



Learning Mathematics in Primary Education with *Liber Domus*: The Potential of Gamification

Paula Quadros-Flores¹, Daniela Mascarenhas¹, Mário Cruz¹, Fátima Coutinho²

¹Polytechnic Institute of Porto & inED, School of Education, Portugal

² Polytechnic Institute of Porto, School of Education, Portugal

Abstract

Maths is often referred to as a difficult subject to teach. This study analyses the impact of the Liber Domus educational game on maths learning in primary school. It is a case study of the explanatory and empirical type as an attempt to connect the ideas and factors identified in order to understand the causes and effects of a given real phenomenon. Data collection was specifically based on understanding the Liber Domus game as a didactic resource in the learning process of primary school (1.ºCEB) children, from the children's point of view, which is why narrative reports were valued, as well as interviews and occasional participant observation that included a scale for evaluating the quality of digital games for educational purposes. Twenty third-grade children took part. The results suggest that the game can improve maths learning and promote skills such as creativity, teamwork and problem-solving, but there are dimensions that need to be improved. The study highlights the relevance of innovative practices and the participation of children in the design of games that bring schools and research centres closer together, contributing to a discussion on serious games.

Keywords: Gamification, Serious Games, Liber Domus, Active Learning, Mathematics, Primary Education

1. Introduction

Since serious games have experienced a considerable increase in the field of education; according to Laamarti et al. [1], since the time of our ancestors, we have been playing, and serious games can be characterized as having an educational intentionality toward the learners' learning. The authors differentiate the concepts of game (a physical and mental activity governed by predetermined rules) and video games (a type of game that uses a computer as a mediator), while maintaining the playful and entertaining aspects. Serious games can be interpreted in various ways. At first, serious games referred to those that offered a combination of true entertainment and a practical aspect. As the concept has developed, the dominant perception of serious games has shifted to recognize that the main purpose of serious games is not to entertain or to give the player pleasure, but rather the educational, training or awareness-raising intentions of the creator of the game, thus distinguishing them from the purely ludic nature of other types of games.

The literature review on serious games conducted by Laamarti et al. [1] states that serious games have an entertainment component, along with educational intentionality and that their "serious" nature is derived from their ability to transmit information that contributes to knowledge creation and the development of competence. In accordance with the authors, the players find themselves in interactive environments that allow for the acquisition of experience and the stimulation of experiential learning. Gee [2] agrees with the previous idea by stating that well-designed digital games include successful learning principles such as problem solving, immediate feedback, and situated learning. The meta-analysis conducted by Boyle et al. [3] supports the fact that serious games have a positive effect on the acquisition of knowledge, the development of cognitive abilities and student motivation and that this is particularly true when the games are structured into the curriculum. The authors of Deterding et al. [4] agree with the previous findings and further state that the engagement of the user stimulates more meaningful learning, especially in playful learning situations. Recent studies support the effectiveness of serious games in certain educational situations. For example, Gundersen and Lampropoulos [5] found that serious games had a positive effect on students in terms of developing computational thinking and programming skills at both the elementary and secondary levels, as well as increasing student engagement and academic performance when games are incorporated into the curriculum. Similarly, Miranda, Nascimento and de Oliveira [6] carried out a systematic review of knowledge assessment in serious games, analyzing 116 papers and identifying the assessment methods used by the researchers, including how they assessed the students' knowledge and provided recommendations for measuring knowledge gains in digital educational contexts.



Given that the designer's intentionality is often implicit and that most games are available on-line without prior evaluation, the goal of this study was to bring the game design team and a group of children in the third year of primary education together to validate the game in an educational context and to identify the game's potentialities and limitations in a school setting. Given that children as users of the game can also contribute to the creation and improvement of the resource itself, this study aimed to understand the game Liber Domus as a didactic resource in the learning process of children in the 1st Cycle of Basic Education. The following research question guided the study: What potential does the game Liber Domus offer as a didactic resource for the Mathematics learning process?

Three specific objectives were formulated as follows, based on the above mentioned research question: (1) to evaluate the opportunities and limitations of incorporating the game Liber Domus - Mathematics Module 1 into the curriculum; (2) to compare the alignment of the game with the Aprendizagens Essenciais (Essential Learnings) and with the Profile of Students Upon Completion of Compulsory Schooling; and (3) to analyze the behavior of children while they played the game and their communication abilities.

