst 40% played both games. The time spent on activities involving the games ranged from 20 minutes to 3 hours, with an average time of 72 minutes.

The purpose of use also varied. 67% of the teachers reported using the games with the intended dual purpose to simultaneously be a social and learning activity (aligning with the original intention of the package). This was also reflected in open-ended responses, such as one teacher who noted:

"The games were used as an icebreaker activity with discussions about data sharing. For example, social media, advertising, web searches, location data, and cookies."

In contrast, 33% reported using the games solely for relation-building purposes. The open-ended responses also show that several teachers used the games as primarily a social activity for the students, with one teacher commenting:

"I didn't use them as educational games, only to 'shake' the class together at the beginning of the year."

Some teachers adapted the games. While 60% reported using the provided teacher's guide, some open-ended responses reveal that some teachers integrated the games into teaching activities in different ways to better fit their needs. For example, one teacher asked students to write reflection notes about their data usage and security. Another adjusted the games to fit a different learning topic.

While several teachers reported using the games in small groups within singular classes, one of the teachers described using the games to build relationships across different first-year classes:

"The main goal of the game session was relationship building and getting to know each other across classes in 1st year upper secondary."

4.2 Teachers' Views: The Value of the Games for Building Relationships and Data Literacy

Table 1 provides an overview of the teachers' experiences with *the DiD! Game Package*, based on their responses to Likert-scale items. The results show that the package was perceived as engaging, easy to use, easy for students to understand, and effective in contributing to relation building and social environment. However, the contribution of the games to learning about digital data was rated somewhat lower than the other areas.

Table 1: Participants' mean ratings of DiD! game experiences (Scale: 1 = very low, 5 = very high)

To what degree did you experience the games as: (N=20)	Mean
... easy to use (for the teacher)	4.6
... easy to understand (for the students)	4.4
... fun and engaging	4.3
... contributing to relation building and social environment	4.4
... contributing to learning about digital data	3.6

To further understand these findings, the following sections focus on the open-ended responses relating to the game package's value in supporting social interaction and fostering data literacy.

4.2.1 Contributing to engagement and relationship building

A key theme in the teachers' answers was that the games facilitated student engagement and relationship building, with nearly all the teachers describing the games as contributing to student engagement and social interaction. Teachers describe especially the first game, *DataDelta*, as an effective icebreaker and "a good way for the students to get to know each other". One teacher described how the students "learned a bit about each other, what they liked and didn't like, and so on".

Several teachers specified that the analogue game-based approach provided a safe context for communication and learning. One teacher reflected that students seemed to be comfortable 'having something physical in their hands' while interacting. Another stated that:

"The game was very concrete and harmless. Everyone participated :) The students got to know each other and had a positive experience together."

One teacher described that using the game package in small groups provoked positive interaction and laughter, concluding that:

"It worked well, reservations to share and the 'fear' of embarrassing themselves disappeared quickly."

4.2.2 Fostering data awareness through reflection, conversations and discussions

Another theme was that the games were beneficial for increasing awareness of the sharing of digital data. One teacher stated that the students seemed to have "become more aware of what they allow their apps to collect information about". Similarly, another teacher stated:

"The students became more aware of digital traces and how quickly information can be found."

Several teachers reported that the games provided a good starting point for learning about data trails, particularly through enabling reflection, conversations and discussions. One stated that the games "contributed to interaction, and reflection based on a shared understanding and belonging". Another teacher wrote that the games provided:

"A good starting point for discussing the importance of privacy and being mindful of the data one shares."

Two teachers also reported on their own professional learning and increased awareness about students' digital practices. The first teacher reported learning about how students searched for information online, and the second teacher explained that the games were: "Useful for the teacher to get to know the students' digital everyday lives".

4.2.3 Challenges in facilitating digital data reflections

As detailed (see Section 4.1), several teachers chose to use the games solely for relationship building and did not directly address data topics with students.

Additionally, some teachers reported challenges in facilitating students' reflections and discussions about digital data. One teacher explained that, during *Data Iceberg*, the students became very focused on "playing memory" and that instead of discussions about types of data, there was "laughter, accusations of cheating, and so on". The teacher reflected that the students "spent more mental energy trying to remember where things were than thinking about different types of data" and suggested removing the memory element.

Another teacher experienced difficulties in facilitating reflective discussion about data, reflecting on the role of the pre-play introduction:

"The students enjoyed themselves in the groups and spent all the time on the game. I perhaps should have been clearer that this also related to digital skills, as there wasn't a very reflective discussion around the questions once the game was completed."

5. Discussion

The above findings highlight how teachers experienced using the *DiD! Game Package* in different ways, reflecting their priorities, classroom contexts and student needs. We identified four analytical themes: 1) *Variation in use*, 2) *Contributing to engagement and relationship building*, 3) *Fostering data awareness through discussions*, and 4) *Challenges in facilitating digital data reflections*.

The first theme was the *variation in use* regarding the number of games, time spent, purposes, adaptations, and integration. On one hand, these differences could be understood as stemming from the game package's double purpose encompassing both data literacy and students' social interaction, and that the teachers were free to use the games as they saw fit with their students. The timing of the survey may also be influential, as it was conducted two months after the teachers received the game package. Trialability has been identified as a key factor for teachers' adoption of games (Kebritchi, 2010). In this case, the teachers were encouraged to use the games during the introductory week and thus had limited time to experience the games themselves beforehand.

On the other hand, *variation in use* could also be interpreted as a sign of flexibility in the game package materials. A review by Bacsá-Károlyi & Fehérvári (2024) identified time constraints and the lack of adaptability of games as important *institutional* factors hindering teachers' gameful practices, alongside inadequate materials and a lack of professional development opportunities. *Individual* factors include teachers' attitudes, such as confidence in the advantages of using games or belief in games increasing student motivation (Bacsá-Károlyi & Fehérvári, 2024).

The second theme was the *games' contribution to engagement and relationship building*. The teachers reported that the students became engaged, started good conversations, and got to know each other. The analogue, physical concreteness of the games was also described as contributing to a safe learning environment. This resonates with existing literature on the social and immersive spirit of games and the construction of failure as harmless and safe (Ness et al., 2024; Whitton, 2018).

The third theme was *fostering data awareness through reflection, conversations and discussions*. Teachers describe the game package as providing a good starting point for learning about digital data through conversations, discussions and reflection. The potential for learning opportunities can be connected to research highlighting social affordances of analogue learning games (DeJong, 2023; Sousa et al., 2023). Bayeck (2020) argues that board games serve as alternative learning spaces, facilitating learning beyond knowledge acquisition as players interact and engage in various social practices within specific game environments.

Interestingly, the games also contributed to teachers' understanding of students and their digital lives. During gameplay, if students are encouraged to talk and reflect on their everyday online practices, this can make the students' level of awareness about data more accessible to the teacher. This highlights the indirect potential of analogue learning games to increase Teacher-Student dialogues about digital data, and consequently, improve the teacher's capacity to adapt future data literacy activities to fit students' learning needs.

The fourth theme concerns *challenges in facilitating digital data reflections*, as some teachers observed imbalances between entertainment/fun and learning when using the games. Such imbalances may be linked to design issues within the games themselves, as well as to individual player traits and preferences (Arnab, 2020). Not clearly communicating the learning aim of the game activity before playing was mentioned by one teacher

as contributing to low reflection levels. This aligns with a study by Sanchiz et al. (2024), which argues that providing the purpose of learning beforehand is crucial to prevent playful and fun elements from overshadowing actual learning during the activity, particularly when students have prior gaming experience (Sanchiz et al., 2024). Research on the impact of students' understanding of the game context also emphasise the need for pre-play, in-game, and post-game activities (Bado, 2022; Kim & Pavlov, 2019). However, overemphasising instruction and scaffolding during learning games may undermine qualities of immersion, autonomy, and surprise that are essential for engaging and motivating playful learning experiences (Arnab, 2020; Barendregt, 2014; Sharp, 2012).

Jobert and Sanchiz (2025) argue for the importance of developing teachers' professional knowledge in using games for learning, for instance, to foster teachers' skills in implementing and adapting game-based activities to meet the specific needs of a particular class. While the previous experiences of teachers were not the focus of this study, the findings can be seen to support the existing research's emphasis on teachers' knowledge of how to implement learning games, and overcome potential barriers, identify benefits and limitations of using and adapting games in diverse teaching situations (Bacsá-Károlyi & Fehérvári, 2024; Bado, 2022; Hébert et al., 2021).

6. Conclusion

The teachers reported that using the *DiD! Game Package* created opportunities for social interaction and supporting data literacy. The findings show a variety of uses as teachers adapted the games and activities to their students' and group needs, different learning aims, and other situational aspects. This shows that distribution cannot guarantee how educational games and related resources will be used in practice. Getting an overview of the various ways the games were used could inform future iterations of the package and lead to a more varied and broader range of supporting materials. Limitations of this study include its reliance on online surveys and teachers' self-reports. Future research could incorporate students' experiences and utilise qualitative interviews and observations to provide more depth and nuance.

The digitalisation of everyday activities occurs across formal and informal settings, and digital practices are often deeply socially motivated, even in educational contexts. With the current rise of AI and data-driven systems, raising awareness among all students about the impact of our digital actions across multiple platforms and activities seems even more crucial. Hence, the informal sociality and playfulness of analogue game-based learning environments, such as *the DiD! Game Package*, appears to provide a relevant and productive approach for teachers to support students' data literacy.

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A Physical Chemistry Escape Room With 4 Metals

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Abstract: Natural sciences such as chemistry are inherently fascinating, but they can also appear complex—often requiring substantial prior knowledge before one can fully understand the phenomena involved. To make scientific topics more accessible and reduce apprehension, game-based approaches have proven highly effective. Problem-solving and experimentation within a gamified environment tend to be intrinsically motivating, encouraging participants to engage actively—often learning without even realizing it. This paper presents a physical chemistry escape room consisting of five task stations. The stations can be played sequentially (1 to 5) or in a parallel rotation format, where four are completed before finishing together at the final station. The thematic focus of the escape room is on metals, with four key metals—aluminium, copper, iron, and zinc—at the centre of each station’s learning objectives. At each station (approximately 3–4 m² in size), players are challenged to solve riddles—either clearly visible or hidden (e.g., in envelopes, inside or under books, in newspapers, or on the walls)—by using information provided on surrounding posters and materials. The tasks are designed to convey scientific knowledge related to the four metals, such as properties including mass and magnetism. Activities include crossword puzzles, numeric or pictorial codes, combinatory questions, and hands-on physical experiments. Examples of these experiments include determining the density of metals using various methods or constructing a lemon battery at the final station. The game has been successfully tested with children aged 6 to 12 years. With slight adjustments to pacing, it is expected to be also suitable for older participants—for instance, as a quick and enjoyable way to review previously learned chemistry content. Overall feedback has been very positive, and it appears that all participants leave the game with enhanced knowledge about the four featured metals.

Keywords: Chemistry, Escape room, Metals, Gamification

1. Introduction

Escape room games are a special kind of gamification. The main objective of escape room games is to solve a series of tasks — either in a set or flexible order — to exit the room or environment where the game is held. In some cases, the goal might also be to discover a hidden treasure.

In the Cambridge dictionary, the following definition for escape rooms can be found: “Escape rooms are a game where people are locked into a room and have to find a way to escape by finding clues (= signs or information that help you to find the answer to a problem or mystery) in it, and solving puzzles, or a special room where this is done.”[1]

A subgroup of escape rooms are educational escape rooms. They have emerged as effective tools for increasing engagement and motivation in learning contexts. Solving interconnected challenges in a gamified way can be especially positive for the encouragement of problem solving of abstract or complex topics as for example in science education.[2, 3].

The escape room described in this paper concentrates on the four metals aluminium, copper, iron, and zinc. It was developed to let the participants – originally specifically children - learn interesting things about the metals’ properties. In this sense it should foster curiosity for natural sciences.

2. Background and Related Work

Natural sciences like chemistry are incredibly fascinating, but they are often perceived as difficult. To make these topics more accessible and less intimidating, games can be a powerful tool. By embedding problem-solving and experiments in a playful, gamified environment, learning becomes more engaging and enjoyable. Research has shown that gamified learning environments can improve both motivation and learning outcomes.[2] In fact, people often learn without even realizing it and may desire further exploration of a topic.

As escape room games offer structured, goal-oriented environments that combine storytelling, puzzles, and physical interaction [4], they have become increasingly popular in both formal and informal education settings.

The goal behind designing this chemistry escape room with incorporated hands-on experiments on the four metals (aluminium, copper, iron, and zinc), described in more detail below, was to make chemistry more accessible to children by creating tasks that are engaging, interactive, and simple enough for even younger kids to solve - with just a little bit of support.

3. Game Design and Structure

3.1 Concept and Objectives

In this escape room game four metals (aluminium, copper, iron and zinc) play the main role. They were chosen because of their obviously different properties which makes them distinguishable from each other quite easily. Aluminium is very light, copper has a copper shine, iron is magnetic, and zinc is silvery shining but non-magnetic. Furthermore, these four metals are often familiar from everyday life. In the household, e.g. aluminium foil, copper wires for electricity or iron tools are well-known.

In the escape room the players get motivated to identify, investigate, and apply their knowledge from daily life and from additional information slides in the escape room about the four different metals.

By solving the tasks at the different stations, the players can touch, weigh, and test the metals to identify them and to learn more about their properties. This also includes determining volumes (by measuring, calculating and using Archimedes' principle) and masses and then calculate densities with the density formula. The participants can additionally gain information from the information poster slides at each station – which is also very useful for solving the riddles. In the last station, the players should have enough information to construct a functioning battery (the lemon battery) that lights a lamp - hereby completing the “mission”.

