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Article

# Serious Games and Experiential Learning: Options for Engineering Education

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## Abstract

This research delves into the use of simulation games as a learning tool in logistics education, with a focus on the Logistics Simulator and Production Game Simulator. Through an analysis of these two cases, relevant findings were uncovered. Firstly, simulation games can recreate concrete experiences, allowing students to engage with challenging problems in a practical manner. In addition, simulation games offer a platform for experimentation with diverse scenarios, enabling students to hone their decision-making skills in a safe environment. Furthermore, the degree of motivation and engagement exhibited by students was found to be positively correlated with their experience gained through simulators. However, while the results obtained from the simulator were associated with student motivation and engagement, the study did not yield conclusive evidence in terms of student learning outcomes. The findings underscore the significance of employing strategies that enhance student motivation and support deep learning, thereby enabling students to apply and transfer knowledge to new situations. Notably, simulation games have great potential in logistics education as they facilitate faster and more enjoyable comprehension of key decision-making factors. Nevertheless, limitations of this study include the small sample size in both cases, which restricts generalizability, and the lack of consideration for sociodemographic factors in the baseline survey. Future research should address these limitations for more reliable findings on the specific needs of students in game-based and experiential learning contexts.

## 1. Introduction

During the past decade, various Information and Communication Technologies (ICTs) have emerged, including Big Data, Cloud Computing, Artificial Intelligence, Internet of Things, Machine Learning, Virtual Reality, Augmented Reality, among others. These innovations have transformed the paradigms of societies, changed the skills and competencies demanded by employers, and renovated the way knowledge is created, transmitted, and assimilated. Rather than considering technology as a threat, it should be seen as an opportunity to make improvements in the field of education. The potential of ICTs to promote learning opportunities depends on the ability to design activities that align pedagogy and technology for the benefit of students [1].

Furthermore, younger generations prefer to have a more prominent role in their learning, and methodologies that only allow the transfer of information in one direction are not enjoyable for new students [2] [3]. Additionally, students seek quick feedback and have a strong desire to achieve [2] [4]. One of the most significant changes in education in recent years is the shift from a teacher-centered to a student-centered approach [5].

In the past, the teaching content was delivered using a traditional approach where the instructor transmitted content through lectures, but the new generations require educators who recognize their audience and use a variety of teaching methods to engage students in the learning process.

Moreover, it is crucial to consider that ICTs have also contributed to conceptualizing a more complex world, where a greater number of variables are interdependent, leading to greater uncertainty and ambiguity. While the business environment has changed, the traditional schemes of people and tools continue to be maintained [6].

In this scenario, a constructivist theory that promotes reflection and experimentation among students is highly desirable. Additionally, if this theory is accompanied by tools that allow students to experiment with different decision-making strategies, receive quick responses, and understand the consequences of their decisions, it can challenge existing paradigms and provoke meaningful learning. This combination would be very useful.

In this paper, the authors use two different simulation games and combine them with Experiential Learning (EL), which is a constructivist theory created by Kolb [7]. EL emphasizes that students generate knowledge from their experiences and reflections. In this theory, teaching is not about transmitting information, but about engaging students in active and reflective learning, selecting meaningful experiences, and building their knowledge based on their existing understanding [7] [8]. Such situations are often found in the real world, but in recent years, they can also come from virtual or augmented reality, case studies, narratives, and learning challenges, among others. The idea of using simulation games to provoke meaningful learning in students is not new, and some areas of knowledge seem to favor this type of methodology. For example, in the field of nursing and medicine, there are several studies related to the use of simulators following Kolb's cycle [9] [10]. There are other areas where the creation of simulators seems to be an appropriate tool due to the costs or risks that could be generated in the real world, such as flight simulators, police training, financial simulators, and logistics simulators [11] [[12].