This study belongs to the project "Schoolers and Scholars: Role-Playing Games in the Teaching and Learning Process in the 1st and 2nd Cycles of Basic Education", promoted by the Research Centre for Innovation in Education (InED). The partnership with the public elementary school and the research center presents an alternative way to improve education using innovative educational methods and materials. Collaboration allows schools to adopt new ways of teaching and to develop and utilize educational materials produced by researchers at the research center, contributing to an up-to-date approach consistent with contemporary educational requirements. Furthermore, this type of collaboration promotes critical thinking and scientific curiosity, encouraging a culture of lifelong learning and innovation.

The study was carried out under the framework of the Supervised Teaching Practice of the Master's Degree in Teaching in the 1st Cycle of Basic Education and in Mathematics and Natural Sciences in the 2nd Cycle of Basic Education. Permission was given by the class teacher to carry out the study and the parents/guardians of the children were informed about the study so they could provide informed consent to participate in the study. The ethical principles of educational research were respected throughout the study (i.e., voluntary participation, anonymity and confidentiality of the collected data, without the possibility of identifying the participants). The results of this study are expected to help make informed decisions concerning the incorporation of the game Liber Domus in educational settings.

2. Theoretical Framework

A key component of Liber Domus is its ability to allow students to interactively solve problems and learn about science in a contextualized way. This provides an opportunity for students to assimilate complex academic content in an enjoyable and cognitively stimulating environment.

Educational games have the potential to transform how students learn Mathematics and Science, and Liber Domus may be one of them. The creators of the game believe that it will be an alternative to traditional teaching methods of Mathematics and Science.

The developers of Liber Domus assert that by incorporating game like components, students' interest and focus may be maintained for longer periods of time, leading to greater amounts of active, cooperative and meaningful learning. According to the developers' blog, educational games are created using psychological principles, specifically those related to increasing students' intrinsic motivation. Specifically, these include the use of reward systems, progressive challenges and competitive opportunities. Thus, educators view gamification as a method for creating an entertaining and enriching learning experience.

Gamification of education is recognized by many as an effective method for improving student's motivation and engagement in their studies [4] though there are multiple forms of gamification, and the two most common are using full-fledged educational games (serious games), and adding elements from games into non-game contexts (points, levels, etc.) to traditional educational settings [8].

Therefore, Liber Domus is an example of an educational game because it is a full-fledged game that has been integrated into the educational system, and therefore is a serious game. As opposed to the more typical gamification practices that focus on the symbolic rewards, the full educational games (like Liber Domus) create an immersive learning environment that encourages students to actively, reflectively and persistently participate in their own learning. Research has shown that this type of learning creates higher levels of motivation, academic performance and content retention [9].



In addition, Su and Cheng [10] argue that when educational games are incorporated into the curriculum, they help to create more dynamic and accessible learning environments that encourage students to take risks, and see mistakes as opportunities for learning, instead of failure. The study of Su and Cheng is consistent with the findings of more recent research by Sailer and Hense [11] who conducted a systematic review and found that both game based and gamified approaches to education consistently lead to increased motivation, engagement and academic performance, when the design of the educational game or gamified approach is aligned with specific educational goals, and when the educational game or gamified approach is used in conjunction with the educational teaching/learning process.

Although educational games have been shown to be beneficial, there are barriers to implementing educational games in schools regarding time allocation, resources available, and training for teachers that require careful and intentional planning for curriculum incorporation [12]. The Student Profile at the End of Compulsory Education [13], part of the Essential Learning Outcomes for primary school Mathematics, highlights the importance of developing students' cognitive abilities and knowledge to meet the challenges of a constantly evolving environment. Educational games and gamification are emerging pedagogies with considerable potential to increase students' motivation and interest in Mathematics, promote critical thinking and active learning, and allow for experimentation, error correction, and teamwork [14]; [15]; [17].

