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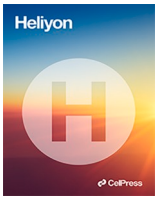

Research article

The educational impact of a comprehensive serious game within the university setting: Improving learning and fostering motivation

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ABSTRACT

The integration of technology in higher education has transformed teaching, turning students into active participants in their learning. Faced with the limitations of conventional methods, the integration of technological and creative methods adapted to current demands is being sought.

Proficiency in word processing and spreadsheets is crucial in university education, especially in social sciences and law, where the lack of specialized technical training affects academic performance. This study analyzes the impact of incorporating serious games with technological tools and active teaching methods on students' motivation, engagement and academic performance.

The research study suggests using active serious game approaches for learning spreadsheets. Two dynamic group games are designed: one with a closed structure and one in which students actively contribute to the creation of the game. A classroom experiment was conducted with a pre-post design, two experimental groups and a control group.

The control group used master courses and practical work, while the two experimental groups used two different types of games. A total of 575 students participated in the study, and their academic performance, motivation levels and engagement were assessed using an SIMS questionnaire.

There were three main findings drawn from the study. First, students who used serious games showed a significant improvement in their learning outcomes compared to the control group that used the traditional methodology. Moreover, students who used serious games and had the opportunity to co-design certain aspects of it showed a higher level of learning improvement. Secondly, at a motivational level, a difference was found in the external regulation motivation of the students when they used various serious games, taking into account their sex and academic year. Thirdly, we found that the level of students' engagement dramatically increased among those who used serious games compared to those who used a traditional teaching method.

1. Introduction

The field of computer science and technologies plays a crucial role in our daily lives, but many university teachers still opt for

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traditional methods, ignoring the negative effects on motivation, a key component at this level of learning [1]. The significance of addressing motivation in improving academic achievement, which is directly tied to educational quality, is underscored by earlier research [2,3].

Recent evidence [4] suggests that the continued use of traditional practices in higher education can negatively affect motivation. Implementing active methods, such as games, can improve the student's autonomy, commitment, effort and cooperation [4]. Gamification and serious games (SG) have been a valuable resource for teachers for many years, successfully applied in face-to-face environments, e-learning platforms [5] and MOOC courses [6], developing essential skills and knowledge that are vital for students' future success.

The COVID-19 pandemic in 2020 underscored the need for universities to adapt to changing environments. Teachers were forced to explore and adopt technological tools in order to enhance learning in virtual environments due to the shift towards online classes [7].

Thus one positive aspect of the impact the pandemic had on university contexts, and specifically the Computer Science department of the King Juan Carlos University, is that it now has a desire to stay up-to-date. At this university, teaching spreadsheets in hybrid situations was complicated as the content was so practical, which meant that instructors began to use learning strategies that applied gaming principles to their educational and professional work. This resource has been successfully used in fields that require practical experience, e.g. medicine [8], or corporate business [9] among others.

Scholars have carried out studies to examine the potential impact of engagement [10], sex or the specific course being studied on the use of gamification to improve motivation. The findings indicate that gamification has a good effect on engagement but a detrimental effect on performance, regardless of sex or course [11,12]. Conversely, some studies have noted an increase on motivation when compared to the traditional approach [11].

However, how can these resources be used to improve learning about spreadsheets? There are numerous cutting-edge materials that enhance student learning and motivation [13,14]. Gamification [15], for example, is a strategy employed by teachers to engage students in the classroom. It involves incorporating game mechanics and elements into educational contexts. On the other hand, SG [16] are educational games specifically designed for teaching purposes. The advantages of using play as a learning method include reinforcing meaningful learning, internalising concepts in the short or long term, and fostering innovation when confronted with simulated problems. Research on SG has grown in popularity in recent years, resulting in a substantial increase in the number of publications [17]. This is the resource used in this research study.

The main objective of this study is to assess the influence of SG on learning outcomes, motivation, knowledge acquisition, and engagement levels in the comprehension of spreadsheet concepts. This study spans three academic years, using two versions of a SG. In addition it is compared to another academic year where a traditional approach was used.

1.1. Literature review

1.1.1. From traditional teaching to active methodologies

Traditional teaching, characterised by passive students [18], has been replaced by technology advancements that impact both daily life and education [19]. However, resistance to changing educational methods persists, negatively impacting motivation and learning [20].

Deci and Ryan's self-determination theory emphasises the variability in student motivation, from intrinsic to demotivation [21]. To counteract demotivation, transforming teaching methodologies by adopting cutting-edge tools in university education is essential [20]. Seeking authentic experiences and more sophisticated educational settings can serve as an effective catalyst for transforming old passive teaching methods [22], ultimately leading to increased student motivation.

Intrinsic motivation is critical to long-term academic success. Serious games, due to their attractiveness and level of challenge, can enhance this motivation in students. These games often incorporate elements that stimulate curiosity and interest, such as quests, challenges, and rewards [23]. In addition, engagement is a crucial factor for academic performance [24,25] have shown that gamification and serious games can significantly increase student engagement, resulting in better knowledge retention and higher grades.

Technological breakthroughs are driving constant changes in the educational field. Active pedagogies, such as project-based learning or gamification, become crucial tools for enhancing teaching and learning [26]. They enable active learning and yield successful outcomes for both students and teachers [27]. Most of these methodologies are supported by software technologies, e.g, the workshops of Moodle platform.

The Strategic Framework of **Education and Training 2020** (ET2020), emphasises the importance of innovation in the education and training sector. It aims to support education systems in achieving four key goals, one of which is to enhance creativity and innovation in education [28].

Active approaches empower students to exercise autonomy and initiative by allowing them to make choices and take action [29]. Likewise, students acquire the ability to create, assume the consequences of their actions, express their individuality and to manage their own learning [30]. These new ways of teaching are used not only to internalise concepts but also to improve soft skills [31] in educational or business settings. Students not only acquire knowledge, but also the practical skills to use that knowledge.

1.1.2. Games and education

A lack of student motivation necessitates the use of instruments to attain learning, achieve confidence, and enhance performance [32]. Games and videogames are effective not only in education, but also in other contexts [33].

Notable active techniques include project-based learning, flipped classroom, problem-based learning, and game-based learning. Gamification, as defined by Hao [34], refers to the implementation of "*a playful design in a different context, including game-like*

experiences that promote a variety of desired activities and behaviours." It provokes significant interest among researchers and is being used in diverse training programmes, both in academic and personal/professional settings.

