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 at 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 at 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 IIEM, 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.

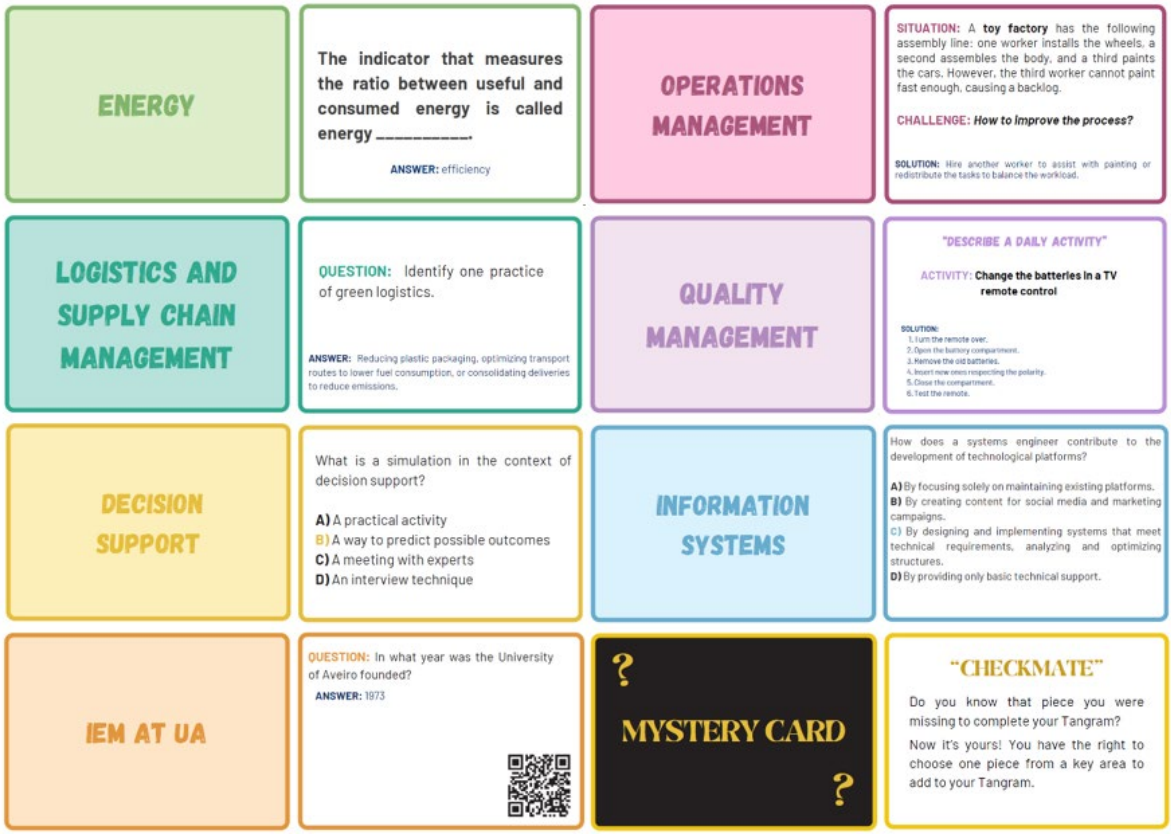

Figure 3: Examples of EGI MASTERS' cards, one from each deck

6. Discussion and Conclusions

The experience of using GBL in the IIEM 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. mong 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. he 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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