A fundamental difference exists between gamification and serious games within this context. Gamification refers to the application of game elements in non-game contexts to motivate and engage students [4]; serious games, however, are designed to provide an educational experience and provide an environment for students to explore, learn from mistakes, make decisions, etc. [1]. Liber Domus is intended to be a serious game, since it has been designed to align the content of the game with the curriculum and include a gradual sequence of increasing challenges, instant feedback, and engaging game mechanisms.

Studies over the past few years continue to show that educational games have a positive effect on learning Mathematics. Digital games were found to promote adaptive learning and increased persistence in solving problems [17]; instant feedback and dynamic visualization of mathematical problems was found to improve students' understanding of mathematical concepts [18]; and educational games were found to improve critical thinking and emotional engagement of primary school students [19]. In addition, research indicates that the use of interactive tools to aid in the representation and manipulation of mathematical objects can assist in creating meaning, facilitate logical reasoning, and promote collaborative efforts [20]. Systematic reviews and recent studies also suggest that using a combination of both physical and virtual manipulatives can lead to a substantial improvement in conceptual understanding and student achievement, particularly in areas where students typically struggle such as fractions [21]; [22].

In the area of games and gamification in Mathematics education, several systematic reviews and studies have shown that there are consistent improvements in students' learning and motivation when the design of the game aligns with the curriculum and includes an appropriately graduated series of increasingly difficult challenges, instant feedback, and engaging game mechanisms [8]; [14]; [23]; [24]; [25]); broader reviews on serious games in Science and Mathematics also generally support these findings and emphasize the important role of educators in incorporating games in a way that will maximize their educational effectiveness [26]).

3. Methodology

This study adopts an exploratory and empirical case study design aimed at understanding the educational potential of the digital game Liber Domus within a real classroom context. The purpose was not statistical generalization, but an in-depth analysis of the implementation process, students' interactions, and the pedagogical implications emerging from the experience. The research was developed within the framework of the Supervised Teaching Practice of a Master's Degree program. Therefore, the intervention was naturally restricted to the class where the trainee teacher carried out his/her pedagogical practice. The participants were selected through convenience sampling, as the study involved the intact group assigned to the trainee teacher. The sample consisted of twenty third-grade students (6 girls and 14 boys), aged between eight and ten years. This number corresponds to the total number of students in the class. The bounded nature of the study (one class, two sessions, one module of the game) allowed for close monitoring of interactions and behaviors in a naturalistic educational setting. The researcher assumed a dual role as teacher-researcher, conducting participant observation throughout the intervention. This methodological positioning enabled direct access to



students' verbalizations, collaborative dynamics, and problem-solving strategies, while ensuring ecological validity. Data collection included participant observation, field notes, audio-visual records (photographs, audio and video recordings), students' multimodal narrative productions, an interview with the cooperating teacher, and the application of the Evaluation Scale for the Quality of Digital Games with Educational Purposes (IAQJED) [27].

The qualitative data were analyzed through a descriptive and interpretative approach. The analysis consisted of organizing the collected evidence according to the three analytical dimensions of the IAQJED (usability, user experience, and learning principles). This procedure enabled the identification of convergences between observed behaviors, students' verbal and written expressions, and the teacher's perceptions. The data were systematized in analytical tables to support comparison and interpretation. The triangulation of different data sources strengthened the internal consistency and credibility of the findings. Although quantitative scoring was obtained through the IAQJED instrument, the emphasis of the study lies in the qualitative interpretation of students' experiences and pedagogical implications emerging from the intervention.

3.1 Research Design

In order to assess Liber Domus - Mathematics Module 1 as a digital educational game, the "Instrument for the Evaluation of the Quality of Digital Games with Educational Purposes (IAQJED)" by Rogers, Sharp & Preece (2013) was applied. It evaluates the game's quality in terms of aesthetic aspects; functional aspects; and the way it implements pedagogical principles [2], [27]). A good usability leads to an improved learning development, that is, to a higher degree of engagement and motivation, and consequently to a flow-state [27]. The IAQJED is general and multi-dimensional since it includes eighteen categories grouped into three categories: usability, user experience, and learning principles (see Table 1).