According to Deterding and other authors [24,35], games have one main element: motivating and creating emotional connection and engagement. These encompass various elements, with SG being among the most well-known, in addition to gamification. While both approaches fall under the umbrella of using games for educational purposes, SGs adhere to a more comprehensive and exact framework, with clearly defined objectives and specific mechanics.

SGs can serve as a complementary tool to gamification, but with significant distinctions, as they are designed as games that prioritise educational objectives rather than recreational ones. These open up countless opportunities [36] and propose innovative approaches to education at primary and secondary levels. However, in higher, serious educational levels, such as for university education, they are not as commonly used as in other educational stages or together with traditional methodologies [32].

1.1.3. Serious games

SGs originated in the commercial sector, for use in fields such as health and medicine [37], and military contexts [24]. During the mid-20th century, the term SG emerged in the educational context to denote technologies, avatars, or entire games [24]. The assembly of these games requires a detailed complexity, not only at a technical or development level, but also at a strategic level [36]. This process is deliberate, methodical, and developed to a high level of maturity, resulting in near-perfect autonomous execution. The game is meticulously crafted to actively engage students and provide them with an immersive experience.

The methodology employed in the design of SGs is of paramount importance. The execution is primarily dependent on the intended goal. Designers often employ a variety of strategies, ranging from point systems to symbolic figures, in order to cater to the demands of students or projects. It is believed that customising the SG design to accurately assess and cater to the specific requirements of the group [38] is most in demand due to the ability to effectively cater to the specific needs of the intended audience.

Alternative approaches, such as scenario-based design [39], which seeks to create games that simulate real-world situations, or universal design for learning (UDL), which prioritises the creation of inclusive and efficient games, are appealing methodology for game design considerations [40].

Game-based learning such as gamification and particularly SG, appears to be a suitable method within the framework of the European Higher Education Area (EHEA) [41], leading to substantial learning and assimilation of concepts through experiential means [42]. They enhance the teacher's innovative capacity and appear to be a superior methodology in comparison to master classes. Several studies have shown that the integration of gaming elements in educational environments can improve both engagement and academic performance of students [24,43].

While there are no inherent drawbacks [44], there are certain limits to consider, such as the teacher's familiarity with technological resources and the time required for their design and implementation.

Other studies [45–47] have demonstrated the effectiveness of gamified tools in teaching spreadsheets. These tools have consistently yielded positive outcomes, enhancing comprehension, performance, and proficiency in this area. Because there is a lack of studies that exclusively focus on SGs, our research could act as a catalyst for future studies based specifically on this methodology.

2. Materials and methods

2.1. Educational context

This research study was carried out at the King Juan Carlos University. Students from many academic disciplines participated in the study with a shared objective of acquiring proficiency in spreadsheet software and word processing applications. Each of them was affiliated with the Faculty of Economics and Business Sciences.

The experimental setting pertained to the field of Applied Computing. The course carries a total of 6 ECTS credits and is compulsory. The subject was included in the curriculum of accounting, administration, economics, and finance programmes. The completion of the degree occurred either in the first semester or the second. The subjects where this study took place were divided into two distinct sections, both focused on the acquisition and proficient use of: a word processor, and spreadsheets.

The experiment focused on the contents of the second section, which have a weight of 70 % in the evaluation of the subject, and were.

Topic 1 The Excel user interface.
Topic 2 Creating and basic changes to data.
Topic 3 Tools to organise and present information.
Topic 4 Use of functions such as analysis and planning tools. Report analysis with data segmentation and simple macros.
Topic 5 Creation and editing of graphics and small data charts.

The percentage assessed during the experiment was 15 % for the second block of content.

2.2. Description of serious games

The objective of this study is to measure the impact of an SG on the teaching of spreadsheets. Therefore, two SGs were used, their titles were: The Zombie World and Invasion. The design of both SG included multiple approaches, such as prototyping, Universal

Design for Learning (UDL), and Scenario-based Design. In addition, both are quiz-style games that test the student's knowledge in a particular subject.

In order to avoid losing points and failing, students must answer the questions properly. Prior to commencing gameplay, a clip was shown that used storytelling techniques to immerse the student in the game's dynamics, instil passion, and evoke curiosity. The clip outlined the goals of each game and highlighted the challenges.

The goal of The Zombie World is to find a vaccine to stop a global spread of zombification. The digital board represents a city with floor-type squares and building-type squares. The gamers are divided in two teams, the Zombies and the Resistance. Both move collectively, while each player in the group answers the questions individually.

The "floor" type boxes contain individual questions and award 100 points to the winner. The "buildings" type boxes generate group questions (Fig. 1), with competition and rewards.

In the "building" type boxes, every member of each team must respond to a question as quickly as possible. The winning team receives a total of 500 points, which are divided evenly among all members of the group. Additionally, they are awarded a tool that aids in the development of the life-saving vaccine for the population. The dynamic fosters collaborative learning as the entire team assists the player in addressing individual inquiries in a reciprocal manner. The board contains concealed objects that are distributed around the squares. These objects offer advantages to the group and can be used at the most opportune moment for the team.

Moreover, the presence of six distinct characters, three for each team, enhances the game's excitement by awarding advantages to their respective owners. The allocation of exceptional players is conducted using Kahoot and Moodle [48], where students with the highest score select avatars, forming teams such as Zombies or Resistance.

The Invasion uses a game board that represents a global geography, consisting of individual tiles (Fig. 2). The objective in this game is to conquer as much territory as possible to prevent an "alien invasion". Again, there are two teams, aliens and humans. They advance collectively through the regions they have conquered and respond independently. The team that conquers the highest number of tiles wins the game.

The tiles contain privileges and punishments (see Fig. 3), creating a gaming strategy. Turns involve choosing the tile, executing an action and responding to a question to conquer territories.

Before finishing the activity, the game introduces missions, which are strategic duels between gaming groups. These duels are aimed at acquiring various potions to manufacture the vaccine in The Zombie World, and acquiring different tiles/territories in The Invasion. The decision revolves around selecting between a standard boxes or a duel as a means to regain points or essential objects/tiles to win the game.

Both games are run on a freemium open access platform called *Genially* for which the King Juan Carlos University holds a professional license for the teaching faculty. The system is user-friendly and convenient for both students and teachers, as it focuses on the development of interactive material [49].

The game visuals, including the storytelling elements, have been generated using artificial intelligence technologies provided by *Midjourney, BlueWillow, D-ID,* and certain application filters such as Instagram.