The two main learning objectives can be summarized to:

- Introducing the properties of common metals (density, magnetism, colour) and of related alloys
- Encouraging scientific reasoning, mathematical thinking and problem-solving in a playful learning environment

3.2 Setup and Logistics

The game is organized into five task stations, each occupying around 3-4 m² - depending on the possibilities in the current playroom. The activity can be run in two formats:

- Sequentially (stations 1 to 5 in order), or
- in parallel (especially for larger groups) with a clockwise rotation from station 1 to 4 and the 5th station with all players.

Each station is supervised by game instructors. Their functions are:

- to help players when they need a hint or have a question to the setup
- to pay attention that the game is played in the right order (some items - like for example envelopes with alchemical symbols or padlocks - can only be opened after having solved a certain riddle or using a decoding mechanism before) or,
- to reset all the puzzles and to reprepare the stations for the next group.

At every station, various tasks are placed - obvious to find or hidden somewhere at the station (e.g. in an envelope, in or under a book, in a newspaper, or on posters).

Additionally, posters with information for the station's topic (e.g., the periodic table of the elements) can be found in the station area close to the table.

Playing in the parallel mode, players take a break after completing a station until also the other groups have finished their stations, and all stations have been reprepared. After that, all groups move on clockwise to the next station.

Every task station needs around 15 to 30 minutes (depending mostly on the age of the participants) to be completed. In total, the escape room lasts between 2 and 2.5 hours, depending on group size and age. Especially for smaller children, a break of around 15 minutes after two stations (for eating, drinking and relaxing) is often necessary and helpful to recharge their batteries for the next tasks.

Figure 1 depicts the room arrangement for a specific run of the escape room game, with the beamer presentation for the introduction, the task stations with various items and the informational slides visible.

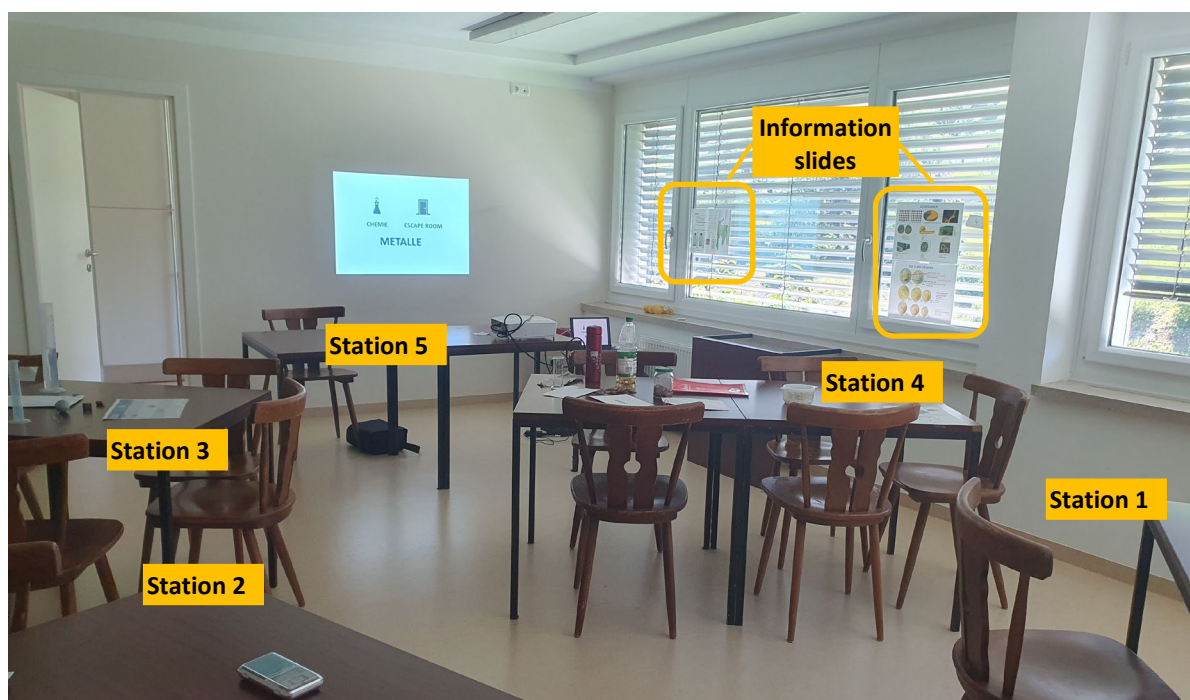


Figure 1: The set-up of the escape room on one occasion; Photo M. Kröppl

It must be stated that all materials (poster information slides, work sheets, decoder disc, decoding machine,) have been designed and created by the author herself.

4. Station Overview and Task Description

The various tasks on the stations should give players things worth knowing about the four metals (e.g. properties like colour, mass, magnetism, usages, positions in the periodic table of the elements, ...). They include crossword puzzles, number or picture codes, combination tasks and doing real physical experiments (like for example determining metal densities via different methods or cleaning copper coins with vinegar and salt). The last task is to build a lemon battery with lemons, wires and two different metals and to activate a small lamp.

The following chapters will describe the tasks at the five stations in more detail. For the different riddles, always the solutions will be shown (available also for the game instructors) – in the game, the question fields would be empty for the participants.

4.1 Station 1 - Story Introduction

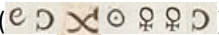
The game begins with a welcome letter inviting the children into an imaginary alchemist's lab and describing the goal of the game – finding a solution to build a battery to activate a small lamp.

It says:

"Welcome to my alchemy lab! Nice of you to come visit! Unfortunately, I must dash off quickly. I need to see if I can find a battery. Somehow, I still need to make that little lamp light up today. But feel free to look around the lab already. Who knows, maybe the answer lies in your hands. To make a battery, you need two different metals and an electrolyte. A good combination is one noble metal and one base metal. A few metals lie upon the table. If only I could tell what they are. Could you perhaps help me? Feel free to use anything in the lab and experiment as you wish. I'll be back soon! ..."

The table contains:

- metal objects (made of aluminium, copper, iron and zinc)
- a small magnet
- a small lamp
- a chemistry book
- an envelope with a small padlock
- a small key

- an envelope with alchemical symbols ()
- a newspaper text “Interesting facts about metals”

After the introduction to the game and reading the welcome letter, the players start to play. When they begin to investigate the items on the table, especially the small lamp should catch their interest, as - concerning to the welcome letter – this lamp should later be turned on with a battery. The players might be interested in exploring also other objects on the table - for example the metal objects – and to test them with the small magnet. This allows participants to easily identify iron, as it is the only magnetic metal among the four used in the game. By comparing the weights, they can determine the lightest metal – aluminium. Copper is typically recognized from electrical wires and is distinguished by its noticeably different colour. The remaining metal must therefore be zinc. The participants should now try to memorize the metals carefully as riddles and information to these four metals will appear at every station.

The players may also be curious to read the newspaper article “Interesting facts about metals” which will give them some basic information about metal properties. Participants will realize that, maybe unexpectedly, in most cases, they already know some of these properties — sparking their curiosity about what else they might discover during the game.

Another object catching the player’s interest, could now be the envelope with the small padlock. They surely detect a same-coloured small key on the table and might be curious to try to open the envelope. Inside the envelope, they find a pen and a decoder disc with four circles: the outer circle with numbers from 1 to 26, a circle with letters from A to Z, another circle with alchemical symbols and the inner circle with roman numbers.

With the discovered decoder disc, the “alchemical” symbols on the other envelope can now be deciphered to “METALLE” (metals). Inside this envelope, the players find – as maybe already expected from the deciphered word - a riddle about metals.

When the players look around, they will realize, that additionally to the items on the table, poster information slides are placed at the station. On the posters, information can be found concerning the periodic table (elements, names, atomic number, metals and non-metals) and a basic design of a battery and a galvanic cell made with the metals copper and zinc. The last information is already a hint for the last station of the escape room, where a lemon battery will be the final experiment.

Looking at the posters, the players will find hints for the solutions to the four questions of the “riddle about metals”. The solution code to this riddle then reveals to “1 2 1 1”.

Solving this riddle is not the last task at station 1. On the table, there are still unexamined items – a chemistry book and a newspaper. When browsing through the chemistry book, a hidden word search for precious metals can be found.

Surely, the players might already know some precious metals like gold or silver. But do they also know their chemical symbols? For being able to search the precious metals listed on the riddle, their full names should therefore be known. Here, the periodic table from the poster information slides can help to decipher the chemical language code. Looking then at the yellow highlighted letters, the solution word to this riddle will then turn out to be “METALLE” (metals). The players can thus reach the envelope with the alchemical symbols either by solving the puzzle with the precious metals or by deciphering it using the decoder disc.

Finally, by exploring the newspaper on the table, an “extra tricky chemistry riddle of the week” appears inside. For solving this riddle, the players again need to know something about the chemical symbols (help can again be found in the periodic tables) and some properties of the metals (metal/non-metal, precious/base and magnetic/non-magnetic). Additionally, a mathematical riddle must be solved – with chemical symbols and by using the decoder disc. The solution code for station 1 so turns out to be “4 1 1”.

4.2 Station 2 – Density and Mathematics

The aim of Station 2 is to let the players learn more about different properties of the four in this game investigated metals and their usages.

The players find

- a box with four density cubes (aluminium, iron, copper, and a wood cube as control)
- measuring tools (calculator, geometry triangle, small scale)

- a small magnet
- a hexagram puzzle with alchemical signs
- and an envelope with the letters “B D”.

When looking around the station, the poster information slides for the four metals in the game with pictures, usages and properties – and even alchemical symbols - should be an eye catcher.

Looking at the posters, the answers to the hexagram – matching alchemical symbols and metals - can be found with “2 4”. As soon as the players decipher the code “2 4” to “B D”, the envelope can be opened. In the envelope, a worksheet with a table for the calculation of the densities and the identification of the metals can be found.

To determine the densities, the cubes must be weighed and their masses recorded in the table. Their edge lengths (always 2 cm) also need to be measured. With the formula shown on the work sheet, the volume of the cubes can then be calculated as 8 cm^3 . By applying the density formula, the densities of the four cubes can be determined - and by comparing them with the densities given on the work sheet – their materials can be identified.

To complete the table, the players fill in three columns describing specific properties of the tested materials – whether they are metals or non-metals, magnetic or non-magnetic, and precious or non-precious. A small magnet can help to identify magnetic materials.

By using the first letters of the element names placed correctly in the table and converting them to their positions in the alphabet, the solution code for Station 2 can be generated: “1 6 3 8”.

4.3 Station 3 – Density of Irregular Objects (Archimedes’ Principle)

The aim of Station 3 is to let the players learn about the Archimedes’ principle for determining volumes and together with the masses of the investigated irregular objects their densities and to so identify the materials.

At Station 3, the following items can be found on the table:

- four irregular metal objects (a silver sphere, a copper shining cylinder, a darker silvery shining cube and a silver right-angled strip)
- graduated cylinders in different sizes with water
- a mechanical decoder “machine” with moving slits and coded inputs
- measuring instruments (calculator, geometry triangle, small scale)
- a small magnet
- small keys
- and newspapers with different coloured padlocks.

Additionally, in the station area there are posters on the Archimedes’ principle and geometric solids.

At first glance, there appears to be no task to be solved on the table. Therefore (and maybe with the hint of an instructor), the players investigate the poster information slides. And there - on one of them - is a riddle. The question of the riddle is the following: “When a man – in this case Archimedes – enters a bathtub, will the water level in the bathtub change and when yes, how?” By looking at the poster information about the Archimedes’ principle or maybe even doing a small experiment by placing a metal object in a graduated cylinder at the table and looking at the change of the water level, the right answer “The water is overflowing.” can be found. Next to the answer the players see a blue key sign.

As the answer to the question with Archimedes and the bathtub is the blue key, the players can now conclude that the newspaper with the blue padlock can be opened. Inside, they find a work sheet with a table to fill in masses of metals, volumes and a column to calculate the densities of the metals.

Since the metal objects are only roughly geometric solids, measuring and calculating their volumes with the mathematical formulas shown on an information slide will only yield approximate results. Therefore, a better method is applied at this station using the Archimedes’ principle. By following the table on the worksheet, the players see that they need to measure the masses of the metals (using a scale, as in station 2) and determine their volumes — this time by placing the metal objects in graduated cylinders filled with water, reading the water levels before and after insertion, and calculating the difference.

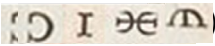
After calculating the densities and concluding which metals the four objects are made of, the results can be entered in the mechanical decoder machine screen with the four slits. By first decoding the symbols of the table headers, the stripes with the shapes of the four metal objects can be placed in the right positions.

The solution code for station 3 can so be found to “1 2 4 3”.

4.4 Station 4 – Alloys and Coins

This station introduces the concept of metal alloys and their everyday applications, using both real and toy Euro coins as learning tools.

Materials on the table include:

- Euro coins (1c, 2c, 5c) (real coins and play coins as decoration for the topic)
- a bottle of vinegar
- table salt
- a small graduated cylinder
- a scale
- a small magnet
- a wire
- a red folder with a red padlock
- a newspaper article about “Nitinol - a shape-memory alloy”
- two envelopes with puzzles and a battery setup diagram
- a note paper with a scheme for the set-up of a lemon battery
- some notes
- a newspaper article about how to clean copper coins
- an envelope with a paper clip symbol
- an envelope with alchemical symbols 

Additional information slides give information about alloys with some examples from the daily life and descriptions of the Euro coins (sizes, weight and especially interesting the metals used for the coins).

To start the game at station 4, a game instructor (for safety reasons) starts with a small experiment. He takes the wire from the table and requests the participants to attentively watch the following experiment. When the wire is put in a small bowl with hot water (practically taken from a thermos flask), the wire immediately forms a paper clip. This is nice wow effect for all players! In a self-designed paper article the players can then find out that the paper clip consists of a so called memory alloy called “Nitinol”.