Table 1. Definition of each dimension

Dimension I – Usability	The extent to which a game is easy to learn while simultaneously challenging enough to engage the player in new discoveries. Interaction with the interface, including tutorials, buttons, menus, gameplay, safety, and functionality, are aspects that reveal the system's efficiency and effectiveness.
Dimension II – User Experience	The extent to which a game engages the player by promoting an enjoyable and immersive experience through narrative and aesthetic resources such as colour, language, setting, sound, characters, and meaning.
Dimension III – Learning Principles	The extent to which learning principles related to comprehension and problem-solving, associated with learner self-efficacy, can contribute to the development of cycles of skills and competencies both inside and outside the school context.

Technical Fluency, Student Engagement/Satisfaction & Alignment to Math Curriculum can be evaluated through an assessment of the individual components that comprise Technical Fluency, Student Engagement/Satisfaction & Alignment to Math Curriculum. Student narratives of the games story line provide another avenue for assessing student written communication.

Data Collection is based on the Evaluator – Player Interaction with the game; Analysis of the indicators that are most pertinent to the specific goals/aims of the game; One indicator is assessed at a time during the evaluation process.

A five-point Likert Scale is used to evaluate the degree of agreement or disagreement to each indicator: ALWAYS (5 points); NEVER (1 point); NOT APPLICABLE (0 points).

The Total Score is derived by adding together all of the scores assigned to the indicators across the three dimensions using the same Likert Scale, which ranges from 18 (the minimum) to 90 (the maximum). The evaluations use the following criteria for educational purposes: 1-18 (Inadequate); 19-36 (Low Quality); 37-54 (Fair Quality); 55-72 (Good Quality); 73-90 (Excellent Quality) as shown in Table 2 [27].

Table 2. Classification of the results obtained using the IAQJED

From 1 to 18 points = inadequate for educational purposes
From 19 to 36 points = low quality for educational purposes
From 37 to 54 points = fair quality for educational purposes
From 55 to 72 points = good quality for educational purposes
From 73 to 90 points = excellent quality for educational purposes



These evaluations allow you to evaluate your entire video game using the total of all three scores or to review them individually to find out where your game has room to grow.

You can also apply the results of the above study to the video game Liber Domus, Mathematics Module 1, which is currently being developed by Kendir Studios (<https://www.kendirstudios.org/>) as "lightweight", "fast" and "simple". The goal of this module is to provide a positive experience for students, while making teaching easier.

This module offers players the option of selecting from 6 different types of math-based games that offer various different areas of mathematics at 3 different levels of difficulty. For elementary schools, the authors focused primarily on the chess, shop and safes games, which deal with "relationships between fractions" and "numerical expressions".

After evaluating the Liber Domus games in Mathematics Module 1, the authors evaluated the first level of the chess, shop, and safes games since those aligned with the educational level of the group of students studied.

The chess game will promote logical-mathematical reasoning, attention, concentration, memory, and creativity in the student [20] while the safes game will help deepen the students' understanding of the order of operation and develop their ability to think relationally. As stated by Cardoso and Mamede (n.d.) [28], one of the largest challenges to teaching fractions in elementary school is the complexity of the concept of a fraction yet the importance of fractions to children's mathematical learning. In addition to providing students with an opportunity to learn about fractions and how they can be represented, the shop game will enable students to interpret fractions and how they can be used to represent relationships among quantities.

An implementation plan was created to implement the games to the participants. Once implemented, the authors administered the IAQJED to each of the selected games, in accordance with the normative guidelines of the tool, and the procedures for the analysis and classification of the data collected. Following the collection and analysis of the data, the authors interviewed the participating teacher, and analyzed the multimedia narratives.

4. Presentation and Discussion of the Results

The delivery of the implementation was divided into two sessions. Prior to these two sessions, the trainee teacher had time to develop his conceptual and technical knowledge of the game Liber Domus.

According to the developer's blog, the game is designed to promote intrinsic motivation, emphasizing internal satisfaction rather than external rewards. This design intention, however, should be distinguished from the empirical evidence gathered in this study. Based on classroom observations and students' verbal reports, three elements appeared to contribute to engagement: (1) overcoming personal challenges; (2) collaborative dynamics; and (3) the novelty and unpredictability of the tasks. These findings emerge from the collected data and not from the developer's claims.