The Zombie World served as the initial model for this experience, which was subsequently improved through changes suggested by the students themselves and the teacher. These improvements were made in response to identified issues in both, the gameplay and assessment aspects.

The next academic year, The Invasion was developed. It was an improved version of The Zombie World, not so much in the game system and objectives, but in the agility of the teacher's work and accumulation of points. This version improved user friendliness, question design and the process of awarding points and rewards. A more cooperative theme was integrated with boxes set in physical board games such as *The Island or Catan*. The teacher no longer provided the questions in their entirety. Instead, the students were

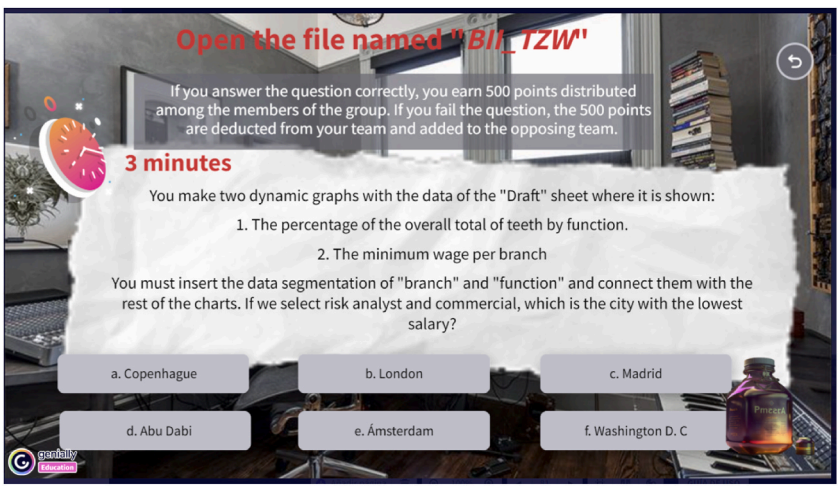

Fig. 1. Example group question for The Zombie World.

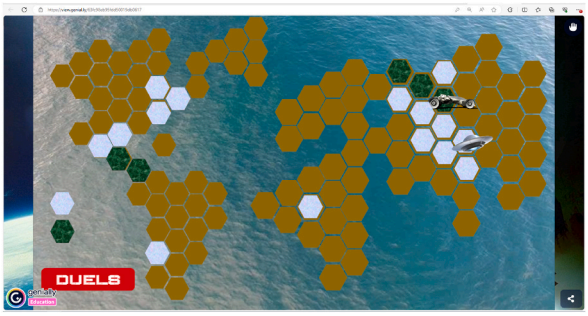

Fig. 2. The invasion Gameboard.

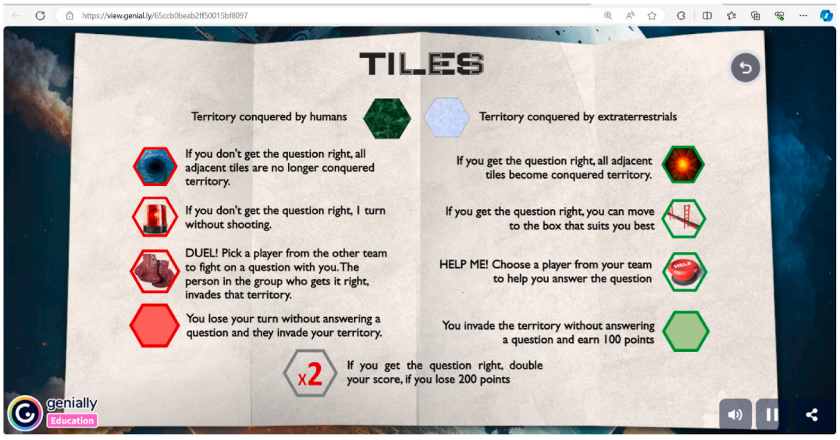

Fig. 3. Tile type in EG2.

required to occasionally create their own questions using the topic material. Failure to prepare these questions would result in a deduction of points. Thus, The Zombie World can be classified as a closed-structured SG, while The Invasion is an open game with a higher degree of cooperation among students.

Ethical approval

This study was approved by the Human Research Ethics Committee of the King Juan Carlos University, on October 2021 with an internal registration number of 2004202212722. All participants were informed of the study objectives and provided written informed consent prior to participation. The authors declare that there are no conflicts of interest related to this study. All necessary measures were taken to ensure the transparency and integrity of the research. Questionnaires were anonymized, and patients were free to opt out of the study whenever they felt uncomfortable.

2.3. Methodology

Two different methodologies were employed. A traditional approach, involving the participation control group (CG), and a methodology using SGs in two experimental groups. The experimental group 1 (EG1) used The Zombie World while the experimental group 2 (EG2) used The Invasion.

The main research question is: To what extent can the use of SG enhance students' learning experience in learning spreadsheet concepts? In order to address this question, we will formulate the following hypotheses.

- H1. The use of SG in teaching spreadsheets improves students' academic performance compared to the traditional methodology.
- H2. The type of SG used impacts student motivation when teaching spreadsheets.
- H3. The use of SG in teaching spreadsheets enhances student engagement with the subject compared to traditional methodology.

The second hypothesis, H2, examines motivation based on the type of game used, and is only conducted in EG1 and EG2 after the completion of the activity, working off numerous studies that demonstrate an increase in motivation with the use of SG [33,50,51]. Based on this, our study aims to assess the impact on motivation according to the game chosen.

To test these hypotheses, both an observational design and a quasi-experimental design have been used. They are detailed in the following sections.

In order to achieve uniformity in the activities, both the traditional methodology, which involves practical work, and the active methodology, which involves games, use questions. These questions might be in the form of essays, multiple-choice, or practical exercises.

2.3.1. Participants and groups

The total number of participants in this study was 575, all of whom were students in the specified grade levels outlined in section 3 (educational context). The students' age range was between 18 and 22 years old, as they were primarily first and second year students.

The students were divided into two groups: the CG which followed a traditional teaching approach, and the EG which used SGs The assignment of the groups to the control or experimental conditions was random, since it does not depend on the experiment itself, but on the enrollment of the students in the course to which they correspond, this not being a factor chosen by the experiment. The individual assignment to the control or experimental conditions was not carried out because the groups could not be divided.

Table 1 displays the duration of the study, which spanned four academic years. Some courses worked exclusively with EG1 and EG2, while others just focused on the CG.