On the other hand, games have always been an option to voluntarily invest a large amount of time to improve performance. With the development of ICTs, games have achieved greater complexity and realism, which has motivated a significant part of new pedagogical designs to focus on the creation of games, particularly serious games (SG). SGs are often digital games designed for purposes beyond entertainment [12]. They offer an alternative that facilitates the development of traditional and digital skills [13]. Games can immerse students in complex situations where many variables are involved [14]. In contrast to entertainment games, serious games (SGs) are designed to provide learning content to the player [12]. When combined with other active learning techniques, SGs have the potential to serve as a powerful tool for generating engagement, motivation, and learning among students.

This article presents the characteristics of two cases in which a simulation game is utilized as a starting point for generating a Kolb cycle through experiential learning. It is of significance as it showcases the efficiency of combining a constructivist theory that is grounded in a tool enabling students to observe variable behavior, engage in experimentation, decision-making, reflection, model construction, and the integration of these elements to provoke significant learning outcomes. The result of combining experiential learning (EL) and serious games (SGs) is the development of skills in students, heightened motivation, and the generation of knowledge.

## 2. Literature Review

EL is a constructivist theory of learning that proposes a series of activities for students to construct their knowledge. In this theory, teaching is not centered on transmitting information, but rather on engaging students in active and reflective learning, where they select meaningful experiences and build their knowledge based on their existing understanding [7] [8]. This type of learning follows a recursive cycle of concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE), which naturally occurs in a continuous process of meaning-making [15] [16]. CE refers to a new experience or situation that triggers a stimulus for active engagement in a task. RO involves reflection on the new experience and recognition of any discrepancies or gaps between the learner's understanding and the experience. AC refers to the new ideas or modified thoughts that arise from reflection, including interpreting and updating experiences with new knowledge. Finally, AE refers to the learner's application of conclusions to the outside world, also known as the testing stage with new experiences. Rather than a closed circle, this set of activities should be considered as a spiral, where each cycle forms the basis for the next step in the learner's learning.

In this spiral, each stage of the cycle depends on its predecessor and follows a continuous step-by-step logical pattern. According to Kolb, learning occurs naturally as part of a continuous process of meaning-making through personal and environmental experiences, where the learner perceives, reflects, thinks, and acts in a situation. Therefore, experiential learning involves defining and organizing learning activities following this cycle, aiming to increase learners' interest, motivation, and engagement through different learning options, pathways, and autonomy [17]. Experiential learning also helps to create a stronger connection between learning engagement, practices, and reality for learners [18]. Additionally, it can be related to immersing learners in situations where they can learn outside of the iterative cycle process, such as problem solving, decision making, or policy making[19]. This approach has brought about changes in subjects where didactic teaching had been the dominant method of knowledge transfer.

This perspective is particularly relevant in engineering education to address immersive hands-on interventions and simulations involving the development of technological solutions[20]–[23]. Despite some arguments against experiential learning, such as cultural differences, contextual conditions, people's emotions, or the stage at which learning occurs, scholars also recognize its popularity and wide use in teaching practice [24]. Moreover, an additional advantage of this learning model is that it can be combined with other didactic techniques.

The flexibility of experiential learning has facilitated its association with the use of serious games or simulators. Using simulation games have gained enormous popularity in the last decade due to their numerous benefits [25]. Serious games provide flexible learning [26], improve learning outcomes [27], facilitate understanding [28] [29], generate engagement [30]-[32], and stimulate student motivation [33] [34]. The power of this resource lies in its ability to motivate individuals to voluntarily invest significant time in developing skills, acquiring knowledge, or participating in research [35] [36].

Some authors also cite additional attributes that simulation games bring to teaching, such as: (i) well-designed games can adapt to reality and establish a set of desirable skills in the contexts that students face [37]; (ii) they encourage active learning or action learning [38]; and (iii) they enhance learning and understanding of complex subject matter [39]. When we have simulations that efficiently represent real-world conditions, students tend to identify with them and create concrete experiences upon which knowledge can be built.

## 3. Research Methods

This study employs an instrumental multiple-case study as its research method, as stated in references [40] and [41]. Cases are considered unique entities due to the particularity of their conformation and can serve as instruments for learning about specific aspects of interest. In this study, two cases, namely Logistics Simulator (LOST) and Production Game (PRO Game), were analyzed as educational innovations, with a focus on their technological and pedagogical use with university students. As mentioned in reference [42], advancements in technology, research development, and teaching practices can lead to improvements in education. Therefore, the instrumental interest of the two cases in this study is to explore the link between learning experiences involving simulation games and gamification, and the active learning of university students for educational innovation.