After this amazing experiment, the envelope with the paper clip symbol can be opened. Inside, a crossword puzzle for alloys can be found. All answers can be found on the information slide about alloys and in the newspaper article about nitinol. In both cases, the hidden word — formed by arranging the red-circled letters — is “EURO”.

By looking at the items on the table and combining them cleverly, the word “EURO” from the crossword puzzle should lead to the envelope with the alchemical symbols. By using the decoder disc, the symbols can be deciphered to “EURO” which allows this envelope to be opened – a quiz about EURO coins emerges. All answers to this “extra difficult” riddle can be found on the information slide about the Euro coins.

After having solved all questions, the players will realize that in the quiz always the red key marked the correct solution. This understanding leads the players to the red map with the small red padlock. In there, another quiz about Euro coins can be found. The second quiz can be solved by weighing 5-cent Euro coins and measuring their volume using Archimedes' principle (which was the experimental topic of the previous station), followed by calculating their density. Comparing the result with the metal densities given at the quiz work sheet the players realize that the cent coins only have a copper coating but consist mainly of iron making them therefore magnetic. This leads to the solution code “1 1 3 1”.

After solving the quizzes about the Euro coins, there is still something to be done at station 4. On the table, a paper note provides interesting information about how to set up a lemon battery, a newspaper clipping explains how to clean copper coins, and there are also some additional notes.

The final step at Station 4 is to carry out a chemical experiment. Each group cleans one copper coin (resulting in a total of four cleaned coins for Station 5 if four groups are playing), following the method described in the

newspaper article. This experiment is fascinating for the players — like magic, dull copper coins are quickly transformed into shiny ones by swirling them in salty vinegar

4.5 Station 5 – Lemon Battery and Treasure

The fifth station marks the grand finale. The goal here is for players to combine all the knowledge they have gained about the investigated metals from the previous stations to assemble a battery and power a small lamp.

From the very beginning, the story's objective was to build a battery using a noble and a base metal to light the small lamp (or, in a variation, to power a small clock). Now, the participants apply their knowledge to construct a functioning lemon battery — as demonstrated in Station 4, this is indeed possible. A scheme how to set up a lemon battery with the metals copper and zinc is shown on the poster information slide.

On the table, the players find:

- lemons
- copper coins (cleaned in Station 4)
- zinc nails or platelets
- wires with crocodile clips
- a small lamp (from Station 1) and maybe additionally a small clock
- an envelope with a lightbulb symbol
- and a treasure chest with a number lock.

By using the cleaned copper coin from station 4 and some zinc nails or platelets, inserting them in the lemons as shown on the scheme on the poster and connecting them in the right manner together with the small red lamp, which had already been on the table at the first station, the lamp can successfully be powered by lemons! (see Fig. 2)

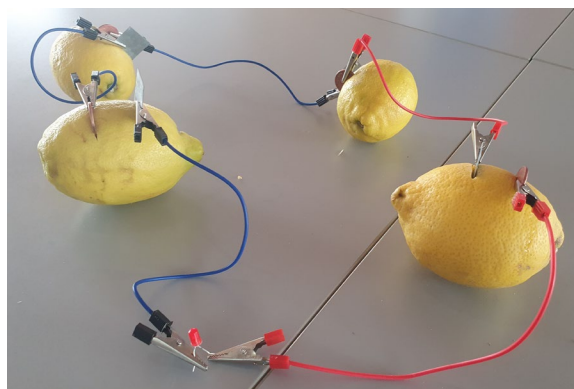


Figure 2: Lemon battery with shining lamp; Photo M. Kröppl

5. Results and Discussion

The “Chemistry escape room” was tested in over 15 workshops in 2023 and 2024 at “KinderUni” events. Participants were children aged 6 to 12 years, with varying group sizes (mostly 16 to 20 participants).

Although no formal pre/post testing was conducted, the following insights emerged through informal observations and anecdotal feedback:

- Most children really enjoyed solving the puzzles, were engaged and eager to participate.
- Particularly well received was that the children learned interesting facts about the metals and carried out practical experiments.
- Many participants left with some additional knowledge about the four metals addressed in the game and featured at all four stations.
- Teams of four to five often showed improved collaboration and communication over time when solving tasks at the different stations.
- The organizers from the “KinderUni” reported that the overall feedback to this escape room was very positive. So, even additional workshops were organized as there were so many children on the waiting list.

These observations suggest that the escape room not only increases motivation but also promotes long-term memory formation through active participation and storytelling. Structured evaluation tools (e.g., short quizzes or reflection forms) will be introduced in future implementations.

6. Conclusion and Future Work

This project demonstrates how gamified, narrative-driven formats can significantly enrich chemistry education for young learners. This escape room encourages the players – and it this special setup already children - to try out things with hands-on experimentation and playful exploration. It brings science closer to the participants and also enhances their curiosity.

Planned future developments include:

- Adaptations for secondary school level with more complex chemical content
- Implementation of quantitative assessment tools for measuring learning outcomes

This model introduces a scalable and dynamic framework that integrates scientific content with creativity and enjoyment, enhancing both accessibility and long-term retention.

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From Chance to Strategy: Advancing Educational Games about Vertebrates for Elementary Students

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Abstract: This study presents the development and improvement of an educational game aimed at enhancing elementary students' understanding of vertebrate classification. The original version used a dichotomous key to help classify five groups of vertebrates: fish, amphibians, reptiles, birds, and mammals. Initial implementation showed promising results, with average post-test scores exceeding 80% and high student satisfaction. However, limitations were found, such as excessive reliance on chance through dice-rolling, limited strategic options, and lengthy gameplay that reduced engagement, especially in the later stages. In response to these limitations, the game was redesigned to encourage visual observation, reasoning, and strategic decision-making. Players must now analyze animal traits, justify their choices, and select cards that match the game's objectives. The development process involved collaboration with experts including university lecturers, science teachers, game designers, and students aged 10–13. Data were collected through classroom observation and informal interviews and used to refine the game across multiple iterations. The revised game promoted higher student engagement, critical thinking, and strategy through trial and error. Mistakes made during gameplay helped students remember animal traits more accurately and improve in later rounds. While the game supported advanced thinking skills, some areas still needed improvement. Experts suggested simplifying the scoring system, improving the clarity of animal images, and enhancing the game's replayability. Some experts recommended immediate revision, while others believed students would adapt through repeated play and become more familiar with the game.

Keywords: Vertebrates, Educational games, Game-Based learning, Iterative design, Observation and analysis

1. Introduction

Educational games are learning tools specifically designed to teach certain skills or concepts. They are often linked to curriculum standards to support formal learning objectives. Although educational games have attracted academic interest since the 1970s, there is no clear evidence that they are more effective than traditional teaching methods (Engström, 2020). However, game-based learning offers many advantages. It increases student motivation and engagement through interactive and enjoyable experiences (Qian & Clark, 2016). When students actively participate in gameplay, learning becomes more meaningful and less monotonous. This positive engagement also encourages students to explore complex topics with greater interest and confidence (Dichev & Dicheva, 2017). The combination of fun, challenge, and competition in educational games can stimulate curiosity, improve memory, and support deeper understanding of concepts (Kapp, 2012).

In biology education, there are still many limitations in teaching materials. For example, lessons on vertebrate classification often follow a teacher-centered approach. Students usually learn by listening to the teacher and looking at pictures of common animals. They are then asked to classify animals by comparing external traits using their existing knowledge (Ausubel, 2000). These materials often provide oversimplified generalizations and fail to show the diversity of life. As a result, students may develop misconceptions, especially when they encounter unusual animals such as egg-laying mammals (e.g., platypus, echidna) or mammals with reptile-like traits (e.g., pangolin) (Diamond & Bond, 2004). These cognitive challenges show the need for new teaching strategies that promote analytical thinking and deeper understanding.

Educational games about vertebrates can offer a new and promising way to improve biological knowledge. These games use real biological features of animals and combine them with game mechanics that naturally engage students in learning. Many studies have shown that both digital and board games in biology can increase motivation, support learning outcomes, and promote critical thinking about ecosystems and biodiversity (Gros & Wisson, 2020; Moreno et al., 2020). Chang et al. (2019) also found that immersive gameplay helps students develop analytical thinking and better understand complex ideas. A clear example is the VERT card game by Punyasettro and Yasri (2021), which allows students to explore vertebrate phylogeny through competitive and cooperative play. Their study showed that students gained more self-confidence and

improved their understanding of evolutionary relationships, showing the potential of well-designed classification games.

Although educational games are increasingly used in biology classrooms, there are still few empirical studies on how game mechanics affect students' conceptual understanding. Most existing research focuses on the motivational effects of gameplay (Qian & Clark, 2016; Dichev & Dicheva, 2017). Only a few studies explore which game features help students develop classification skills and increase engagement. To fill this gap, this study aims to examine what characteristics of an educational game can improve learning and student engagement. The focus is on a game developed for teaching vertebrate classification at the elementary level. The study presents findings from redesigning the original game into a new and improved version.

2. Research Design and Methodology

This study used a design-based research (DBR) approach to develop and improve an educational game about vertebrate classification. DBR is a flexible but systematic method. It supports both practical innovation and theoretical understanding in real classroom settings (Anderson & Shattuck, 2012). The main goal of this study was to improve the original game step by step using evidence from practice. The research was guided by one question:

What features should an educational game have to support students' classification skills and learning engagement?

The study took place in two phases:

Phase 1: Testing the Original Game (Amass Me)

The original game was tested with Grade 4 students, aged 9 to 10. Data were collected through classroom observation, informal interviews, and post-game assessments. The results showed that the game helped students learn the content. Most students scored above 80% in the post-test. However, there were some problems. The game relied too much on luck, especially from rolling dice. It also offered few chances for students to plan or use strategy. In addition, many students found it hard to understand the symbols used in the game. These problems led to the redesign of the game.

Phase 2: Developing and Testing the Revised Game (Vertebrate Auction)

The new version of the game was designed to solve the earlier problems. It kept the same scientific content but changed how students played. The new game encouraged students to observe, analyze, and plan. It helped them identify both common and unusual traits of animals more accurately. The new version was reviewed by experts, including science educators, teachers, gamers, and board game designers. Their suggestions helped improve the game's accuracy and usefulness in real classrooms. The revised game was tested with students aged 10 to 13. These students had already learned some basic ideas about vertebrates and could handle more complex thinking tasks. During testing, the researchers observed classroom interactions and interviewed students informally. They used this information to improve the game further. The results gave insight into how students learned and engaged with the new game design.

3. Original Game Concept: Amass Me

The original game, Amass Me, was developed to support the cognitive and educational needs of Grade 4 students (ages 9–10), aiming to cultivate basic knowledge of vertebrate classification, rule-following, reasoning, and decision-making skills through playful learning. It was designed for both classroom use and informal home learning, with content and visuals tailored to be age-appropriate, colourful, and engaging to maintain student interest and autonomy.

The gameplay combined elements of chance, analytical thinking, and strategy. Players rolled dice to match biological traits on animal cards and used a dichotomous key for classification. Correct classifications were rewarded with coins, while mistakes incurred penalties. The central mechanics required players to manage luck (dice outcomes), knowledge (trait analysis), and decision-making (action choices) to classify ten animals and collect the most coins.

Game components included 55 animal cards, 8 special cards, coins, classification boards, dice, and bases—designed for clarity and visual appeal. Icons on dice represented five key biological traits: body covering,

appendages, respiration, reproduction, and thermoregulation. Game visuals were created using Canva and refined with expert input.

Each of the five dice displayed six faces, each depicting different trait values commonly used in vertebrate classification. These were proportionally repeated to reflect real-world biological variation, providing both realism and gameplay balance. The trait categories and representative values were as follows:

Table 1: Characteristics of vertebrates shown on dices

Dice	No.	Characteristics
1. Body Covering		
	1	Has scales
	2	Moist skin
	3	Has hard scales
	4	Has feathers
	5	Has hair
	6	Nothing shown
2. Animal Appendages		
	1	Appendages are fins, has 5 fins, and tail fin moves side to side
	2	Appendages are fin-like, has 4 fins, tail fin moves up and down
	3	2 pairs of appendages, front pair are wings not connected to hind pair
	4	2 pairs of appendages, front pair are wing-like connected to hind pair
	5	2 pairs of appendages, used for movement or grasping objects, and/or has 1 tail
	6	No appendages
3. Respiration		
	1	Breathes using gills
	2	Larvae use gills but adults use skin and lungs for breathing
	3	Breathes using lungs
4. Reproduction		
	1	Lays eggs with jelly-like covering
	2	Lays eggs with hard shell
	3	Gives birth to live young
5. Body Temperature		
	1	Body temperature does not change with environment (warm-blooded)
	2	Body temperature changes with environment (cold-blooded)

These symbols guided players during gameplay to identify which animals they could attempt to classify based on the dice results, integrating biological concepts directly into the core game mechanics.



Figure 1: Components of the original game “Amass Me,” including animal cards, dice, and classification boards

3.1 Gameplay Summary

- Each player received 5 animal cards and 10 bases.
- On their turn, players could roll dice, draw/discard a card, or use a special card.
- Players rolled five dice and placed cards with at least three matching traits.
- Cards were classified using the dichotomous key for rewards or penalties.
- The game ended when a player successfully classified all ten animals.

3.2 Playtesting and Findings

Initial testing with Grade 4 students showed that they were excited to play. However, many students had trouble understanding the rules and the meaning of the symbols. This confusion caused the game to progress slowly. The researchers adjusted the rules by changing the required number of matching dice faces from three to two. After this change, the game became easier to play. Students showed more cooperation with each other, became more emotionally involved, and used more strategic thinking. Informal interviews confirmed that students enjoyed the game. They also helped each other and became more skilled over time. In a different trial, 29 Grade 4 students played the updated version of Amass Me. After playing, their test scores averaged 83.8 percent. This score was higher than the 80 percent benchmark and the difference was statistically significant with a p-value less than 0.05. These results showed that the game helped students improve their understanding of how to classify vertebrates.