2.3.2. Dependent variables and measurement instruments

This section details the variables used to validate the hypotheses. These variables encompass four key aspects: the assessment of learning outcomes based on subject grades (SUB) and activity grades (ACT), measurement of learning improvement (LIM), evaluation of motivation (MOT), and assessment of engagement or commitment (ENG). Table 2 presents a summary of the variables, their relationship to the hypotheses, the measurement instruments used, and the analytical method applied.

2.3.3. Learning outcomes and knowledge acquisition

Three distinct variables were used to assess learning outcomes and determine whether hypothesis H1 is valid or not.

One aspect to consider is the changing qualities of the activity used, namely the ACT, which assessed the immediate outcome of the method employed. It is measured on a scale of 0–10 through practical exercises in the CG or the serious game (EG). The questions used in both experimental groups were equivalent to the activities used in the CG. The same practical, essay or multi-response questions made the tests similar.

The second variable was the subject grade (SUB), which measured the learning demonstrated by students at the end of the course. The instrument with which it was measured was a final course exam similar for all the groups, CG, EG1 and EG2. It was an exercise of 15–17 questions, mostly practical, where they demonstrated all the skills they had learned.

The third and final variable in the analysis of knowledge acquisition was learning improvement (LIM), used to ascertain whether learning was improved when utilising the SG. The instrument used to measure it was a pre-post test. The multiple choice tests, comprising four responses, were only conducted in the EG, using the same scale from 0 to 10 as SUB and ACT. To calculate whether there are differences between EG1 and EG2, the LIM variable was calculated by subtracting the initial score from the final score.

2.3.4. Motivation

The MOT variable, used to validate H2, was assessed using a validated Situational Motivation Scale (SIMS) questionnaire, [52]. This scale comprises 14 items categorised into four dimensions: Intrinsic Motivation (IM), Identified Regulation (IR), External Regulation (ER) and Demotivation (D). The students assessed each item based on the prompt: *"What are your reasons for wanting to participate in the game?"* In addition to motivational questions, the questionnaire also asked demographic questions about age, sex, and academic level.

The questionnaire was administered through Microsoft Forms in the four weeks following the completion of the game, allowing time to obtain a significant number of responses. Since it was carried out outside regular school hours, it was shared on Moodle and Instagram. Motivation was just assessed in SGs, thus 238 students participated out of the 366 belonging to EG1 and EG2.

Although the questionnaire is already a validated instrument, its internal consistency was tested with the sample of the study. A descriptive analysis of the four dimensions analysed was performed and Cronbach's alpha was calculated, resulting in 0.707, an acceptable level of reliability."

2.3.5. Engagement

This variable (ENG) is associated with hypothesis H3, which aims to assess student engagement. In the CG, the activities were assessed using Moodle ethnograms through the instrument used in the ACT variable, practical exercises. Thus, a score of 1 indicated

Table 1
Distribution of participants into groups and academic courses.

Course \ Groups	CG	EG1	EG2
2019/2020	151	0	0
2020/2021	58	87	0
2021/2022	0	37	115
2022/2023	0	86	41

Table 2
Hypotheses, variables, instruments and statistical method.

Hypothesis	Variables	Units of measure	Instrument	Statistical M.
H1. Using SG in teaching spreadsheets improves student academic performance compared to the traditional methodology.	Subject Grades (SUB)	Scale from 0 to 10	Deliveries and points.	ANOVA
	Activity Grades (ACT)	Scale from 0 to 10	Exams	Tukey test
	Learning Improvement (LIM)	Scale from 0 to 10	Pre-post test	Mann-Whitney U Student-t Descriptive analysis Bonferroni Test Comparison of means Cohen's test
H2. The type of SG used impacts student motivation when teaching spreadsheets	Motivation (MOT)	Likert scale 1 to 7	SIMS questionnaire	Descriptive analysis Correlation analysis Kruskal-Wallis Student-t ANOVA Bonferroni Test
H3. The use of SG in the instruction of spreadsheets enhances student engagement with the subject compared to traditional methodology.	Engagement (ENG)	% of classes attended/classes taught	Delivery of tasks and participation in activities.	ANOVA Binomial/ Bonferroni analysis.

that all or some of the activities were submitted, while a score of 0 indicated that no activities were submitted or the student was never present. Students in EG1 and EG2 who actively participated in the activity and received feedback, were considered. It is assumed that a positive result (a score of 1) includes those who participated in the activity, a negative result (a negative result (a score of 0) corresponds to individuals who opted not to participate or did not take the subject) indicate students who did not take the subject.

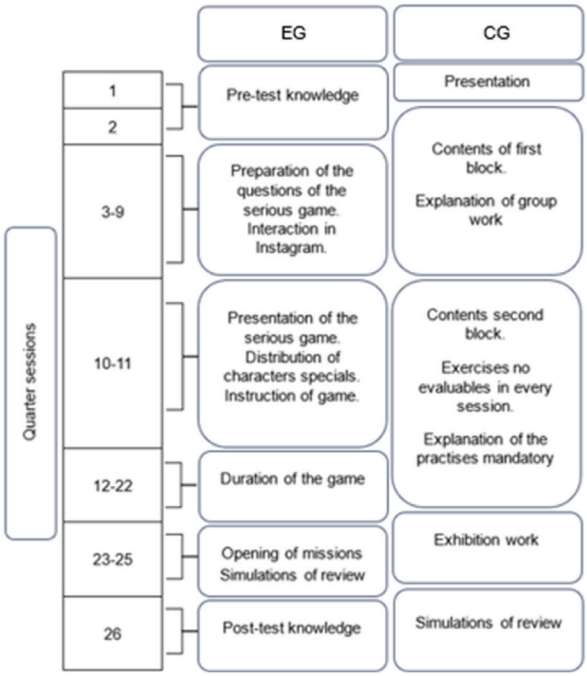

Fig. 4. Global session processing procedure for serious gaming exemplified by the EG vs CG session processing procedure.

In the case of the EG, a record of participation and commitment to the activity was kept every day. Those who attended the class, those who played, those who asked questions and those who were asked questions were recorded. On the other hand, with respect to the CG, the delivery of the practical exercises on the platform was taken into account.

2.3.6. Timing

As shown in Fig. 4, the semester had a total of 26–28 sessions, which varied according to the academic calendar. For the EGs, the game began in the tenth session and was completed on the last day of the semester, having a duration of 15–18 sessions.

Two weekly sessions were held, lasting 20–25 min, that focused on the second section of the syllabus, specifically on spreadsheets. The remaining time was dedicated to providing theoretical explanations and addressing any problems in sessions lasting 1 h and 40 min.