### *3.1 Units of analysis and sample*

The two case studies in this research consider four units of analysis based on the experiential learning cycle. The first part of the study involved the participation of 47 students, comprising 21 females and 26 males. In the second stage of the study, 44 students participated, consisting of 20 females and 24 males. In both stages, all students were enrolled in an industrial engineering course.

### *3.2 Data collection and analysis*

Data for this research was collected from multiple sources, including the syllabus, game simulation scores, assignments, final exams, and surveys. The collected data was structured to analyze the learning objectives, the description of game activities, as well as information related to motivation, engagement, and learning achievements.

### *3.3 Ethical issues*

In this study, ethical considerations were given due importance, including various ethical dilemmas that needed to be addressed, as referenced in [43] [44]. These dilemmas encompassed participants' involvement, data handling, and dissemination of knowledge. The study ensured that participants were well-informed and willingly participated, while also maintaining anonymity, confidentiality, and respect for the data provided. Data handling was carried out following the evidence collected, both on the platform and the learning products. Dissemination of knowledge was done while upholding the confidentiality of participants and acknowledging the funding body that supported the project.

## 4. Case Narrative

### *4.1 Description, Objective and Simulation Games*

For this study, data from two simulation games designed for logistics education, namely LOST and PRO Game, were utilized. Both simulation games are accessible on the GOAL Project Platform (refer to Fig. 1), and were used by the students who participated in this study. The students engaged with the simulation games for a period of five weeks, with LOST being employed in the January to May 2021 semester, and PRO Game being utilized in the August to December 2021 semester.


**Figure 1.** *GOAL Project Platform Portal (https://goalproject.co)*

### *4.1.1 Logistics Simulator*

*Academic Objectives*

LOST is a business simulation game designed to enable students to swiftly and enjoyably acquire a deep understanding of logistics concepts. The game facilitates the creation and recognition of relationships among the diverse variables within the system, enabling students to observe the consequences of their decisions across various functional areas of a company. Additionally, LOST fosters the development of intrinsic motivation among students, motivating them to devise and experiment with new strategies in the realm of logistics operations within a company.

*Description*

The simulator in this study replicates the operations of a small company engaged in the production of various types of balls. The first scenario involves the operation of two facilities: a factory for production and a store for retail sales. At the beginning of the game, students are provided with a set of randomly generated data that mimics the data received by their peers. The players are then required to make decisions related to the quantity and types of balls to be produced, the raw materials to be used, and the selection of suppliers with varying characteristics such as cost, quality, and delivery times. At the end of each turn, the balls produced must be shipped from the factory to the warehouse, and players must decide on the quantities to be shipped, taking into consideration transportation costs and capacity.

Each turn of the game provides an opportunity for students to analyze and observe various important details, such as demand for each product, the production capacity of the company, raw material availability, supplier delivery times, product quality, inventories, pollutant emissions, economic utility generated by each product, and more. In order to avoid overwhelming students with the complexity of the logistics system in the first scenario, some elements have been simplified to facilitate decision-making. For example, there are no defective products in production, supplier delivery times are fixed, factory and store storage capacities are large, and pollutant emissions from factories are negligible. However, data are still present in the game, and participants are expected to recognize their relevance for decision-making (with modifications introduced in later scenarios).

Furthermore, there are some data that students should consider in their decision-making that are not directly provided within the data set offered by the game. For instance, while raw material costs, machinery operating costs, labor costs, and selling prices are described in the game, the profitability of each product is not explicitly stated. However, it is anticipated that students can develop insights from these data.

Students must consider that their decision-making is constrained by various factors such as production capacity, costs, and raw materials, as well as random factors that are generated by the simulator. The outcomes or consequences of their decisions and these random events will in turn shape their future decision-making. Fig. 2 can be referenced to better understand the logic of the game.