Figure 2: Implementation of Amass Me to Support Vertebrate Classification Learning in Grade 4

3.3 Analysis and Limitations

Amass Me helped students feel more motivated and engaged. It also supported their understanding of core concepts. The use of visual symbols and the need for decision-making encouraged teamwork and reduced stress. However, some students found the game too complex. There were many symbols to learn, and the game relied too much on chance. These factors made it harder for some students to follow. The game also

took a long time to complete. This long duration may have caused some students to lose interest, especially if their skill levels were different from others.

To solve these problems, the game was redesigned. The new version focused more on observation. It reduced the role of luck and gave players more control. The rules were clearer, and the mechanics allowed for better strategic planning.

4. Revised Version of the Game: Vertebrate Auction

To address the limitations identified in *Amass Me*, the game was redesigned and renamed *Vertebrate Auction*. This revised version enhances students' observational and analytical thinking while minimizing randomness. The game incorporates five types of cards:

1. Dichotomous Key Cards These five visual reference cards illustrate essential traits used in vertebrate classification. Designed for clarity and instructional value, they help students distinguish between groups based on observable physical features.

2. Animal Cards Each of the 54 double-sided animal cards features a full-color image on the front and key classification details on the reverse. These traits align with the Dichotomous Key Cards and provide diverse examples for comparative analysis.

3. Main Target Card This card presents the core scoring criteria: players earn 2 points for collecting one animal from each vertebrate group, and 5 points for collecting two from each. This encourages players to diversify their collection strategically.

4. Additional Target Cards These supplementary goal cards feature specific traits that players must identify in the Animal Cards. Bonus points are awarded for matching the required traits, reinforcing detailed observation and trait recognition.

5. Auction Cards Players use numbered bidding cards (1–6) to compete for animals during each round. Higher bids allow earlier selection, fostering strategic planning in card acquisition.

4.1 How to Play: Vertebrate Auction

1. Game Setup Place the Main Target Card and draw three Additional Target Cards to be displayed in the center. Each player receives 5 Dichotomous Key Cards and a full set of Auction Cards (1–6).

2. Gameplay Structure The game consists of 6 rounds. In each round, players compete to collect animals through an auction mechanism. By the end of the game, each player will have 12 Animal Cards to classify.

3. Auction and Selection At the start of each round, reveal Animal Cards equal to twice the number of players. Players then bid using one Auction Card. The highest bidder selects first, followed by others in descending order. Each player repeats this process to obtain two animals per round.

4. Classification and Scoring After six rounds, players classify their 12 Animal Cards using the Dichotomous Key Cards and score according to the Main and Additional Target Cards. The highest scorer wins.

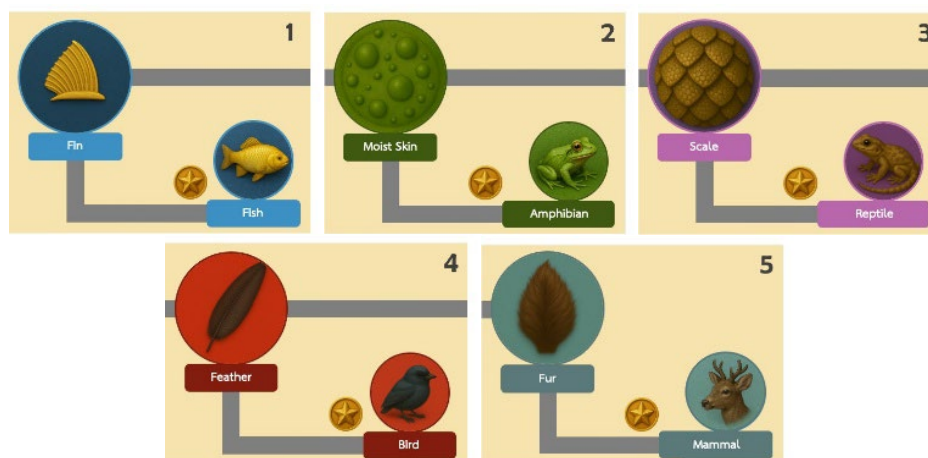


Figure 3: Dichotomous Key cards

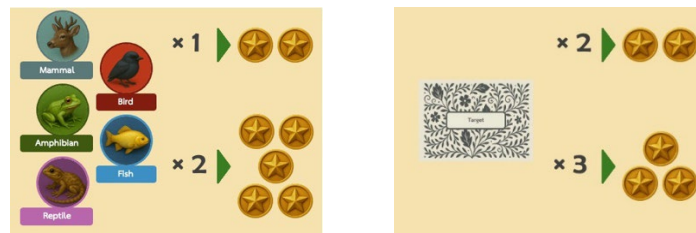


Figure 4: Main Target cards



Figure 5: Animal cards

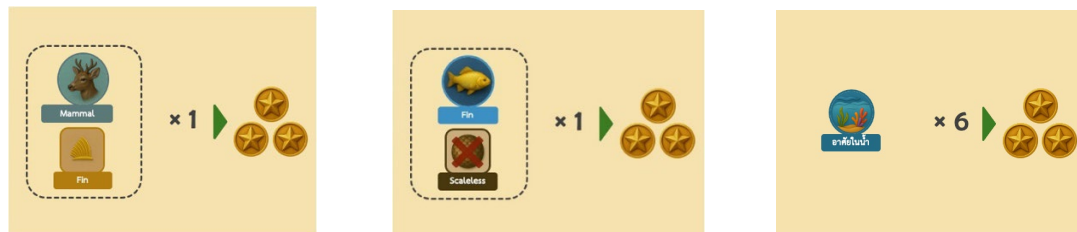


Figure 6: Additional Target cards



Figure 7: Auction cards

5. Research Findings

During the prototype development phase of the Vertebrate Auction game, the researchers conducted a playtest with experts in relevant fields. The purpose was to gather diverse feedback for improving the game and identifying design flaws. The expert responses were thematically analyzed and grouped into three main themes as follows.

Theme 1: Complexity of the Scoring System

One major change from the original version was the scoring system. The revised version allowed players to earn points through multiple methods. This design aimed to promote strategic thinking and encourage players to carefully observe and analyze animal characteristics to score as many points as possible. The scoring rules were as follows:

- 1) Players received 1 point for each animal card they correctly classified using the dichotomous key. This rule encouraged accurate classification through observation and reasoning.
- 2) Players received 2 points when collecting one complete set of animals from all vertebrate groups, and 5 points when completing two full sets. This aimed to motivate players to collect cards from all categories.

3) Players received 2 or 3 additional points, as indicated on the bonus target cards, for collecting animals with specific traits. These traits often represented animals that are commonly misunderstood, such as pangolins, whales, bats, or stingrays.

Examples of expert comments in this theme include:

- “The game might be too difficult for students because there are many things to pay attention to.”
- “The scoring system is quite complicated, but if students play a few times and become familiar with it, it should not be a problem.”

Theme 2: Fairness of the Scoring System

A consequence of adding more ways to earn points in the revised game was the imbalance between the points awarded and the level of difficulty described on the target cards. Some targets were hard to achieve but gave only a small number of points, while others were easy but gave more points. As a result, some players lost motivation, especially when they received difficult target cards or cards with low rewards. This imbalance may have created unequal chances of winning among players. Examples of expert comments in this theme include:

- “The card asks for 7 warm-blooded animals but gives only 1 point. That’s not interesting.”
- “Collecting animals with shells is too hard. There is only one card out of fifty, and it’s not even guaranteed to come up.”

Theme 3: Overall Game Presentation

The overall presentation refers to how game components are arranged to help communicate ideas or support reflection after gameplay. Experts agreed that the game effectively conveyed biological knowledge about vertebrate animals, including shared and unique traits. Examples of expert comments in this theme include:

- “The overview after playing is clear. When the answers are revealed, the teacher can use them to ask questions and help students summarize the lesson.”
- “The symbols are a bit visually crowded, but the shapes and layout help make them easier to observe.”

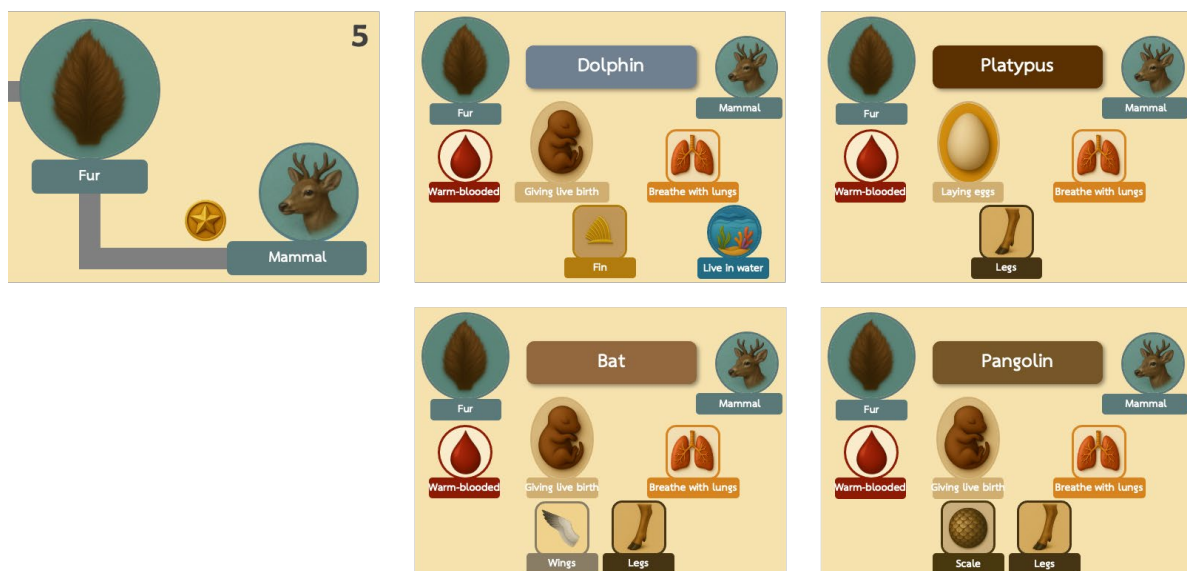


Figure 8: Final Set of Mammal Cards Collected by a Player During Vertebrate Auction Gameplay

Theme 4: Player Interaction

One issue that the early version of the revised game could not fully address was the lack of interaction among players. Initially, each player was given three individual target cards. This rule made players focus only on their personal goals. To solve this problem, the target cards were placed in the center so that all players worked toward the same goals. This change required players to plan their bidding order carefully in order to compete for animal cards that matched the shared targets. Examples of expert comments in this theme include:

- "It feels like everyone is playing on their own."
- "The auction doesn't feel meaningful because, in the end, I still get the card I want."

5.1 Student Playtesting and Feedback

After the game prototype was refined to ensure its accuracy and classroom suitability, it was tested with a small group of students aged 10 to 13. The goal was to evaluate students' perspectives on the game. The testing was conducted by classroom teachers to reduce bias during implementation and data collection. Informal interviews were guided by the following questions:

- Did you find the game enjoyable? Which parts did you like or dislike?
- Would you be interested in playing this game again? Please explain why or why not.
- Are there any parts of the game you would like to see improved or changed? If so, please describe.

Students' responses were analyzed thematically and grouped into three main categories. These themes reflected the game's strengths, challenges, areas for improvement, and learning-supporting features. A summary of each theme with sample student quotes is presented below.

Theme 1: Challenges and Limitations During Gameplay

A common theme in student feedback was the complexity of the scoring system. Many students noted that tracking points—especially when trying to complete both main and additional targets—was difficult and sometimes confusing. This complexity occasionally distracted players from the core learning goal, which was vertebrate classification. Sample student comments include:

- "The scoring system should be improved because keeping track of points is quite complicated, especially with so many targets to monitor."
- "It's fun, but the scoring is a bit too complicated."
- "During the game, players might forget to complete the main target."
- "Counting the score is really confusing."

These responses suggest a desire for a simpler scoring system to promote smoother gameplay and sustained engagement. Interestingly, the feedback also implies that players placed more importance on classification tasks than on scoring, which aligns with the design goal of encouraging repeated play to improve classification fluency and accuracy.

Theme 2: Difficulty in Identifying Animal Types

Another key challenge was the difficulty of identifying animals based on the pictures on the cards. Students said that without prior knowledge of animal characteristics, it was often hard to classify animals correctly. Examples of student feedback include:

- "Identifying the animals just from the pictures is quite hard if you don't already have background knowledge."
- "Some pictures are difficult. For someone like me who doesn't know much, they are really hard to understand."

This theme highlights the gap between visual interpretation and conceptual understanding. It also shows the importance of background knowledge for gameplay success. The designers intentionally included this challenge to encourage players to observe, interpret, and build knowledge gradually through the revealing of biological traits on the reverse side of each card in subsequent rounds.

Theme 3: Positive Learning Experience and Educational Value

Despite the challenges, most students provided positive feedback about the educational value of the game. They found it both enjoyable and helpful for understanding vertebrate classification. Examples of student comments include:

- "It's fun and educational."
- "This game is really good for teaching animal classification. After scoring, the game explains the animal's features, which helps players learn more."

These responses confirm the game's objective of making science learning engaging and meaningful. The game's iterative structure encourages analysis of classification features, supports the application of prior knowledge, and helps students refine their strategies through repeated play and interaction with others.

6. Conclusion

This study demonstrates the potential of educational board games to enhance elementary students' conceptual understanding of vertebrate classification. Through a design-based research (DBR) approach, the game Amass Me was iteratively improved into Vertebrate Auction, incorporating feedback from both experts and students. The findings highlight key design features that support scientific thinking, such as the use of visual cues, shared goals, and strategic decision-making. The revised game reduced reliance on chance, increased player agency, and fostered meaningful interaction—addressing the limitations observed in the original version. Both expert evaluations and student feedback emphasized the game's educational value, especially in promoting observation, analytical thinking, and collaborative learning. Challenges such as scoring complexity and animal identification were acknowledged, suggesting areas for further refinement. Nevertheless, the game successfully transformed traditional instruction into an engaging, student-centered experience.