The semester structure of EG1 and EG2 comprised the introduction of the topic, a preliminary assessment of knowledge (pre-test), the implementation of intervention activities, and a final assessment of knowledge (post-test).

The game was explained and specific characters were assigned during sessions 10–11. The subsequent ten sessions were exclusively devoted to the game, providing students with the opportunity to thoroughly revise the material. Sessions 23–25 involved the execution of gaming missions and simulated exams, while the last session focused on conducting the knowledge acquisition post-test.

The CG's structure varied, consisting of a presentation session (1st session) followed by sessions 2–21 dedicated to explaining and engaging in activities related to the first and second sections. The tasks used to compare EG1 and EG2 activity were the mandatory practices that were carried out in sessions 10 to 21. Sessions 22–24 comprised the execution of a group work presentation from the first section, while sessions 25–26 involved mock tests.

3. Results

This section presents the findings of the analyses conducted: assessment of learning outcomes, motivation, and engagement. To analyse the results, we used the SPSS software, including parametric tests for variables that meet assumptions and normality, and non-parametric tests for variables that did not exhibit normality.

The significance level is standard for all variables ($p < 0.05$).

3.1. Knowledge acquisition

Of the 575 students, 36.34 % were in the CG and 63.65 % in the EG (36.5 % in EG1 and 27.1 % in EG2). Regarding the academic year, the number of students was consistent, ranging between 127 and 151.

The uneven distribution is due to study-specific factors, such as the availability and willingness of students to participate in the different groups.

We performed an analysis of variance (ANOVA) to test for differences between the groups. The results show that there are no significant differences in prior academic performance between the groups ($F(2, 572) = 1.23$, $p = 0.29$), suggesting that the groups are comparable in terms of initial performance.

Although the distribution between the groups is not perfectly equal, the measures adopted and the analyses performed allow us to ensure that the results are valid and comparable.

3.1.1. Correlation analysis between teaching methodology and grades

A one-way ANOVA analysis was conducted to determine whether there were any variations among the CG, EG1, and EG2 groups. It revealed significant differences in subject grades (SUB) and activity grades (ACT), as shown in Table 3.

The effect size showed that serious games had a positive impact on student grades, especially in the activities (ACT), where a moderate to large effect size was observed. Differences in effect sizes between SUB and ACT, as well as between EG1 and EG2, may be due to variations in game implementation and student response to these methodologies.

Bonferroni correction was applied in post-hoc analyses for multiple comparisons, adjusting the significance level (α) by dividing by the number of comparisons. Analyses of variance (ANOVA) showed significant differences in subject ratings (ASIG) and activity ratings (ACT) between groups ($p < 0.001$). Post-hoc tests with Bonferroni correction indicated significant differences between the control group (CG) and the experimental groups (EG1 and EG2), but not between EG1 and EG2.

3.1.2. Pairwise analysis of the Tukey test

The results are analysed in pairs, both from ACT and SUB, to identify the actual disparities and determine between which specific pairs differences exist. This was done using the post-hoc tests of the Tukey test, and the results are shown in Table 4. Based on the

Table 3
Comparison of the grades between the experimental and control groups.

	CG (N = 199)		EG1 (N = 202)		EG2 (N = 137)					
	M	SD	M	SD	M	SD	F	p	d (CG vs EG1)	d (CG vs EG2)
SUB rowhead	5.509	1.831	6.137	1.880	6.330	1.716	9.883	<0.001	0.338	0.462
ACT rowhead	4.795	3.290	6.810	2.936	6.269	3.047	21.589	<0.001	0.649	0.462

information provided in this initial study, it may be inferred that the experimental groups exhibit superior learning outcomes compared to the CG.

3.1.3. Cohen's test

As we can see in Table 5, in terms of effect size regarding ACT, the intervention based on serious games (especially in EG1) had a significant and positive impact on activity scores. The differences between EG1 and EG2 on ACT were small and negative, indicating that EG1 performed slightly better.

For SUB the intervention also improved grades in the spreadsheet content block, with a moderate impact on EG2 and small on EG1 compared to the control group. The differences between EG1 and EG2 in SUB were minimal, suggesting that both experimental groups had similar results in this aspect.

3.2. Analysis of knowledge acquired

An analysis was carried out to compare the learning differences before and after the treatments in order to determine whether the students had truly acquired knowledge.

The results revealed a significant difference, as indicated by the Student's t-test. The pre and post knowledge tests were carried out only on EG1 and EG2 – a total of 366 participants – of whom 283 provided responses.

3.2.1. The Student's t-test

Our analysis of the differences between the pre-post tests found statistically significant differences in the total sample and in EG1 and EG2 (see Table 6).

To analyse whether the differences between the pre and post tests were the same in the two games, a *t*-test analysis was carried out and significant differences were found between the games, with a higher score in EG2 than in EG1 (see Table 7).

An independent samples *t*-test was performed to compare the post scores of the EG1 and EG2 games. A statistically significant difference in post scores was observed between groups ($t(274.470) = -3.007$, $p = 0.001$), with a moderate to large effect size (Cohen's $d = 0.346$). From this analysis, we can conclude that students acquired more knowledge compared to their original level, and that EG2 had better scores than EG1.

3.3. Analysis of student motivation

3.3.1. Descriptive and correlation analyses

The dimensions chosen are the most commonly mentioned in previous studies on motivation in educational contexts and are considered fundamental to understanding students' behavior and academic performance [53–55].

A descriptive analysis of the four dimensions of the SIMS questionnaire was carried out, using the Pearson correlation coefficient to examine the relationships between the dimensions. Table 8 displays noteworthy relationships identified between IM and IR, IM and D, IR and ER, IR and D, as well as between ER and D. There was no significant relation observed between IM and ER.

Table 4
Post-hoc pairwise test with Tukey to compare the ACT and ASIG variables.

	CG (N=199)		EG1 (N = 202)		EG2 (N = 137)	
	ACT	SUB	ACT	SUB	ACT	SUB
CG	–	–	**<0.001**	**0.002**	**<0.001**	**<0.001**
EG1	**<0.001**	**0.002**	–	–	0.236	0.604
EG2	**<0.001**	**<0.001**	0.257	0.604	–	–

Table 5
Cohen's test.

Group	ACT (d)	Sub (d)
CG vs EG1	0.647	0.338
CG vs EG2	0.462	0.460
EG1 vs EG2	**−0.181**	**0.106**

Table 6
Learning improvement of each experimental group.