The students recognized that many of the skills they acquired during gameplay, such as persistence, quick thinking, and collaboration, can be transferred to other areas of study, thus recognizing the game as a tool for both socio-emotional and cognitive skill development. The introductory discussion served as a diagnostic opportunity for the trainee teacher to tailor instructional strategies to students' needs and interests. Although the game design aligns with principles of intrinsic motivation described by the developer, the pedagogical impact observed in this study derives from the way the activity was mediated by the teacher within the classroom context.

In terms of the game-based method of instruction, the students were initially engaged with an introduction to the game, the objective of the session, and the rules, which stimulated their curiosity and demonstrated that the game would make lessons more dynamic. The developer claims that "earning stars" and aligning challenge with reward may enhance learning motivation. In the observed sessions, students demonstrated enthusiasm when progressing through levels; however, motivation appeared to be more strongly associated with collaborative problem-solving and task completion than with symbolic rewards alone. Student autonomy and decision-making were supported by automatic progression, intermediate achievements, and active feedback. The developers of the game incorporated a clear, child-friendly narrative, and various elements of the game that promoted a socially enriching experience and enjoyable mechanics to facilitate fluency and to promote the development of students' interpersonal skills.

The Liber Domus game was utilized by the working groups during the sessions, after having been installed on the computers prior to the sessions. The activity included interactive challenges such as finding equivalent fractions, comparing fractional values, and solving numerical expressions through



mental calculations. The trainee teacher presented the game context, reviewed the rules, and monitored each working group's progress, while also providing support as needed. After completing the challenges, each student created an individual narrative text that reinforced the learning that occurred, and generated qualitative data. The IAQJED was utilized to analyze students' strengths and weaknesses in mathematics, and to evaluate the usability and educational effectiveness of the game. An interview was conducted with the cooperating teacher at the conclusion of the project to discuss the incorporation of the game into the cooperating teacher's pedagogical practice, the challenges he encountered in using the game, and suggestions for improving the game's use.

4.1 Analysis of the Implemented Sessions

The students arrived at the classroom and were presented with an organised classroom space. The first PowerPoint slide had been placed on the whiteboard with the student groups identified and their respective assigned desk locations. Their curiosity was piqued, and a clear structure was established for transitioning into the activity.

S1: "Wow, what is that?" S1 asked, "Are we going to be doing some type of lesson today?"

S2: "Look," S2 exclaimed, "there are computers at each of our desks!" S2 thought it likely they would get to play something during class.

S3: "That looks like a lot of fun!" S3 said, "I'm curious to know how we will use them."

With the students arranged according to their group assignments, the lesson started with an introduction of a fictional character welcoming the students to a challenge of overcoming three mathematically based hurdles working together as a group to unlock a safe. The hurdles to overcome included: filling a chessboard by determining equivalent fractions; evaluating the price of items using fractions; and mentally calculating the value of numerical expressions.

Fig. 1. Presentation of the Game to the Class



The students then began the activities using their own configured computers as a group and while positively competing among themselves and with other teams (Figure 2).

Fig.2. Implementation of the Liber Domus Game



The student teacher walked throughout the room helping the students, as well as promoting critical thought. There was also an obvious level of enthusiasm and cooperation during the time the students were working through the different stages of the game, and each team was sharing ideas and strategies for getting through the next stage.

The trainee teacher gathered the data as he/she circulated throughout the classroom by observing student interactions, and the students' verbal responses while playing the game, and how students used problem-solving strategies to overcome the challenges presented. The preliminary data gathered along with the cooperating teacher's post-interview feedback were organized into an analysis table (see Table 3).