This research contributes to the growing body of literature on game-based learning by offering empirical insights into how specific mechanics influence learning and engagement. It also underscores the importance of iterative design grounded in real classroom contexts. Future research could explore long-term learning outcomes, scalability across diverse educational settings, and the integration of such games into broader science curricula.

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AI Declaration: The authors declare that AI tools were used to assist in language refinement and grammatical accuracy checking of this manuscript. Specifically, AI was employed to improve clarity, coherence, and formal academic tone without generating or altering the substantive content, data interpretation, or conclusions of the study. All revisions suggested by the AI tool were reviewed, verified, and approved by the author(s) to ensure accuracy and alignment with the intended meaning.

Ethics Declaration: This study was conducted in accordance with ethical standards for research involving human participants and was approved by the Institutional Review Board (IRB) of Kasetsart University prior to data collection (Approval No.: COE67/060). All participants, including students under the age of 18, were informed of the purpose and procedures of the study, their right to decline or withdraw at any time without penalty, and the measures taken to protect their personal data. Written informed consent was obtained from all participants and, where applicable, from their legal guardians before participation. The researchers affirm that all data were anonymized and treated confidentially, and that the information collected will be used solely for academic and research purposes.

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Development of a Serious Game for Practicing Pronouns

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Abstract: One primary aspect of civic education is to build inclusive societies where everyone can feel valued, respected and celebrated for their individual diverse attributes. While a civilised society exercises tolerance, empathy, compassion and forgiveness, in the daily walks of life there are no second chances to make the correct first impression. Many individuals are exceptionally apprehensive when having to interact with minorities through fear of causing unintentional offence or emotional damage in first encounter situations. Serious games can offer an immersive and educational training experience where mistakes can be made with far fewer ramifications than in real life making them significantly more risk free. This paper explores the development of *Pronouns in Practice*, a serious game designed specifically to address inclusive communication, with a focus on pronoun use. This paper will review the literature on the use of serious games in Equality, Diversity and Inclusion (EDI) related areas particularly looking at pronoun related training in the Educational Sector. The prototype will be constructed using subject experts in conjunction with user and design requirements identified in the literature review and a design framework that is outlined. The paper will present a preliminary design framework for development and evaluation of serious games in EDI related subjects and will particularly look at the use of simulations in initial human interaction with the use of pronouns. The paper intends to produce a prototype to address alleviating concerns with general interaction associated with using pronouns.

Keywords: Serious games, EDI, Pronouns, Game-Based learning, Educational game

1. Introduction

EDI initiatives have become vital to the positive culture of educational institutions (Corsino and Fuller, 2021) with studies suggesting more work is needed in the field (Cumming, Miller and Leshchinskaya, 2023; Mendoza *et al.*, 2015). As awareness grows around issues of identity, one major challenge has been the ability to equip individuals to engage respectfully and confidently with members of the LGBTQIA+ community. A crucial segment of this is the appropriate use of gender pronouns, which can be a source of discomfort or anxiety for those unfamiliar with newer linguistic norms. To mitigate these concerns and foster inclusivity, new pedagogical approaches are required. Traditional EDI workshops often involve face-to-face exercises, role-play scenarios, and group discussions. Appropriately integrating innovative technology such as serious games can offer alternative methods to facilitate inclusive dialogue and engagement, potentially broadening the training's effectiveness and accessibility since, while traditional EDI workshops can be impactful, they may not suit all learners equally. Research has suggested that diversity programs by-in-large tend to aim to control the training participants' behaviour (Dobbin and Kalev, 2016). As a result, this can backfire by ultimately triggering bias rather than fully informing and explaining said bias as people push back against challenges to their autonomy. It is further proposed that a solution to this would be to engage people in working for diversity by having participants engage with those affected by these biases more prominently. Furthermore, for people to learn it is required that the learner come to accept and embrace differences (Kolb and Kolb, 2005), be they a difference in the learner's knowledge, differing beliefs and/or differing life experiences. Creating safe spaces for diverse learners is core EDI workshop goal. Serious games are interactive, immersive digital experiences designed for educational purposes and can offer an alternative or help supplement workshops learning in these areas. This paper introduces *Pronouns in Practice*, a serious game designed to be used within higher education workshop environments, including staff training and help complement EDI initiatives by simulating real-life interactions involving pronoun use, in a risk-free and engaging virtual environment.

2. Serious Games in EDI

Serious games have been increasingly recognised as powerful tools in education and professional training, offering a unique balance between engagement and learning and can educate the user in a wide range of ever-increasing learning topics (Boyle *et al.*, 2016). In the context of EDI, games can offer participants an opportunity to experiment with their perceived correct responses, help participants explore diverse perspectives, and simulate sensitive social interactions without real-world consequences. Studies have demonstrated that such digital environments can foster empathy (Ferreira *et al.*, 2021) and provide a safe space for making mistakes. This is an essential component of learning in socially delicate areas such as gender identity.

For participants who may find direct role-play daunting, serious games can offer simulated interactions in which users control their pace and engagement levels. *Pronouns in Practice* is designed to digitalise key elements of these types of workshops, offering an experience that is consistent, repeatable, and accessible across different settings and demographics.

2.1 Previous Games on EDI and Pronoun Learning

EDI is a large, complicated umbrella-like term which is used as a buzz acronym that mitigates its complexity. While serious games have been widely explored as tools for teaching a variety of topics related to EDI, a clear gap exists in games focused on pronoun usage and inclusive language. Moreover, there is a distinct lack of empirical evidence associated with the use of serious games in EDI topics and in the serious games academic discipline in general. Although games exist in EDI related subjects, their discovery in academic databases is difficult if specificity in search terminology is not used (Hainey *et al.*, 2024). This gap may be due to the perceived sensitivity or complexity of the topic, which can make it difficult to design engaging learning experiences. Another challenge is balancing respectful representation with the risk of reinforcing stereotypes.

Through researching existing serious games and related literature, no examples were identified that explicitly focused on pronoun use as a primary learning objective. While some touch on broader themes of identity or inclusion, this specific topic remains largely unaddressed. However, several adjacent projects were found that addressed pronoun usage partially or tackled the idea of creating safe spaces for learning sensitive social topics, and how design choices such as perspective-changing and narrative branching can contribute to reflection and self-learning. The following projects are included as examples of related work that explore similar themes, including identity, inclusion and learning through serious games:

A serious game project produced two games; *Change Perspective* and *Diverse Perspectives* (Peters Rit, Volk and Hauptmann, 2024). In the former, users experienced scenarios from two points of view - from that of a Dutch student and then from a German student's perspective with the goal of encouraging users to understand and reflect on different cultural experiences which could aid in a better cultural integration experience. Gameplay is narrative-driven, with choices leading to multiple endings.

Building on the foundations of *Change Perspective*, the researchers later developed *Diverse Perspectives*, a more refined game featuring a wider range of scenarios, including one that specifically addressed pronoun use. In *Diverse Perspectives*, users could select an avatar from three predefined options (female, male and non-binary) and engage with branching dialogue in a 2D visual novel format, similar to the approach used in *Pronouns in Practice*. Notably, the researchers observed a difference between what users said they would ideally do in scenarios vs. the actions they chose to do, a finding that highlights the importance of reflection in scenarios where sensitive social interactions take place.

Additionally, while *Diverse Perspectives* found that switching perspectives increased the nuance and reflection in the gaming experience, *Pronouns in Practice* chose not to implement player avatars, opting to embed the user's presence in the game within the dialogue used. This was in part due to the challenge of representing a full range of diverse identities adequately within the scope of the development. Allowing names within the dialogue allows NPCs (non-player characters) to directly reference users by name thus allowing for a personalized narrative experience. The addition of a "Narrator" allows us to further deepen the scenario by offering qualitative descriptors of how the user's actions have affected the NPCs (how they look after an option is chosen, actions taken such as leaving a room etc.).

An adjacent study was performed to examine interpersonal communication between users while participating in a grouped game experience with the game touching on sensitive topics of diversity and inclusion (Balan, 2024). Using a serious board game and a pre/post interview process, the researcher found the most acknowledged traits that helped dialogue between users (in-order) were; active listening, self-awareness and empathy. It was noted these traits helped create trust and safety between users and helped them engage more in vulnerable conversations.

Another serious game project that had elements of EDI training was that of *Path to Understanding*, a 2D adventure RPG and puzzle game created to address the realization of microaggressions in a hospital setting and how one might respond to microaggressions (Xu, 2024). *Path to Understanding's* objectives align with this paper's serious game in that the researcher's intent was to create a story-driven serious game that integrated interactive and decision-making elements with a goal of fostering skills such as empathy and self-awareness. While the thesis did not include an empirical evaluation or assessment framework, it presented a strong theoretical case for using serious games to foster empathy, improve learner engagement and support long-term

behavioural change. The researcher compares the limitations of traditional EDI training with the potential strengths of serious games, emphasizing the value of immersive environments.

3. Design and Development

The design of *Pronouns in Practice* is guided by knowledge from the creation of serious games previously in educational contexts, alongside established theoretical game-based learning frameworks. By simulating real-life scenarios with branching outcomes, the game promotes adaptive learning (Kolb, Boyatzis and Mainemelis, 2014) by allowing the user to experience a scenario and affect how a scenario might end, depending on their choices. Having this choice allows the user to learn from interactions within the game, offering the user constructivist learning in that they can then adjust their full understanding via feedback and reflection the game provides them at the end of a scenario.

The game aims to recreate EDI workshop scenarios in a digital context, providing structured interactions that simulate real-life conversations regarding pronoun use. By integrating educational content into branching dialogue and contextual scenarios, users are encouraged to consider the impact of their choices. Central to the design philosophy is modularity and adaptability. The game is being developed with the intention of being a persistent learning tool, one that learners can return to over time to refresh their knowledge or engage with new material. Initially, two to three scenarios will be developed and included in the prototype. These will be based on common missteps and teachable moments drawn from real-world EDI training.

An outline of the game's design framework, along with some design principles followed are provided below:

The first two stages of our framework are Project Origin and Project Selection. These stages are the acceptance of a project with Project Origin being the general idea that has been given (create a serious game that does x) and Project Selection being the more refined output of several ideas as to how the original idea could be output as a serious game (the type of genre the game could be, platforms it could be deployed on etc.). During these stages the original concept is expanded to offer choice to the original idea holder since being the subject experts means they might be able to offer insight into how the topic has been learned previously. For most serious games, you can break down the key functionality into two groups our framework uses; teaching games or testing games.

Teaching games refers to a game that's primary function is to impart knowledge on to the user. This knowledge is outlined by our subject experts, pertaining to learning outcomes the original idea holders themselves have. These games usually have a small part for reinforcing the knowledge via a test, but it is not the main structural part of the game, gaining the knowledge is.

Testing games refers to a game that's primary function is to test the user on assumed knowledge that is present before they start the game. The game's objective here is to highlight weaknesses and gaps in the user's knowledge base by testing it and giving useful feedback when the user is wrong.

For example, *Pronouns in Practice* will provide feedback when a user has made an answer but due to the complexity in language and dealing with sensitive topic matters, we do not enforce the feedback as a binary right/wrong function. The game's primary function aligns with a teaching game more, as its primary function is to allow knowledge to be imparted with no prior knowledge needed.

The third and fourth stage are initial constraints; Initial Meeting and Initial Scope. These stages are some of the most important in the design and development process. These stages allow us to outline the limits in scope, time and other resources, such as correspondence with subject experts. This is also where the subject experts will start to fully understand what might be asked of them to provide for the serious game to function.

The fifth stage is Development, and this is the largest of stages. Cycling back constantly in this stage with added feedback from stakeholders and subject experts with their input allows the game to provide an experience that all involved are happy with.

The sixth stage being End Product allows us to decide the finality of the scope of the serious game and separates it from the final stage for a couple of reasons, namely due to the modularity of having maintenance cover only a specific development cycle of the game. Maintenance can be a repeatable stage here, covering for instances of the serious game no longer working due to technical upgrades. The seventh and final stage is End Project or End Phase. This allows us a checkpoint to stop and look back from. Any evaluation on the development itself would be done here along with a review of all that happened before this.

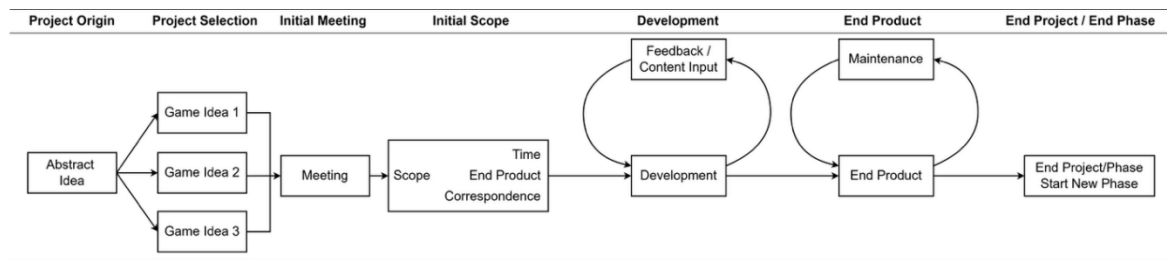


Figure 1: Diagram of framework followed

4. Implementation

To set the groundwork for long-term adaptability and user-driven content creation, two phases of the project were created and worked on in parallel. The first phase being the main base game, with pre-built scenarios already designed that helps simulate common real-life situations involving pronoun usage. Phase two was the development of a scenario editor, a tool that will allow educators to create, customise and modify scenarios to suit their specific learning objectives. A breakdown of both phases are as follows:

4.1 Phase 1 - The Base Game with Pre-Built Scenarios

Pronouns in Practice is a 2D visual novel-style serious game designed as an educational tool to support inclusive communication and discussion in a workshop environment through interactive scenarios. *Pronouns in Practice* is being developed using the Unity game engine, selected for its cross-platform capabilities and deployment options. Unity allows the developer to create builds for a range of technologies including Windows, macOS, and mobile platforms, ensuring broad accessibility and ease of dissemination within varying technical resources.