	LIM_Pre		EG1 (N = 202)			
N = 283 rowhead	M	SD	M	SD	t	p
EG1 & EG2 rowhead	3.101	1.790	6.145	1.733	−22.115	<0.001
EG1 (N = 171) rowhead	3.256	1.936	5.770	1.821	−13.693	<0.001
EG2 (N = 112) rowhead	2.875	1.531	6.420	1.563	−21.132	<0.001

Table 7
LIM averages for each EG.

	EG1		EG2			
	M	SD	M	SD	t	p
LIM	2.701	2.526	3.545	1.775	**−3.257**	**0.001**

Table 8
Descriptive analysis and correlations between the dimensions of motivation.

		Mean	SD	α	2	3	4
1	IM	5.985	0.722	0.684	0.459**	0.003	−0.345**
2	IR	5.874	0.873	0.633		140*	−0.431**
3	ER	4.010	1.310	0.724			0.173**
4	D	1.848	0.792	0.733			

Note: *Significant at 95 %. **Significant at 99 %; $p < 0.01$.

Table 9
Relationship between motivation and game for EG1 and EG2.

	EG1 (N = 88)		EG1 (N = 202)			
rowhead	M	SD	M	SD	t	p
ddIM rowhead	6.006	0.854	5.973	0.635	0.333	0.740
IR rowhead	5.924	0.901	5.844	0.857	0.680	0.497
ER rowhead	3.663	1.381	4.213	1.227	−3.092	0.002
D rowhead	1.798	0.859	1.877	0.751	−0.736	0.462

Table 10
Relationship between motivation and sex.

	Male (N = 128)		Female (N = 110)			
	M	SD	M	SD	t	p
IM rowhead	5.930	0.767	6.050	0.665	−1.283	0.201
IR rowhead	5.888	0.823	5.858	0.930	0.265	0.791
ER rowhead	4.307	1.222	3.664	1.330	3.889	<0.001
D rowhead	1.939	0.847	1.741	0.712	1.939	0.054

To address the second objective of this study, we analysed the relationship between motivational dimensions according to the type of game individually.

3.3.2. Relationship between dimensions and the game

Table 9 shows that statistically significant differences were found between EG1 and EG2 in the dimensions of ER. Specifically, the score in EG2 was greater than in EG1. However, no statistically significant differences were detected in the dimensions of IM, IR, or D.

3.3.3. Relationship between dimensions and sex

The distribution by gender in EG1 was 56 males and 32 females and in EG2 it was 72 males and 78 females. Differences were analysed according to type of game and sex (Student's t) and statistically significant differences were found according to sex in the ER dimensions, with a higher score being obtained by males. No differences were not found for IM, IR or D (Table 10).

3.3.4. Relationship between dimensions and qualifications

Although the subject was the same for the different degrees, to analyse the differences between the dimensions and qualification, the non-parametric Kruskal-Wallis test was used for the dimensions that did not meet the criteria for normalcy (IR and D), while the one-way ANOVA was used if normality was met (IM and ER). No statistically significant differences were found for any of the dimensions.

3.3.5. Relationship between the dimensions and the academic year

The one-way Anova test was used to analyse the differences in the dimensions based on academic years, assuming the normal distribution of the groups. A paired analysis was carried out using the Bonferroni correction (Table 11) and revealed statistically significant disparities in IM, with greater scores observed in the 2022–2023 academic year compared to 2021–2022. Similarly, in IR, higher scores were observed in the 2022–2023 academic year compared to 2021–2022. Regarding ER, there were notable disparities, with higher scores observed in the 2021–2022 academic year compared to 2020–2021. No statistically significant differences were identified for D.

3.4. Analysis of engagement

The sample for ENG, like knowledge acquisition, was 575 subjects, of which 77.4 % showed positive engagement, 16.34 % negative engagement and 6.26 % zero engagement.

The one-way Anova was used to analyse ENG as a function of the game (see Table 12), analysing only positive data. Statistically significant differences were found, with a higher score between EG1 and CG ($p < 0.001$), and between EG2 and CG ($p = 0.024$). No significant differences in ENG were found between EG1 and EG2 ($p = 0.583$).

A binomial analysis was carried out with a Bonferroni test and statistically significant results were found for positive ENG between CG and EG1 ($p < 0.001$) and between CG and EG2 ($p < 0.019$). No statistically significant differences are found between EG1 and EG2.

4. Discussion

Before starting this section, it is recalled that the main objective of this study was to evaluate the impact of serious games on the teaching of spreadsheets in the university context. The hypotheses tested were whether using serious games improves grades (H1), whether this method affects student motivation (H2) and finally whether this method increases student engagement (H3).

A variety of relationships between factors were identified throughout the experiment, such as motivation, different instructional approaches (traditional or serious game), academic performance, engagement, serious games, and knowledge acquisition. The validity of the hypotheses according to the results obtained are described below.

4.1. Hypothesis 1: improved learning acquisition

The first hypothesis (H1) refers to whether using serious game the performance and learning gain of students increases relative to traditional methods. We can accept it by demonstrating that it is an effective method compared to the traditional methodology of the control group since in this particular study, higher average grades are obtained in EG1 and EG2 obtaining a percentage of improvement of 13.08 %.

A concept that emerged parallel to the study was that game-based learning – using serious games or components of it (gamification) – to teach has a positive impact on learning results [56]. This concurs with different authors who have used comparable cohorts and a control group in their studies, comparing traditional methodology and an experimental approached based on gaming [25,51,57–59]. In these studies, the game-based methodology showed superior academic outcomes in students' grades [50].

Regarding spreadsheets learning, previous research has shown that students in experimental groups gained a better understanding of the subject by participating in gamification that involved interactive auctions [47]; students in the experimental group obtained better scores by comparing grades and results in final exams with previous courses during their high school stage. While this content does not yield any findings specifically related to university contexts, it does contain information pertaining to mathematics. In addition, there are other studies that measure academic performance in the context of acquiring proficiency in spreadsheets, like our case study [60,61], and they show that gamification leads to superior outcomes for the experimental group compared to the control group using traditional methods. Contrary to our research, these studies specifically dealt with stages of schooling below higher education.

Papers from several disciplines were found, including engineering and mathematics, that corroborate our findings. This study provides quantitative evidence that supports other favourable qualitative findings in fields such as molecular biology [62] where serious games can be an effective tool for addressing and correcting mistakes in the learning process of this subject. Experiencing failure before receiving direct instruction can help the learning process. This is because students who encounter prior challenges tend to develop a more solid conceptual understanding and an improved ability to apply concepts in novel situations, resulting in better results [62]. In this work, students had no prior exposure to learning using game-based methods, which may be an interesting result in not finding significance in demotivation.