Table 3. Data collected from student interactions, verbal contributions, and strategies during the Liber Domus game, complemented by the cooperating teacher interview

Dimensions	Observation by the Student Teacher	Multimodal Narratives (Children's Voices)	Interview (Cooperating Teacher's Voice)
Usability	The students demonstrated ease in navigating the menus and using the game buttons, with few initial requests for help to understand the rules. However, some groups experienced difficulty in viewing the instructions, requiring additional support to interpret them. Gameplay was smooth for the most part, except for a slight delay observed when transitioning between levels.	"I found it easy to understand, I just didn't know where to click at the beginning." "After we started, it was smooth; you could see where everything was." "The chess part was harder to use because we didn't know what to do first."o que fazer primeiro."	"The game seemed quite intuitive for most children, but some needed additional explanations on how to use certain commands. The tutorial could be clearer or more interactive to facilitate getting started."
Third-Year Students' Experience	The students appeared highly engaged during the game, particularly in levels that included more colourful visual elements and interactive characters. Some groups commented on the game's sound, finding it enjoyable but somewhat repetitive. The narrative captured their attention and maintained focus for the majority of the activity.	"I wish we could see the character or choose it ourselves!" "The colours helped to know where everything was." "I thought the sound was cool, but it got a bit annoying after a while."	"The narrative was well-constructed and engaged the students. They were motivated, especially in the levels with progressive challenges. However, some commented that the repetition of certain animations or sounds could be revised to avoid fatigue."
Learning Principles	The activity promoted collaborative problem-solving, with groups frequently discussing the best strategies to complete the challenges. Some students took on leadership roles, guiding their peers in the interpretation of fractions and mental calculations. Autonomy increased as the challenges progressed.	"I enjoyed helping my group; we managed to solve everything together!" "The fractions part was difficult, but then we understood and it became easier." "It was good to think together because there were things I didn't know, and they explained them to me."	"The game presented situations that challenged students to think critically and collaborate, which is excellent. I observed significant progress in how they approached problems, particularly in the final level. Nevertheless, I think it would be useful to include more hints or visual support for students who struggle more." "However, it is worth noting the vault part of the game, where there was no progression in the difficulty level of the challenges. The challenge difficulty varied rather than being consistent."

This initial analysis highlights both strengths and areas for improvement in the educational use of Liber Domus. In terms of usability, students navigated the interface with relative ease; however, difficulties at the beginning of the tutorial suggest the need for stronger initial scaffolding (e.g., clearer prompts or guided instructions), particularly to support task comprehension and independent engagement. Regarding student interest, the visual and narrative elements sustained attention, whereas repetitive



music was identified as a potential distractor, which may interfere with sustained attention and cognitive focus during mathematical reasoning tasks.

In relation to learning, the collaborative interactions observed, with students discussing strategies, negotiating answers, and supporting their peers, indicate opportunities for socially mediated learning and collective problem solving, which is in line with the curricular emphasis on reasoning, communication, and collaboration in mathematics. In addition, the progressive increase in student autonomy across tasks suggests the development of self-regulation and confidence in problem-solving, particularly when dealing with challenges involving equivalent fractions, comparison of fractional values, and numerical expressions, which were central to the implemented activities. Nevertheless, the cooperating teacher's recommendation to include more hints or visual supports points to the importance of adaptive scaffolding for learners who struggle, and the observation that the vault game lacked consistent progression reinforces the need for a more structured sequence of difficulty aligned with step-by-step learning objectives.

After the last challenge, the character in the game congratulated the students on their accomplishments and informed them of the next activity: writing a narrative text about their adventure in Liber Domus. This allowed the students to reflect on their experience and gave them continued motivation to learn during the next class. The second day of this series of classes started with a review of the previous day's activities from Liber Domus, where students learned concepts involving fractions, mental math, and different ways to solve problems using math. The student teacher explained the objective of the lesson: to transform the experience of the game into a creative narrative through an interactive presentation (see Figure 3).



5. Conclusions

Beyond the specific context of this study, the findings suggest that the successful integration of serious games in Mathematics education depends not only on game design quality, but also on intentional pedagogical mediation by the teacher. Structured scaffolding, alignment with curricular standards, and opportunities for collaborative reflection appear to be key conditions for meaningful learning. For educational practitioners, this study reinforces the importance of critically evaluating digital resources before classroom implementation, ensuring coherence with learning objectives and student profiles. For game designers, the findings highlight the relevance of adaptive difficulty progression, clearer onboarding processes, and the inclusion of differentiated support mechanisms to accommodate diverse learners. Future research could explore longitudinal implementations, comparative studies across different educational contexts, and the impact of teacher training on the effective use of serious games in Mathematics education.

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