Consultation was initially done with a subject expert EDI Coordinator to help build the scenarios. Drawing upon their experiences delivering EDI workshops, the EDI Coordinator provided valuable insights into common real-world issues and sensitive scenarios including pronoun usage. Their expertise ensured that the scenarios created were authentic and reflected workplace realities used in workshops already thus helping the game's design to be of best practice. The game will allow the user to be in or watch a narration take place, with sections asking for user input as to what they or the point of view character should do in that situation. The scenarios are as follows:

Scenario 1: The Presentation - The user is in a professional setting where they witness a colleague, Hannah, accidentally misgender Alex after a presentation. The user sees an interaction play out and helps Hannah decide how to correct herself in the moment.

Scenario 2: The Team Meeting Mix-Up - The user is in a professional setting where they accidentally misgender a colleague they line manage, Jack, during a team meeting. The user has no choice but to misgender Jack in this scenario to enable them to make a choice on how to proceed when they make a mistake. Jack is a transgender man who the user knew before he began his transition. The user must decide how to correct themselves in the moment and how to address it afterward.

Scenario 3: Colleague Misgendering Incident - The user is in a professional setting where they witness a colleague, Ben, misgender another colleague, Hayley, in the office. The user line manages both colleagues. Hayley is a transgender woman who is new to the organisation. The user must decide how to manage the incident in the moment and how to address it afterward.

Game Mechanics

For game mechanics we have adapted a simplistic approach, not wishing to over-complicate the user's experience. A menu screen will allow the user to enter a given scenario. Clicking the "continue" button once the full dialogue of a person has appeared on the screen will continue the scene forward (Figure 2). At a branch path (i.e. when the user must decide) the choices will appear as buttons on the screen, allowing the user to choose only one (Figure 3).

Once a scenario has been completed the user will see a feedback screen (Figure 4). This will provide reminders to the questions asked, the answers given and appropriate feedback. This section will also provide additional open questions to the user that could help further conversation in a workshop setting.

Visuals

For visuals, we have focused on the scenes being simple in design to set up. A 2D background sets the scene appropriately for the location it is being set in. NPCs will appear in one of three locations: to the left, centre or right. This will allow the user to interpret a conversation between several characters at once. As of the prototype, these NPCs will be represented via 2D images/sprites. This will allow easier customisation when the scenario editor is created. A light transparent effect has also been used to emphasise the current speaker.

Interfaces

For user interfaces, we have elected to keep it simplistic. A main menu screen will present the user with their choice of scenario, with a small synopsis for each. When in a scenario, the user clicks the continue button to proceed through the dialogue. For dialogue display, what a character is saying is shown prominently along the bottom of the screen, along with their name to the upper left of the dialogue. This allows the dialogue to be large enough to pull the user's focus but not take up too much space that the NPCs and background are ignored or occluded (Figure 2). When a question is asked, the user cannot continue the scene until an answer is clicked. The game leaves the previously said dialogue line visible at the bottom of the screen so the user can fully realize their answer (Figure 3).

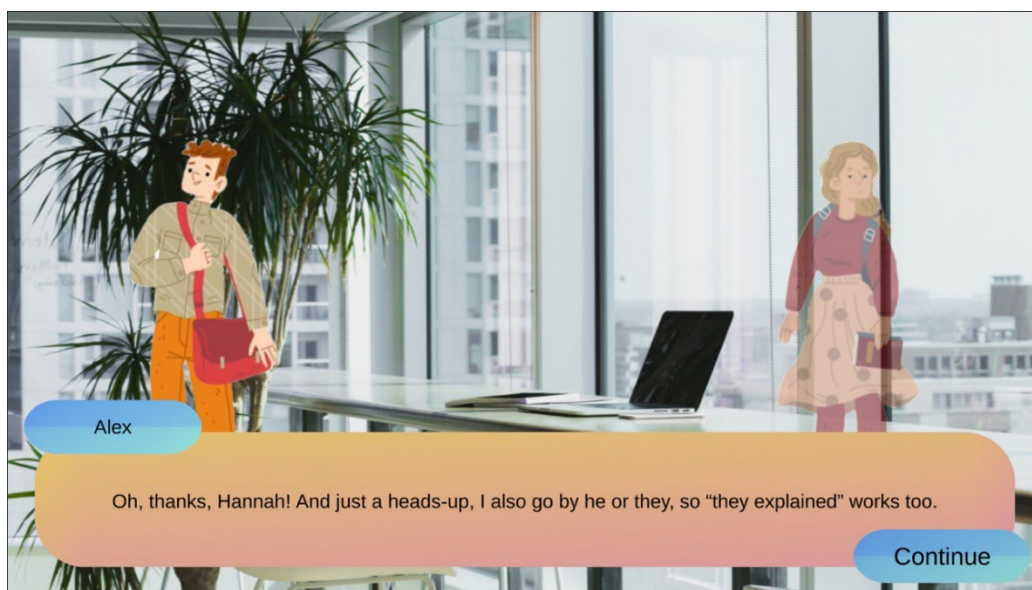


Figure 2: Alex is responding to Hannah

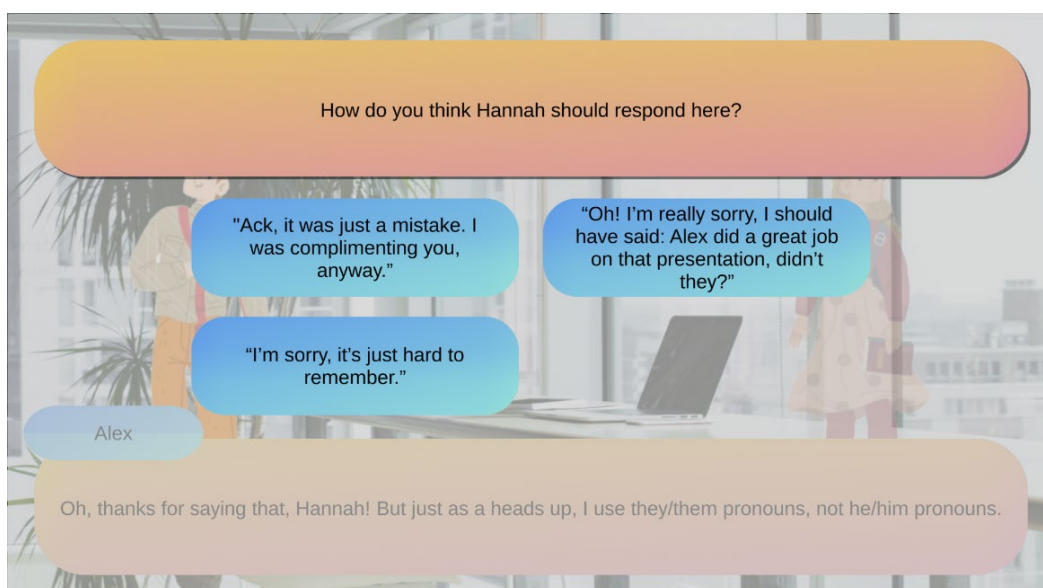


Figure 3: Example of a question

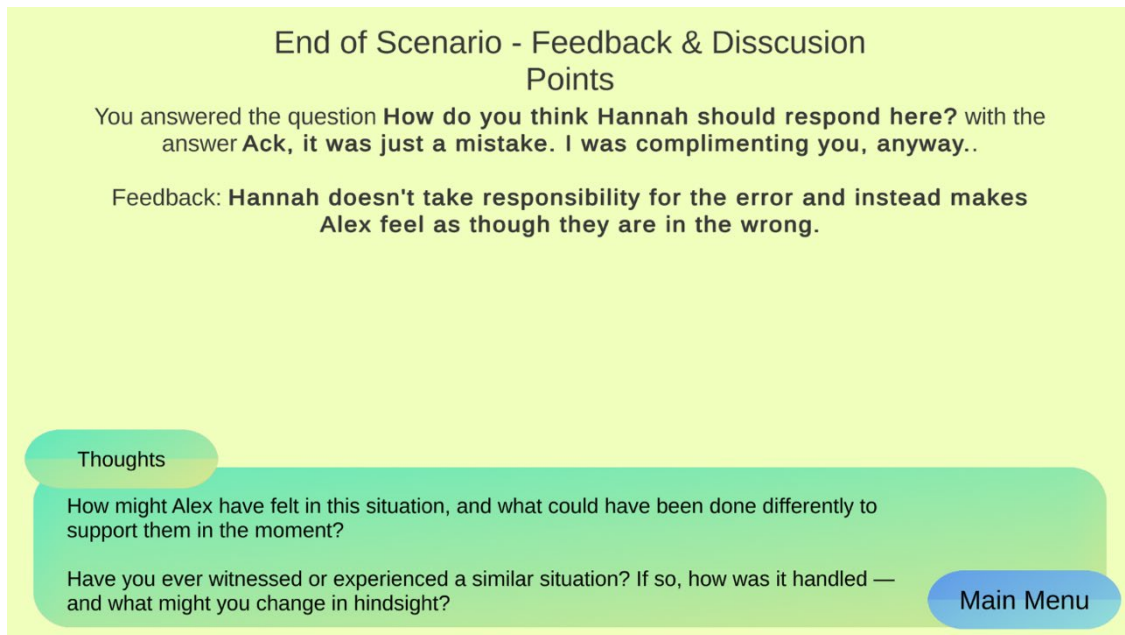


Figure 4: Example of the feedback screen

4.2 Phase 2 - The Scenario Editor

A key aspect of this project was to offer not just a tool with predefined scenarios but to allow some aspects of the scenarios to be customisable. This type of tool aims to ensure the game remains adaptable and future-proof. Drawing upon the idea of Gee's "Insider Principle" (2003), the editor empowers users to move beyond passive consumption of the content and take on active roles in the creation of scenarios. The idea being that learners can deepen their engagement when given the opportunity to customise within any given learning system. This type of flexible editing will allow educators to expand and tailor scenarios to their own pedagogical goals and the specific needs of their learners.

An editor such as this, which allows for the creation and modification of scenarios, also places the power of discussion and representation directly into the hands of the educators delivering the EDI workshops themselves. Another benefit to such an editor is that having this level of customisation means the tool can evolve alongside social discourse and institutional needs. The scenario editor supports more than textual content changes and allows for the changing of visual content such as character 2D sprites and the scene background enabling the creation of diverse scenarios that reflect a broad spectrum of identities and social contexts. Through using this approach, the tool becomes more than just an add-on to the game; it transforms it into a participatory educational tool ensuring that discussions around gender identity, pronoun use, and inclusive behaviour can remain relevant and flexible to evolving conversations and social norms. As this game and tool progresses, the goal is to simplify this editing process so that an educator can change a structured spreadsheet and output a file that the game will be able to read at runtime. By enabling this type of interaction, we allow educators to craft their own unique, context-sensitive experiences. A work-in-progress version of the spreadsheet contains 3 different tabs. They include:

Editor - The main tab of this spreadsheet and the one the user will export from; this is an empty template of what is needed for a scenario. We have provided notes on relevant cells to help with the data input. Formulas have been used to add extra ease to creating the file needed for the scenario to work in the game. For example, the educator simply needs to put a number in the bordered box next to "Total number of NPCs in scene:" and the spreadsheet will add $\text{NPC}(0..n)$ where n is the number they entered into the column while also highlighting green the field they must now fill in with names of NPCs in the scene. This list will then create an easy-to-use dropdown, allowing error catching throughout the spreadsheet.

Example - This tab is provided to allow the users a look at a fully realized scenario giving them an example of one already implemented, to help them in their own scenario creations. For this we have recreated "Scenario 1: The Presentation" via the spreadsheet (Figure 5, 6).

Help and Notes - The final tab will provide help and advice as to how to create your own scenario. This tab will hold developer-specific needs from the user of the spreadsheet for it to work properly with the game. An

example is that the user's name can be inserted into dialogue sentences in the game but to know where to do this the spreadsheet user needs to use "[USER]" for the program to understand the insertion.

Scenario Editor for Pronouns In Practice						
This sheet will use Scenario 01 as an example						
Dialogue Section						
Dialogue No.	Dialogue/Question	NPC Speaking	Location	Dialogue Line	Skip To	End
1	Dialogue	Narration	Center	*Alex finishes the presentation*		☐
2	Dialogue	Hannah	Right	Hey [USER], Alex did great job on that presentation, didn't he?		☐
3	Dialogue	Narration	Center	*Alex looks at [USER], a little surprised at what Hannah had said.*		☐
4	Dialogue	Alex	Left	Oh, thanks for saying that, Hannah! But just as a heads up, I use they/them pronouns, not he/him pronouns.		☐
5	Question	Narration	Center			☐
6	Dialogue	Narration	Center	*Alex exits the room. They seem tearful and distressed.*	11	☐
7	Dialogue	Alex	Left	"Thanks Hannah, I appreciate you correcting yourself!"		☐
8	Dialogue	Narration	Left	*Alex exits the room.*	11	☐
9	Dialogue	Alex	Center	"I'd like it if you could try."		☐
10	Dialogue	Narration	Center	*Alex exits the room.*		☐
11	Dialogue	Narration	Center	*Hannah seems to take a moment to think about her response, then turns to [USER]*		☐
12	Dialogue	Hannah	Right	Hmm. Perhaps we could practice using Alex's pronouns together, [USER]? I think that would help me to start getting it right.		☐
13	Dialogue	Narration	Center	[USER] smiles at Hannah and nods.		☒

NPCS		SPRITES	
Total number of NPCs in scene:	2	WIP, Will add ability to change sprite images	
NPC1	Narration		
NPC2	Alex		
NPC3	Hannah		

Figure 5: Work in progress Scenario Editor

Question Section							
Question Asked	Answers (up to 4)			Answer Jump To (up to 4)			Feedback (up to 4)
How do you think Hannah should respond here?	"Ack, it was just a mistake. I was complimenting you, anyway."	"Oh! I'm really sorry, I should have said: Alex did a great job on that presentation, didn't they?"	"I'm sorry, it's just hard to remember."	6	7	9	Hannah doesn't take responsibility for the error and instead makes Alex feel as though they are in the wrong.
							Hannah understands she made an error and apologises, then corrects herself.
							Hannah does apologise but doesn't really take responsibility for the error.