Regarding the correlation between the use of serious games and students' academic performance, various authors have conducted literature reviews [63] which indicate that while short-term retention of concepts is significantly improved, long-term retention and overall academic performance may not be as effective. The study presented here illustrates how students improved in post-tests compared to the pre-tests in the short term. Moreover, the short-term grades of both the control and experimental groups achieved a higher average compared to the long-term average grades of the subject. By using this approach and conducting a thorough examination of the available research, we can conclude that serious games are an effective strategy for enhancing this particular variable.

In order to further support the acceptance of this hypothesis, it has been observed that conducting pre-post-tests to assess learning

Table 11
Relationship between motivation and academic year.

	2020–2021 N = 49		2021–2022 N = 121		2022–2023 N = 68			
rowhead	M	SD	M	SD	M	SD	F	p
IM rowhead	5.90	0.98	5.91	0.66	6.19	0.56	5.138	0.007
IR rowhead	5.82	0.90	5.76	0.89	6.12	0.79	3.877	0.022
ER rowhead	3.41	1.54	4.31	1.25	3.91	1.08	7.487	0.001
D rowhead	1.77	0.90	1.88	0.80	1.85	0.68	0.365	0.695

Table 12
Analysis of positive engagement between CG, EG1 and EG2.

	CG (N = 200)		EG1 (N = 202)		EG2 (N = 137)			
	M (%)	SD	M (%)	SD	M (%)	SD	F	p
ENG	0.74	0.44	0.89	0.31	0.85	0.35	8.841	<0,001

gain is sufficient to confirm that students improve their performance with serious games.

This has also been demonstrated in other studies, such as those in medicine [64], computing [65] and physical education [66]. In these studies, both the control group and the experimental group had prior knowledge, and a pre-post-test was administered. Positive results were obtained in the experimental group that utilized some form of game-based learning.

The students in Experimental Group 2 exhibited a higher level of learning acquisition, possibly because they no longer used the prototype, and carried out a thorough study of the errors and deficiencies to obtain better results. Something similar arises in other research studies [67,68] where the results of an enhanced prototype are analysed, obtaining improvements.

4.2. Hypothesis 2: effect of the type of game on motivation

The second hypothesis refers to how the type of serious game used may or may not increase student motivation compared to demotivation. In this case, we can validate the acceptance of H2 through an analytical demonstration of how individuals' inherent motivation tends to subjectively recognise the significance of the specific action.

Conversely, as intrinsic motivation rises, demotivation enabling individuals to overcome the obstacles of our H2 and observe that they are more motivated than demotivated. Other studies [69] support the notion that individuals who derive personal enjoyment from an activity are less likely to experience demotivation.

Additionally, individuals who personally recognise the value of an activity can be influenced by external factors, such as rewards or punishments, in their motivation to engage in it. Our study contradicts the findings [70], by demonstrating that external regulation is more pronounced in Experimental Group 2. This suggests that the enhancements made in the 2022–2023 academic year, such as the design of self-formulated questions, rewards, competition, and a theme resembling established board games, have had a positive impact.

There is evidence that supports the notion that both the implementation of gamification and serious games are effective strategies for enhancing motivation [71]. Studies in the educational field helping students to enter the workforce by running simulated games to reduce clinical errors in nursing [72],and give practical experience in the stock market to economics students [73] obtain positive results. This leads us to believe that these types of active method are an effective tool in financial education and learning about the stock market. These methods also enhance preparation for patient safety. In contrast to earlier research, which makes generalisations about student motivation, this study focuses on specifying motivation according to several dimensions, resulting in more comprehensive findings.

While serious games have only recently gained traction in the commercial sector, their application in the educational domain has become extensive. The use of these strategies is not limited to education, but it has gained popularity in recent years across other fields, yielding positive outcomes in both traditional and creative approaches [74] and revealing that students experience enhancements in both their motivation and their abilities in creativity and critical thinking [75,76].

While no statistically significant findings were observed, it is worth considering the customisation of activities using game-based learning, taking into consideration factors such as sex and age, in order to achieve better results [77]. There are studies [78,79] that have found that women tend to exhibit greater motivation and are more influenced by external control. In contrast, our study, along with others, has identified considerable disparities in external regulation and men [80]. This suggests that this particular sex is more focused on attaining goals and accomplishments. In our case, we could assume that males experience a greater sense of satisfaction due to the game's theme, the awards it offers, or the resemblance of the chosen tile to a role-playing game. These findings are intriguing and require further investigation.

Several analyses have employed serious games to examine the theory of self-determination and ascertain motivation levels based on different categories [80]. Similar to the findings of this study, intrinsic motivation yields highly favourable outcomes, fostering a sense of well-being and prompting students to engage in activities for their own benefit [71,76,81].

Regarding the academic year, there are other studies that conduct comparable research using gamification in two academic years [35] also yielding better results in the experimental groups. There are no studies that only use serious games as their methodology or continue their research over more than two academic years, making our experiment unusual in this regard.

This research is unique because it explores an area that has not been studied before. It focused on four specific dimensions: demotivation and external regulation, and explored motivation in a comprehensive manner rather than detailed. Therefore, it is reasonable to assume that this study is distinct from others that have been conducted.

4.3. Hypothesis 3: impact on student involvement

The third hypothesis posited that the use of serious games facilitates students' acquisition of greater engagement and active involvement in the subject matter. The hypothesis can be validated as students engaged with the serious game more than the traditional method.

This study presents findings that are consistent with previously reported results. According to Michael Zyda's research in 2005 [82], students acquire learning and participate more in non-compulsory activities. This serves as a viable alternative to traditional activities, however it should be noted that these findings do not suggest that it directly replaces them [83].

Not only do these authors defend the use of these methodologies to increase participation in higher education, but other studies also support the notion that traditional methodologies require modification and that students are inclined towards more interactive systems [84].

The experiment conducted in this study took place in the business field, an area where previous studies have also reported highly favourable outcomes, demonstrating considerable differences in a simulated game with a pre-post assessment, resulting in an enhancement in student engagement [85].

This positive result, as demonstrated in our study and corroborated by other scholars, can be attributed to the enhanced cognitive focus and attentiveness that students develop through the use of these approaches [83]. Despite the good results found in this and other studies, there are others that emphasise the need to carry out more research to gain a more comprehensive understanding of the efficacy of game-based engagement strategies and their potential to enhance student performance [44].