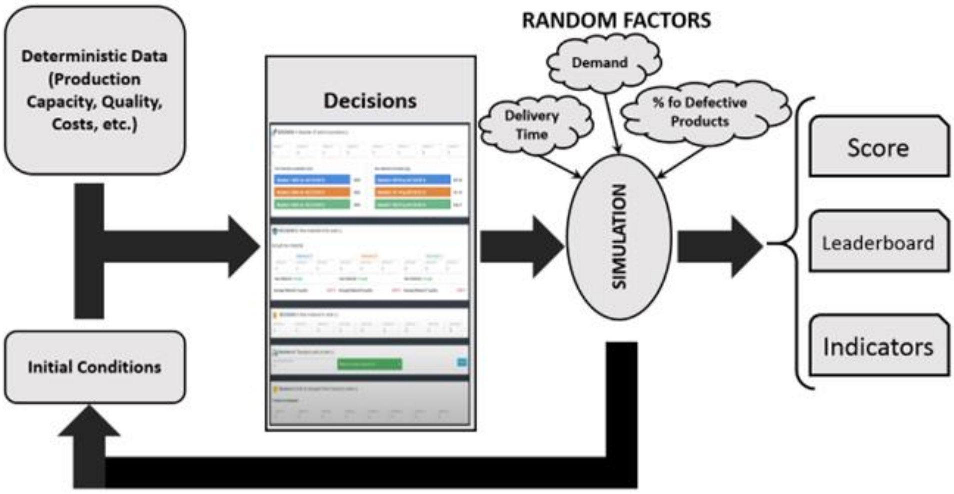



**Figure 2.** *Logistics Simulator Layout Diagram.*

### *4.1.2 Production Game*

*Academic Objectives*

PRO Game is a specialized and focused simulator that targets sequencing problems in the production domain, often associated with combinatorial optimization problems. The goal of this type of problem is to determine the most optimal order for scheduling the production of a set of items, with the aim of optimizing a predefined set of objectives as defined by the company.

*Description*

Sequencing problems are associated with several objectives, including: 1) minimizing the completion date of a set of products in production; 2) minimizing the delay time of a set of jobs with due dates; and 3) maximizing the number of tasks that can be performed within a specific time frame. The simulator recreates the operation of a shop floor with a set of tasks to be performed. In the first scenario, the shop floor utilizes a single machine. When the game begins, all students receive a randomly generated data set. Players must make decisions regarding the sequence in which a defined set of tasks should be performed. Each task is assigned a due date, a processing time, and a cost per unit time of tardiness. Once the data set is generated, the scenario is defined and there are no further random variables modifying the system behavior. In the first scenario, we only consider cases where the shop has a single machine and the task times for producing the parts are fixed (i.e., there is no variability in the production time). When considering an example with 20 different products in this scenario, it is worth noting that the possible number of solutions for this problem is extraordinarily large (2.43 x $10^{18}$). The template displayed in Fig. 3 illustrates the initial interface of the game.

In this diagram, when a participant changes the order in which the pieces are made, the costs indicated in the last row are automatically adjusted. This allows participants to determine with complete certainty whether that change in the order of manufacturing the pieces increases or decreases the total costs.