Figure 6: Work in progress Scenario Editor

5. Conclusions and Evaluation Plans

This paper has provided an overview of the development of *Pronouns in Practice*, a serious game designed to address the challenges of pronoun usage and promote inclusivity in educational settings. By simulating real-life interactions through a series of branching dialogues and scenarios, the game allows users to practice engaging with diverse identities in a risk-free environment. We have also outlined a design framework that was used to guide this development. As highlighted previously in the paper, traditional EDI training methods may not always be comfortable or effective for all learners, particularly when it comes to addressing sensitive topics like gender identity and pronouns usage. Serious games offer an innovative and engaging alternative, fostering empathy,

encouraging self-reflection and can help provide a safe space for experimentation without real-world consequences.

The game is currently in its final stages of development, with its core game mechanics and an initial scenario completed. The scenario creator tool, while still a work in progress, is expected to be finished prior to evaluation with participants.

To evaluate the effectiveness of *Pronouns in Practice* and to further explore the potential of serious games in supporting EDI training, we will conduct a dedicated workshop. The game itself will be presented and tested at the workshop at the University of the West of Scotland in June 2025. This workshop is an integral part of the game's development, offering an opportunity to engage participants, primarily educators and subject experts from the higher education sector, in a structured and reflective session. The workshop will centre around two EDI areas: British Sign Language (BSL) and pronoun usage. Our goal is to create an environment in which participants can interact with complex social topics through low-risk and engaging serious games experiences.

The workshop will begin with a presentation introducing core terminology, key concepts, relevant literature and the introduction of our serious games. Participants will then play two serious game prototypes, including *Pronouns in Practice*. This hands-on segment will allow them to experience the scenarios that have been designed. Following this a debriefing session will follow, encouraging open discussion about the educational value of the games, their realism and their potential applications within the participants' own institutional contexts and needs. By providing a structured space for guided conversation following the simulated scenarios, we aim to foster an environment that encourages dialogue around the sensitive issues, namely pronoun usage and inclusive practices. These post-game discussions are designed to promote an exchange of thoughts, deepen participants' understanding of their own choices and offer insight into how others engaged with the branching dialogues. We hope to support valuable self-reflection and interpersonal learning, building on the emotional and cognitive experiences gained playing the serious game. Feedback from these sessions will be used to refine both the game and the scenario editor tool, and to explore the game's future potential in broader EDI training contexts.

The evaluation in relation to future empirical evidence will take cognisance of the fact that there are two groups that will benefit from the serious game. Firstly, the users who will be educated using the game and secondly the instructors that will customise the scenarios to use in sessions. Evaluations will focus on learning effectiveness and usability and customisation of the scenarios alongside assessing shifts in participants' confidence, awareness and attitudes regarding pronoun usage and inclusive communication.

Evaluation will be a mixed methodology to collect both qualitative and quantitative data. In relation to learning effectiveness this would be a Randomised Controlled Trial (RCT) with a pre-test/post-test experimental control group. A control group would learn in a normal session without exposure to the tool and an experimental group would learn with the tool. Data will be collected through valid questionnaire instruments analysed with descriptive and inferential statistical techniques. The data will be tested to ascertain conformity for parametric analysis i.e. normality of distribution, homogeneity of variance and interval or ratio data. If this is the case, then dependent (within) and independent t-tests (between) will be used for comparisons. If not, then Wilcoxon-matched pairs signed ranks tests (within) and Mann-Whitney U tests (between). Instructor evaluation will be performed through focus groups and semi-structured interviews to collect detailed information on usability, customisability and effective integration.

Future workings include using participant feedback to better the scenario editor, focusing on usability and addressing any obstacles participants find in creating their own scenarios. In the future, we hope to expand the game's reach and collaborate with additional stakeholders to further develop the tool and assess its impact in educational settings. Another expansion could also be to focus on a larger range of diversity-based scenarios; cultural differences, disabilities and other parts of identity such as sexual orientation. Through continued refinements and input from additional stakeholders, *Pronouns in Practice* aims to contribute to a more inclusive and understanding environment in educational institutions and learning.

Ethics Declaration: Ethical clearance was not required for this research but is being sought out for the planned workshop.

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

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Games Inclusion Lab: Accessible Games with Neurodivergent Adults Through Iterative Play and Design

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Abstract: The benefits of games, widely studied and described today, extend to audiences with specific accessibility needs. However, for these people, their therapeutic function tends to be prioritised over entertainment, creating phenomena of exclusion of players in all their fullness (Spiel and Gerling, 2021; Wästerfors and Hansson, 2017). In the Games Inclusion Lab (GameIN) Action Research Project, some basic premises were proposed for the creative processes of games that, instead of being for a specific target audience, were created in frequent contact with their everyday contexts, promoting accessibility through constant iteration. Thus, its primary objective would be to promote playing together, regardless of the skills and specificities of each person, with inclusion in the daily contexts of neurodivergent adults in Portugal as a case study. This paper aims to describe a crucial part of this process, which includes the operationalisation of the premises of co-design, ethics and research in the context of developing a games kit accessible to this audience. To this end, monthly sessions, 30 in total, were held with three groups of neurodivergent people, in particular autistic people and/or people with intellectual disabilities, including a total of 28 participants, aged between 19 and 54 years old ($M = 30.70$; $SD = 9.94$). The games kit was implemented with a set of three games (digital, tabletop, and physical platforms) within a common narrative element (Monsters), plus two published tabletop games that were adapted to better fit the cognitive accessibility needs of the participants. This study illustrates how an iterative co-design approach, involving neurodivergent stakeholders, can successfully foster the development of playful and inclusive games while ensuring that diverse perspectives are integrated into the game design process.

Keywords: Inclusive design, Intellectual disabilities, Accessible games, Iterative playtesting

1. Introduction: A Playful Game Environment

Intellectual Disability (ID) is a developmental condition characterized by significant limitations in both intellectual functioning and adaptive behavior, affecting conceptual, social, and practical domains (American Psychiatric Association, 2013). Over time, perspectives on disability have shifted from models of exclusion and segregation toward frameworks emphasizing integration, inclusion, and empowerment (Emygdio da Silva, 2009; Sousa et al., 2023). Within this evolving context, the present study aims to relate the role play and creativity can have in the social integration of people with intellectual disabilities (PwID), promoting inclusive, engaging, and intrinsically motivating activities that not only matter with regards to accessibility but also the dignity and well-being of these individuals. In this regard, the concept of *playfulness* and *CoLiberation* (Koven, 2024) promotes the sense of “well-played”, through engagement and enhanced participation, especially through cognitive-behavioral strategies that foreground fun, imagination, and game challenges.

The following work explores the development phase of a games kit which incorporates inclusive design for meaningful playful activities with PwID, within the context of the Games Inclusion Lab (GameIN). This action research project is based on some basic premises that were proposed for the creative processes of games that, instead of being exclusively developed for a specific target audience, were created while in frequent contact with their everyday contexts, promoting accessibility through constant communication and iteration. Thus, its primary objective would be to promote playing together, namely PwID, their relatives, friends, social support workers, and others, regardless of the skills and specificities of each person, with inclusion in the daily contexts of neurodivergent adults in Portugal as a case study. To seek this goal, the concepts of Play, Playfulness and Playful in the daily environments were deeply analysed to be integrated in the game developed within the proposal research.

Setting up an activity through designing fun (for a joyful environment) but with a balanced level of competition, will generate an individual immersion on the activity (*flow*) or within the teamwork

(*CoLiberation*). Instead of a player being on flow self-transcendence (Csikszentmihalyi, 1975), Koven evokes a wholeness experience of Liberation through a group collaboration (Koven, 2024). Like the framework of playful work design (Sharp, 2023), where a playful reflection on elements of play could enhance an enjoyable space and challenge interactions within a working environment context, a playful space aligns with ludic play and imaginative engagement, while the work achievements reflect agonistic play, emphasizing challenge, goals, and self-competition.

Since literature identifies play as an activity, therefore, as a characteristic of certain behaviors (Huizinga, 1949; Caillois, 2001), or as personality trait, playstable tendencies such as amusing or curiosity (Proyer, 2017; Barnett, 2007). Play is also considered as a behavioral approach, how the self engages with tasks in a playful manner (Mainemelis and Ronson, 2006), such when daily tasks are framed as play, and individuals tend to focus on the process rather than outcomes, experiencing increased intrinsic motivation and positive affect (Heimann and Roepstorff, 2018; Webster et al., 1990). However, externally imposed play or failed engagement (a daily boring demand, missing a message or failing a task) can undermine these effects, leading to disengagement or frustration (Fleming, 2005; Suls, 1983).

This is one of the relevant characteristics of play, consisting of a dual-nature, which is often described along the intersections of improvisation/spontaneous (*Paidia*) with rules and skill dimensions (*Ludus*) (Huizinga, 1949; Suits, 1978; Caillois, 2001). While ludic play is open-ended and imaginative, agonistic play is structured and competitive, which this duality spans all conceptualizations of play as a behavior, personality, and approach. To create a meaningful and playful environment for a community where PwID participates at an equal level, it requires a game design adequate for fun and competition.

Designing fun involves using imagination and humor to create enjoyment during work, enhancing affective experiences (Lieberman, 2014). Players may craft playful narratives, reframe tasks, or engage in role-play to introduce fun into their routine activities. This form of play boosts engagement by balancing personal competence with the complexity of the task.

The integration of play into PwID daily routines, through both fun and competition, suggests a meaningful strategy to enhance motivation, creativity, and well-being. Far from being trivial, play represents a versatile and adaptive mode of engagement that supports both individual fulfillment and community outcomes. Regarding these insights, a playfulness environment was set up within the GamelN project, to reframe everyday situations as enjoyable, intellectually stimulating, or personally meaningful (Barnett, 2007), promoting humor as a specific manifestation of this trait as a cognitive and behavioral form of play (Sharp, 2023).

2. GamelN as a Methodological Proposal

This study aligns with the principles of inclusive research, which is especially pertinent when engaging with PwID, as it emphasizes their viewpoints and values their input (Walmsley et al., 2018). The goal of inclusive research is to actively involve individuals typically regarded as part of marginalized or vulnerable groups in the research process, with the intention of fostering social change and meaningful impact (Kuri and Schormans, 2022). Thus, the present research is based on the co-supervising of PwID, in the sense they were collaborators, working in partnership with the game design team, as also offering guidance on participant recruitment, or overarching components such as playtesting, data collection, and feedback (Bigby et al., 2014).

The study was conducted in two different NGOs (APPACDM and CECD). In APPACDM, two groups of neurodivergent people participated. These consisted of ten participants in each group (N=20), respectively, and both were accompanied by the same three (N = 3) support workers (SW). In CECD, eight participants and three SW participated (N = 11). In total, the study consisted of ten sessions and a sample of 34 people (N = 34).

All neurodivergent participants were adults ranging from 19 to 54 years old (M = 29,23; SD = 8,69), of which seven were female (26,92%) and 19 were male (73,08%). Although SW participated in the activities, they were not the focus of this study, with data collection focusing on the neurodivergent participants (N=28).

3. Procedure

According to the different stages of the research, the project progressed through several phases: (1) obtaining informed consent from participants, in alignment with ethical guidelines for conducting research with individuals with intellectual disabilities (Casimiro et al. 2024); (2) characterizing the three working groups in order to identify potential barriers or constraints in how the sessions should be conducted; (3) validating

ethical values in research involving PwID; (4) conducting playfulness sessions aimed at interaction with the research objects (GameIn games); and finally (5) collecting data through questionnaires and interviews.

Across the monthly sessions held at APPACDM at CECD, PwID and their SW convened in the same space to take part in the planned activities. Each session began with brief introductions by the moderators, one of whom presented the objectives of the research and emphasized the participants' roles as meaningful contributors (Fernandes et al., 2025). An icebreaker activity followed, designed to foster interaction between participants and moderators, as well as among the participants themselves. The moderators then introduced the session's goals, outlining their purpose and the planned activities. These were structured to encourage engagement with the activities in a playful and approachable manner, enhancing both accessibility and comfort.

Regarding gathering observation data during the sessions, each sub-group was supported by at least two members of the research team to assure guidance through the gameplay, and to act as an observer for documenting all the activities and participants' feedback. The observer's notes included insights on aspects such as cognitive and motor accessibility, participants' engagement and behaviors, overall gameplay experience, notable remarks or expressions, and any other relevant occurrences. To further support post-session analysis, each session was filmed using two 360° video cameras with synchronized audio recording. Following each session, moderators also provided supplementary observations to complement the initial notes.

4. Games Kit

One of the main goals of the GameIN project is the creation of a games kit that promotes the inclusion and well-being of PwID through accessible games, playful activities, and social activities of game creation that can be shared by neurodiverse groups which may involve individuals' family members, friends, or social support workers. This study presents a set of decisions made in the project's research process, involving several playtesting sessions, to create components to the games kit.