4.4. Theoretical and practical implications

There are both theoretical and practical implications. The results of this study support [23] self-determination theory, which postulates that intrinsic motivation is fundamental for effective learning. Serious games and gamification in education provide the necessary conditions to foster autonomy, competence, and relatedness among students. Intrinsic motivation is essential for long-term academic success, and serious games can enhance this motivation by being engaging and challenging.

In terms of practical implications, several studies have shown that gamification and serious games can significantly increase student motivation. In a study by García-López it was observed that the use of gamified platforms positively influences motivation, which in turn improves students' satisfaction and academic performance. This improvement in motivation translates into increased engagement and greater willingness to learn [56].

Research has shown that gamification can also have a positive impact on students' grades. A comparative study on the use of gamification in mathematics courses showed that students who used a gamified platform had better academic results compared to those who did not [56]. In addition, gamification can help reduce student demotivation, which contributes to better academic performance [56].

Finally, with respect to engagement, a crucial factor in academic performance, studies have shown that gamification and serious games can significantly increase student engagement, which translates into better knowledge retention and higher grades [24,25]. For example, the use of platforms such as Kahoot! has been shown to increase student participation and interest in the learning process, promoting a more dynamic and collaborative educational environment [86].

In this way, we can say that teachers can practically incorporate serious games into their curricula to increase student engagement. These games make learning more interactive and engaging, which can motivate students to actively participate in their classes. on the other hand, the findings can serve as a basis for gamifying everyday classroom activities. This can include creating challenges, rewards and leaderboards to encourage participation and continuous effort in addition to creating collaborative learning.

The samples of other studies reveal that the sample of this work is more than enough to make a value judgment on the results presented above. Classrooms of 24 students to work on escape rooms [87] or 60 with gamification and Flipped Learning [88] accredit the success of these new and innovative methodologies.

And not only the sample, but also the content worked with SGs or gamification, spreadsheets, has brought highly clear results [60,61]. It is worked through control and experimental groups where the sample is $n = 94$. A reliable value for positive results.

The results suggest that serious games can be applied in other educational contexts to improve motivation and academic performance. This aligns with Deci and Ryan's self-determination theory, which highlights the importance of intrinsic motivation in learning [23]. In addition, previous research has demonstrated the effectiveness of serious games in various areas, such as medical education [62] and business training [85] supporting the generalizability of our findings.

Finally, as occurred in this study, it is worth noting that when students are responsible for creating certain learning materials [89,90] it not only enhances their learning outcomes but also boosts their motivation.

5. Conclusion

This detailed study assessed the efficacy of a serious game as an educational approach, by comparing it to a traditional teaching method in terms of results and knowledge acquisition, motivation and engagement. Two versions of serious games were utilized: a co-design version in which students participate in the creation of the game, and a closed-structure version. The classroom experience revealed significant trends, suggesting ongoing improvements in these instructional techniques.

The results revealed significant differences in academic performance between serious games and traditional methods. Students who used the co-design, characterised by a more specialized game design, had a more significant enhancement in learning compared to students who used the closed-structure version. Regarding motivation, the games had an impact on both intrinsic motivation, and external regulation, with noticeable variations based on sex and the specific type of game. External regulation was particularly evident in the co-designed serious game, indicating that the design enhancements effectively enhanced engagement and commitment.

Differences between sexes in external motivation suggest discrepancies in how in-game incentives are perceived, influenced by personal and social preferences. Upon analyses of the academic years, notable disparities were identified in the levels of intrinsic

motivation and regulation between the years 2021–2022 and 2022–2023. There was an improvement in management during 2022–2023, but external regulation was more prominent in 2021–2022, when only closed-structure game was used. The introduction of co-design aspects during 2021–2022 resulted in an increase of motivation, attributed to the improvements and additional facilities.

In terms of student engagement, the majority actively participated in learning, as seen by the increase in positive scores. This suggests that both experimental groups were successful in improving student engagement. Consequently, it can be inferred that the presence of shared elements in both groups is crucial for enhancing engagement. The correlation between the students' external motivation and their academic progress increases when the students generate their own questions according to the co-design approach. This active engagement prompts them to review the material while formulating these questions, despite the use of anonymous and different questionnaires to assess motivation.

Our observations suggest that serious games enrich the educational experience and improve results. This study supports their effectiveness as valuable educational tools, contributing to the existing literature and suggesting future directions for educational research and development. This analysis contributes to the existing literature by offering a thorough and contextual assessment of the educational advantages of serious games and proposes viable avenues for future research and educational advancement.

- Do emotions change with the use of active techniques such as serious games?
- Are sexes affected by the serious game theme?
- Do students acquire more knowledge if they design all the questions in the serious game?

Despite the enormous sample size and our collaboration with students from several academic disciplines, we have identified some areas of inquiry that remain unexplored and which could add value to the research study, such as carrying out serious games in other areas – legal or other more theoretical areas [77]. Moreover, implementing this in other universities across different countries could give significant results.

In summary, this study demonstrates that serious games can improve motivation and academic performance in spreadsheet instruction. These findings, aligned with previous research [23,25,85], suggest that the integration of serious games in undergraduate education can be beneficial. However, future research in various contexts and disciplines is needed to confirm these results and evaluate their long-term effects.

5.1. Limitations

It could be said that there has been a powerful impact on improving intrinsic motivation by making learning more interactive, improving understanding and retention of content, and increasing participation and engagement. In this way, serious games could be integrated into the curriculum or syllabus by training teachers in their use and conducting continuous evaluations for better adjustments.

On the other hand, despite the fact that the sample size is large and that we have worked with students from different degrees, a number of open lines of research are identified that would add value to the research, such as carrying out the serious game in other areas with law content or in other more theoretical subjects [77]. In addition, doing it in different universities from other countries could be very positive in order to highlight other significant results.

Future research in various contexts and disciplines is needed to confirm these results and evaluate their long-term effects.

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Data availability statement

Has data associated with your study been deposited into a publicly available repository? Yes, the data are available.

The data are available in the public repository e-science data at the following link: https://doi.org/10.21950/KNEKWJ.

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CRediT authorship contribution statement

Lorena Rodriguez-Calzada: Writing – review & editing, Writing – original draft. **Maximiliano Paredes-Velasco:** Writing – review & editing. **Jaime Urquiza-Fuentes:** Writing – review & editing, Visualization, Validation, Supervision, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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