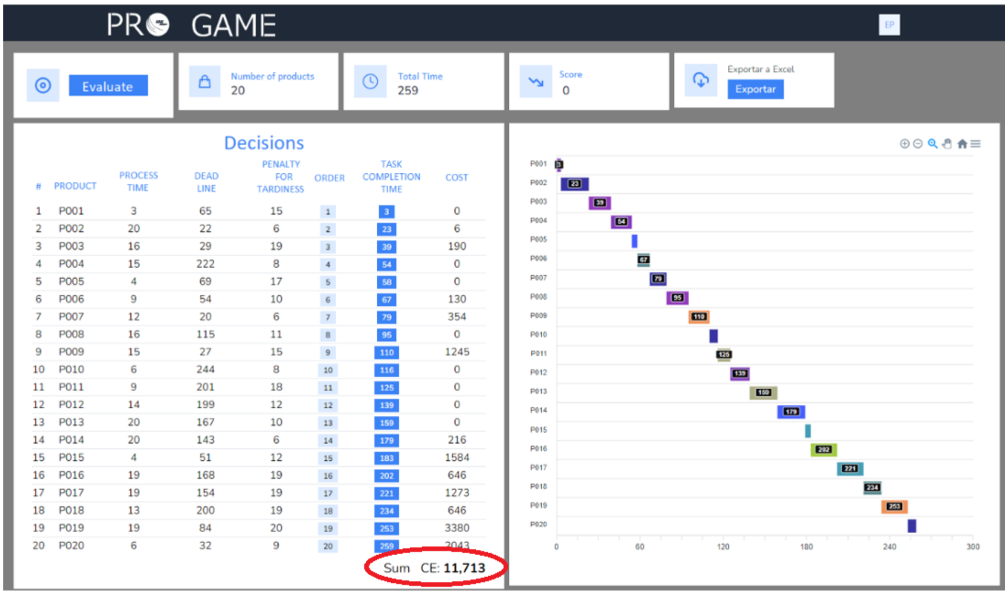



**Figure 3.** *Example of one of the sequencing problems assigned to the students.*

The challenge in solving a sequencing problem lies in the impracticality of experimenting with an extensive set of solutions. Hence, it is advantageous to explore alternative approaches and heuristic methods that enable intelligent and rapid decision-making. Although the number of possible combinations for the order of item manufacturing is exceptionally large, the variables that students need to analyze are relatively small, including process time, delivery time, and cost per unit time of tardiness. Furthermore, these variables are easily identifiable by the participants, and the relationship between these variables and the cost of the optimal policy is quite intuitive. Additionally, when students anticipate or postpone the completion of a task within the simulation, the software promptly updates the solution and provides immediate feedback on their decision. It is worth mentioning that the system immediately updates the results when players make changes in the order of task execution. Once the players have made their final decision, the system compares their solution with a previously calculated one by the simulator (refer to Fig. 4).

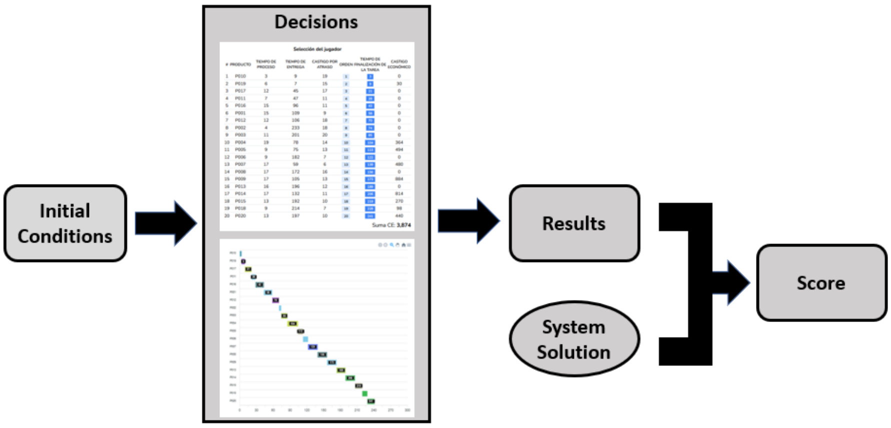



**Figure 4.** *Production Game Layout Diagram.*

## *4.2 Experiential Learning*

According to Kolb, active engagement is the key to effective learning. Merely reading or researching a given topic is insufficient; learners must be actively involved in finding solutions to acquire new knowledge. As mentioned earlier, this learning cycle is typically structured based on the four distinct stages that have been clearly defined by Kolb.

### *4.2.1 The pedagogical design used with the LOST Simulator*

*Concrete experience*

The simulation game was introduced during the initial session of this stage. The presentation of the simulator was facilitated through videos available on the platform, without any additional explanation provided. Participants had the opportunity to watch the videos as many times as needed and played six turns of the simulator to ensure they were familiar with the software, could locate relevant information, and perform calculations related to the game.