During one of the initial icebreaker activities, a conducted playful experience (*Broken Phone*) proved to be especially valuable, as all participants actively engaged in the activity and shared the same feeling of enjoyment. From the research team to the PwID and the SW, everyone took part, laughing at the distorted messages and later sharing the experience with their peers. This moment was particularly significant for the project since it helped bridge the gap between the research team and the PwID and because it validated the project's core intention: that there are games or activities in which everyone can participate in a "CoLiberation" (Koven, 2024) state of mind. By focusing on playful activities and removing the more competitive aspects of games, this session ensured that every participant shared the *magic circle* (Salen and Zimmerman, 2004), and anyone was excluded.

The first working sessions, following the icebreaker activities, were focused on understanding the preferences of the individuals from the focus group, such as the types of movies they enjoy, the games they usually play, and how they typically spend their leisure time. It quickly became clear that digital games (on tablets or mobile devices) are widely used by the group. However, these formats pose some challenges for the project's goals, from ergonomically poor interaction postures (impacting the players' wellbeing) to the isolation caused by non-cooperative gameplay (negatively contributing to their inclusion in social activities).

The possibility of developing a versatile kit, including board games to promote a common shared space and greater cooperation among players, games in public spaces to encourage physical mobility and interaction with various objects (such as masks, clothing items, furniture, etc.), and digital games for the engaging media, emerged as the most suitable working hypothesis.

4.1 Playtest Sessions

Initial testing with the game *Speed Cups* (999 Games, 2014) revealed some accessibility challenges such as some of the cards' illustrations being too complex for the players to interpret and the free-for-all format leading to a clear avoidance of interaction as if they were each playing their own separate game (Fernandes et al. 2025). The six conducted playtesting sessions (two for each of the three groups), with the help of the participants' feedback, helped identify five specific cards to be removed, validate the effectiveness of the game components (in terms of fine motor skills), and verify that all participants were able to overcome the challenges from the game, once they were playing only with the approved cards. Also, experimenting with a variation of the game rules that favoured cooperation over competition revealed that the game could be very

successful in fostering peer support and collaboration between players; a subsequent variation involving team-based competition also led to positive results, contrasting with the less desirable effects of the exclusively competitive free-for-all format.

Similar tests were conducted during the same playtesting sessions with the game *TEAM3* (Brain Games, 2019). Here, more significant changes were required as the game's main feature, the suppression of players' senses (not being allowed to speak, or having to cover their ears/eyes), were outright rejected by some participants because it either made them uncomfortable or simply because it did not make sense to them. Ultimately, the decision was made to remove these elements, pivoting towards a cooperative activity, like what was explored with *Speed Cups*, where participants worked together to build the structures depicted on *TEAM3*'s cards using the game's building blocks. Another successful variation was to have participants work together to try to build the tallest tower possible with the game's building blocks before it fell, or they ran out of pieces (both worked to the participants' amusement).



Figures: 1-3: *Speed Cups* and *TEAM3* playtest sessions

5. Developed Games

This study highlights one of the original game concepts that has been most extensively developed within the scope of the GameIN project: *Monster Lab*, which exists in board game, physical, and digital versions. Given that several PwID expressed a strong interest in horror films, mentioning titles such as *IT* (2017), *SAW* (2004), *Scream* (1996-2022), or *Paranormal Activity* (2007–2014), the team used the monster visual theme, incorporating mechanics that promote cooperation in the physical and board game formats, and puzzles in the digital version for an exciting gameplay.

Following the testing sessions with *Speed Cups* and *TEAM3*, a strong dynamic of mutual support among participants was observed, along with a general interest in team-based competition and widespread ease with the fine motor skills required to manipulate physical game pieces. This led to the development of the first version of *Monster Lab* as a board game, in which players create their monsters by navigating a game board and collecting three components (head, torso, and limbs) from different areas. The monsters' designs were based on artwork from a FuzzInk book, and the game components were developed by the research team.

To minimize downtime between participants' turns, players cooperate as a group to build a path for their shared character piece, guiding it across the board to the zones where each of the three components can be collected. The core mechanic of drawing a path using specific tiles (segments of a pathway), combined with the challenge of moving from point A to point B, effectively encouraged collaboration in placing the path pieces on the game board to reach their goals and build their own monsters.

During the playtesting sessions, each player created a complete monster in each run, and a recurring pattern was observed: participants avoided experimenting with combinations of different monsters' parts, defining their goal as completing a monster's set (head, torso, and limbs).



Figures 4-5: *Monster Lab* prototype (board game version and digital version)

5.1 Development and Evaluation of the *Monster Lab* Mobile Application

Following the validation of the *Monster Lab* board game, a digital mobile version was initiated to explore the potential for inclusive digital play. This decision was informed by findings from preliminary focus groups, which highlighted a strong interest in digital games among PwID and noted the widespread accessibility of mobile platforms. While the process cannot be classified as fully co-creative, analysis grids completed during these interaction sessions by researchers, observing both caregivers and PwID, revealed that design decisions were consistently informed by the preferences, abilities, and challenges of the participant groups.

The first digital prototype *Monster Lab 1.0* (fig.5) functioned as a basic digital demo intended to evaluate user engagement with a single-player mobile interface. In this version, players controlled an avatar tasked with assembling a monster using three components (head, torso, and legs), reenacting the board game. The game allowed players to select and combine parts from eight different monster templates to create unique figures.

Initial playtests indicated diverse engagement patterns: a subset of participants tended to match body parts to form the original monster templates (as was observed in the board game version), while others opted for mixed combinations (see fig. 5). The control interface was also subject to critical evaluation. Observations identified that many users encountered difficulties using a dynamic joystick, prompting a design shift toward directional arrow controls (X and Y axis), which were more accessible and intuitive for the majority of players.

During the playtesting sessions, two participants required continuous assistance from facilitators in order to complete the game. Despite showing visible signs of stress due to the difficulty of the levels, they were determined to continue and did not express a desire to quit. Interestingly, in the final feedback, both participants reported that they had enjoyed the experience and did not perceive the game as difficult, meaning all participants reported enjoying the application. This type of feedback has been observed repeatedly across playtesting sessions.

It is important to acknowledge that this population is often highly agreeable and eager to please, which can introduce a bias in self-reported satisfaction measures. Another possibility is that some individuals with intellectual disabilities may face challenges in accurately interpreting/evaluating their own performance during gameplay. Still, the frequent voluntary replaying of the game suggests a positive level of engagement and acceptance of the mobile version.

5.2 Physical Adaptation of *Monster Lab* and Inclusive Play in Public Spaces

Building on the success of the digital and board game versions of *Monster Lab*, the team then also explored a physical adaptation of the game. The goal was to encourage inclusive play among PwID while engaging them in collaborative, multisensory activities in public spaces.

This iteration aimed to: (1) foster physical activity and cooperation among PwID through hybrid play (digital, analog, and performative); (2) extend game-based interaction into public or semi-public environments; (3) promote social bonding and inclusion through playful, team-based competition; and (4) collect data on gameplay preferences and group dynamics in larger, less controlled settings.

Playtests were conducted with the 3 groups, divided into 2-3 teams to take advantage of the observed interest in cooperation and team-based competition. Each team navigated through different activity stations, completing challenges inspired by earlier tested games (*Speed Cups*, *TEAM3*, *Monster Lab 1.0*), and upon

successful completion of each station, teams received a reward, such as a carnival costume piece (headpiece, torso item, or limb accessory). At the end of the activity circuit, a group vote determined the team with the most creative final mask or costume.



Figures 6-7: Land of Hands activity and game's "carnival rewards"

Since prior sessions were conducted in small groups, these larger-format tests required initial engagement activities to promote group cohesion. Inspired by Bernie De Koven's games, such as the *Land of Hands* (Koven, 2024), the team employed icebreakers focused on physical interaction, to support body awareness and comfort with touch (challenging for some individuals, especially those on the autism spectrum), and verbal expression, to engage participants who experience communication difficulties due to shyness or confidence issues. These activities successfully built a collective "circle of trust," fostering shared enjoyment and collaborative spirit among researchers, caregivers, and participants alike.

5.3 Monster Lab V2.0 Mobile Application

Monster Lab 2.0, the upgraded digital version, maintains the core concept of the original board game. In the first level, players create a monster, but in this version, the customized monster becomes the player's avatar for the following levels. This feature was introduced in response to recurring requests from PwID participants, who expressed a desire to see their created monsters integrated into the game experience.

Once the monster is created in the introductory scene, players must guide their character through ten levels, each progressively more complex. Early levels introduce basic interactions such as character movement, collision detection, pressure plates to open gates, and rotating platforms (figures 8-9). These mechanics are introduced gradually, alongside a color-matching system, where pressure plates correspond to gates and platforms of the same color. The game was carefully balanced, taking into consideration player feedback, to properly guide them towards progressing from simpler to more challenging puzzles.



Figures 8-9: Introductory level (puzzle 2) and a more advanced level (puzzle 6)

In terms of game visual aesthetics, to ensure visual accessibility, the game's color palette was selected based on colour guidelines from Wong (2011). Each color-coded mechanic in the game was tested to ensure it could be accurately interpreted regardless of visual impairment. However, during usability tests with PwID users, two social support workers expressed discomfort with the initial graphic style, which used Risograph and Offset print aesthetics to create a deliberately imperfect alignment (misregistration) for artistic purposes (fig.

10). These users reported visual fatigue, saying “it hurts my eyes” and “I can’t focus on the screen.” Both were later identified as having mild visual processing disorders. Although PwID participants did not report similar issues, the development team revised the art style to improve clarity and reduce visual strain.



Figures 10-11: Tree game asset with the initial (left image) and final visual style (right image)

6. Discussion

Playtesting results indicate varying levels of independence among PwID participants. Two participants were unable to complete the most difficult levels without continuous support. Three required minimal assistance, and six completed the game independently. Among those who completed the game unaided, the time to completion ranged between 15 and 22 minutes. The game offered players the option to choose between a joystick cursor and an arrow key cursor option via a settings menu. While access to the menu turned out to not be intuitive for players, requiring facilitators to assist with navigating the game menus, the arrow key cursor option turned out to be the most effective for players. Following a brief post-play interview, regarding game difficulty and interest, participants described the game as easy and engaging, however the researchers recorded the difficulties that two PwID had in completing the levels, confirming that they would not be able to do so on their own. Additionally, it was noted that verbal feedback must always be cross-checked with the analysis grids used in the research in order to accurately assess the results of the playtest sessions with PwID.

Nevertheless, the findings are significant in demonstrating that *Monster Lab 2.0* can be enjoyable and accessible to PwID, and the Tabletop version, like the physical games experiences from the games Kit, supports cooperative gameplay and inclusivity, positioning them as a meaningful tool for fostering shared play experiences across diverse user groups.

The physical adaptation of *Monster Lab* reinforced the need for accessible, embodied game formats that go beyond screen-based interaction. Key insights included: (1) enhanced cooperation and peer support during team challenges; (2) increased motivation when physical movement and role-play were integrated into the activities; (3) positive reception of mixed-media rewards and the competitive, yet inclusive nature of voting for the best monster mask; and (4) greater engagement among participants, suggesting strong potential for continued development of hybrid formats combining physical and digital elements.

Additionally, the shift to a more spatially dynamic format addressed the physical and ergonomic limitations of prolonged mobile gameplay. Encouraging participants to move through larger environments helped combat sedentarism and promoted playful, social engagement in open or outdoor settings.

The findings suggest that *Monster Lab 2.0* is capable of providing an inclusive gaming experience for a neurodiverse group of players. By combining intuitive mechanics, accessibility-minded design, and engaging visuals, the game fosters cooperation and shared enjoyment across diverse user groups. This supports its potential as a valuable tool for inclusive play and digital engagement in both educational and recreational contexts.

7. Conclusion

Activities created to be accessible to PwID tend to place entertainment as a secondary goal after the accessibility of the activity itself. The GameIN project sought to create a resource that provided shareable activities that are both accessible and enjoyable for a neurodiverse group of individuals, seeking to foster interaction between those who participate in the activities and promoting the goal of further inclusion for

PwID. The observations gathered from all the sessions carried out highlighted the value of a games kit designed to foster cooperation (*CoLiberation*), healthy competition between teams (in a *playful environment*), individual challenge (through digital games), and the sharing of outcomes, such as the creation of monsters in *Monster Lab 2.0* or the masks crafted in the physical version of the game. Both PwID, their support workers, and the researchers who participated in the sessions, as team members of the physical game and icebreaker activities, demonstrated a shared sense of well-being within the playful setting. The fact that these games did not isolate PwID during gameplay, but rather encouraged collaborative problem-solving among all participants, confirms the relevance of the kit in achieving its central aim: promoting inclusive moments of well-being with PwID actively participating in the broader community.

8. Limitations and Future Directions

The study was conducted with a limited group of PwID (N=28), and should therefore be extended to a broader range of institutions. Given that the Gameln project is linked to a wide network of organizations, it is now positioned to enter a dissemination phase, expanding the reach of the kit to many more institutions supporting PwID. This includes the distribution of various game formats, adapted board games and the three versions of *Monster Lab* (board game, digital game, and physical version).

Although these games have already been tested with a group of 28 PwID, *Monster Lab 2.0* still requires updates. A version 3.0 is planned, which will include additional levels and various usability improvements, such as the option to switch between arrow-key and joystick control modes directly within the game screen interface. Moreover, although the adaptations effectively enhanced accessibility for the participants in this study, additional testing is necessary to assess sustained engagement over time and to evaluate the wider relevance and usability of these games across expanded contexts.

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Ethics and AI Statements: The present research was previously approved by the ethics committee of ILIND – Lusophone Institute for Research and Development (Lusophone University), with assurance that all participants involved signed informed consent forms, participated voluntarily, and that their collected data was properly anonymized and protected in accordance with the current data protection legislation. 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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