Once the teachers confirmed that the students were proficient in using the game, the participants were instructed to play a full run of the game, comprising 26 turns on the simulator. The objective of this submission was to gain a deeper understanding of the variables at play in the game. It was required that the scores achieved be higher than 25% of the scores displayed on the leaderboard, equivalent to obtaining a minimum of 500,000 points.

A summary of the results of this activity is presented in Table 1. A total of 94% of the students (44 of them) were able to achieve the expected scores. In the delivery reports submitted, two out of the three members who did not meet the expected score mentioned that their mistakes were due to distractions, while another student expressed a lack of understanding of how the game worked. Table 1 provides an overview of the scores obtained by the students in this submission. Most of the students expressed confidence in being able to improve their scores, with a higher score obtained correlating to a higher percentage of students who believed they could achieve better results.

Furthermore, Table 1 includes ratings provided by players regarding various aspects of the game. After completing the activity, students rated features of the game on a scale of 1 to 10, including Concentration, Goal Clarity, Feedback, Challenge, Autonomy, Immersion, Social Interaction, and Knowledge Improvement. Details of this survey are discussed in the subsequent section (refer to Table 2). The evaluation of the game is based on the average scores assigned by the students for each category.

**Table 1.** *Students' scores obtained on their first submission and evaluation of the simulation game LOST.*

| Score | Percentile on the leaderboard | Number of Students | Game Evaluation | Do you think you can achieve a higher score? |
|---|---|---|---|---|
| Above 900 000 | Within the top 10% | 3 | 9.89 | 100% |
| Between 815 000 and 900 000 | Between 25% and the top 10% | 9 | 9.64 | 89% |
| Between 685 000 and 815 000 | Between 50% and the 25% higher | 17 | 9.54 | 82% |
| Between 500 000 and 685 000 | Between 25% and the lowest 50% | 15 | 9.32 | 80% |
| Below 500 000 | Below 25% with the lower score | 3 | 8.92 | 66% |

*Reflective Observation*

During this stage, the participants engaged in discussions focused on the main variables that could contribute to improving their performance in using the simulator. The discussions centered around key variables relevant to decision-making, the students' existing knowledge of logistics operations, and additional variables that could be considered and how they could be obtained. The students who had achieved the best scores in the game guided the discussion and shared their strategies with their peers.

It was crucial to address and challenge any preconceived ideas that the students may have had at the beginning of the course. While some of these ideas may have had a theoretical basis or were supported by readings, the students often lacked the practical experience to make informed decisions. For instance, a common belief among most students was that inventory levels should be kept low, leading to a suggestion from one student to place very small orders of inventory every week. However, this approach could result in increased costs associated with carrying inventory. Through the discussions, the perception of the participants changed, and students became more curious and discerning about the appropriate decision-making parameters within the game.

Following these discussions, students were asked to play the simulator again. The objective for the final submission was to achieve a score equal to or greater than 75% of the scores displayed on the leaderboard, equivalent to reaching a minimum of 815,000 points. Out of the 47 participants who accepted this challenge, 41 of them successfully achieved the objectives, with four of them scoring above 750,000 points, one student scoring around 720,000 points, and one student obtaining less than 500,000 points.

A notable change in behavior was observed in the strategies used by the students during their initial playthrough of the simulator and after the class discussion. For instance, Fig. 5 illustrates a typical student's decision regarding the order quantity during their first playthrough, while Fig. 6 depicts the order quantity chosen by the same student after the class discussion. These findings suggest that the discussions and shared strategies influenced the students' decision-making approaches in the game.

*Abstract Conceptualization*

This stage commences after the second delivery of the comprehensive simulator game. The primary objective is to engage in theorizing appropriate strategies based on the current conditions in the game, specifically production capacity, demand, ordering cost, product expiration, and economic profitability. To undertake this activity, instructors randomly assign a condition for each of the five different variables, encompassing options such as increase, decrease, or maintain current values. Consequently, students can recreate scenarios in which production capacity is modified by 30%, 10%, remains unchanged, decreases by 10%, or decreases by 30%. Similar options are provided for the other variables, such as demand, and so forth.

Subsequently, teams are formed, and each team is provided with a scenario by the instructors to engage in theorizing and strategizing. The teams are given one week to establish their strategies and submit an essay that discusses and justifies their position on the problem they have been assigned.

Materials orders

Download table as CSV

| | MATERIAL A | | | MATERIAL B | | | MATERIAL C | | |
|---|---|---|---|---|---|---|---|---|---|
| Turn | MPA-1 | MPA-2 | MPA-3 | MPB-1 | MPB-2 | MPB-3 | MPC-1 | MPC-2 | MPC-3 |
| 1 | 13 Delivered | 19 Delivered | 14 Delivered | 9 Delivered | 19 Delivered | 23 Delivered | 23 Delivered | 3 Delivered | 5 Delivered |
| 2 | 13 Delivered | 10 Delivered | 15 Delivered | 12 Delivered | 9 Delivered | 13 Delivered | 12 Delivered | 11 Delivered | - |
| 3 | 2 Delivered | 13 Delivered | 2 Delivered | 9 Delivered | 12 Delivered | 3 Delivered | 7 Delivered | 19 Delivered | 2 Delivered |
| 4 | 19 Delivered | 15 Delivered | 9 Delivered | 10 Delivered | 14 Delivered | 12 Delivered | 11 Delivered | 9 Delivered | 4 Delivered |
| 5 | 12 Delivered | 11 Delivered | 9 Delivered | 12 Delivered | 9 Delivered | 8 Delivered | 17 Delivered | 15 Delivered | - |

**Figure 5.** *Order quantity decisions the first time the student plays the simulator (first 5 turns).*

Materials orders

Download table as CSV

| | MATERIAL A | | | MATERIAL B | | | MATERIAL C | | |
|---|---|---|---|---|---|---|---|---|---|
| Turn | MPA-1 | MPA-2 | MPA-3 | MPB-1 | MPB-2 | MPB-3 | MPC-1 | MPC-2 | MPC-3 |
| 1 | 450 Delivered | 60 Delivered | - | - | - | 430 Delivered | - | - | 300 Delivered |
| 2 | 600 Delivered | - | - | - | - | 600 Delivered | - | - | 500 Delivered |
| 3 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 5 | - | - | - | - | - | - | - | - | - |

**Figure 6.** *Order quantity decisions after classroom discussion (first 5 turns).*

*Active Experimentation*

During this stage, the proprietor of a small business was invited to address the students about the logistics operations of their company. The students were tasked with mapping the primary logistics processes and value chain of the company, and subsequently, utilizing this information to identify and propose modifications in the simulator to accurately represent this company. This entailed determining which elements should be modified, added, or eliminated in the simulator based on the insights gained from the mapping exercise. Drawing upon these changes, the participants were then required to devise a comprehensive strategy and prepare a report outlining ideas and strategies to enhance the operation of the entrepreneur's company.

### *4.2.2 The pedagogical design used with the PRO Game Simulator*

*Concrete Experience*

The simulator was introduced at the outset of this stage in the Kolb cycle. The presentation entailed an explanation provided by the tutor in the classroom, who also played a few rounds of the game with the students to illustrate its functionality. The students were then tasked with playing three complete rounds, encompassing a total of 20 items to be manufactured. The scores obtained in the simulator were not given much emphasis; rather, the primary objective of the activity was to assess the students' proficiency in utilizing the simulator.

Once the tutor confirmed that the students were adept at using the simulator, they were instructed to submit five screenshots wherein their scores exceeded 800 points. The points were calculated based on scores derived from both the system solution and the students' achievements. The game score was determined using the following formula:

Score = (Solution System Cost) / (Solution Player Cost) x 1000

For instance, if the player's cost score was 9120, and the system solution had a cost of 1706, the calculation for the system score would be (1706 / 9120) x 1000 = 187.06.

In this case, all students successfully completed the assigned task, with a game rating of 9.18, and 100% of the players believed that they could attain a higher score. A concise summary of the results of this activity is presented in Table 2, which showcases that all students achieved the expected scores. The delivery reports indicated that many of the comments from the students revealed that the task was completed without significant difficulties. In most cases, the strategy followed by students was to order the tasks based on increasing delivery time. Table 2 illustrates the scores obtained by the students in this submission. Similar to the case of LOST, the students were asked to evaluate the game, and all of them expressed confidence in their ability to achieve higher scores.

**Table 2.** *Students' scores obtained on their first submission and evaluation of the simulation game PRO Game.*

| Score | Number of Students | Game Evaluation | Do you think you can achieve a higher score? |
|---|---|---|---|
| Above 1 200 | 9 | 9.13 | 100% |
| Between 1 000 and 1 200 | 16 | 9.24 | 100% |
| Between 800 and 1 000 | 19 | 9.16 | 82% |

*Reflective Observation*

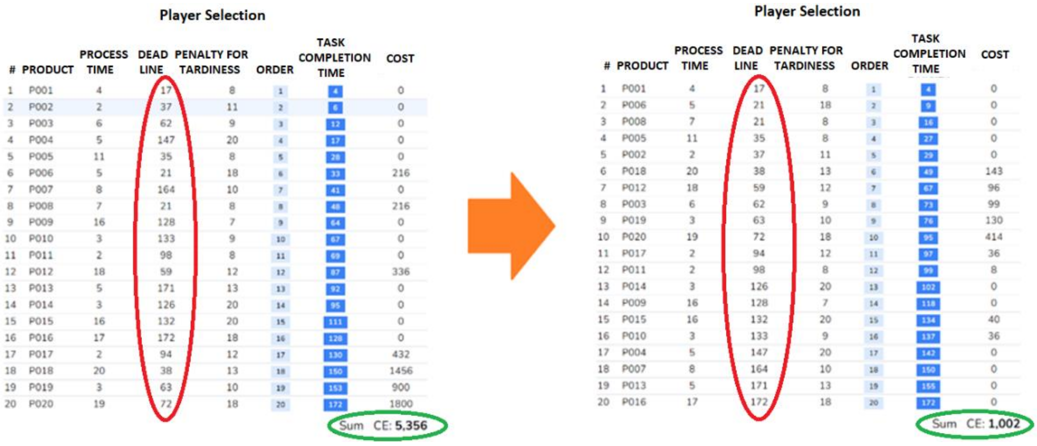
During this stage, the discussion centered around determining the key variables to minimize costs associated with sequencing decisions. The students quickly reached a consensus on identifying and prioritizing the following variables: due date, delay penalty, and task processing time. Moreover, the students were able to devise an algorithm for solving this problem: 1) Sorting the tasks in ascending order based on their due date, and 2) sorting the tasks in descending order based on their penalty. The suggestions proposed by the students in the class were notably accurate, as most heuristics in this domain are founded on these concepts.

It is worth noting that very few students had prior knowledge of this topic, with only 3 out of the 44 participating students (less than 7% of them) having heard of it before. This is likely because not all companies incorporate manufacturing systems in their processes, and only a small number of customers impose financial penalties for delays. Nevertheless, the students expressed that the mechanics of the game and the prompt feedback on their scores helped them comprehend how the different variables are interconnected.

Subsequently, the students were instructed to replicate the simulator to achieve ten scores that demonstrated an improvement in the solution generated by the system. Five of these games involved simulations with 20 tasks, while the remaining five involved simulations with 30 tasks to be sequenced. All participants performed competently, and their strategies aligned with the conclusions drawn in the classroom. Fig. 7 illustrates the strategy followed by the students. The left side of the figure depicts the original problem generated by the software. When the students receive this problem, their strategy is to arrange the tasks according to their delivery time in ascending order (as seen on the right side of the figure). Typically, this leads to improvements in total costs. The tasks are delivered according to the sequence determined by the students. No significant differences were observed in the strategies employed between the first and second deliverable. Our interpretation is that the previous stage (concrete experience) facilitated learning that was reinforced in this stage of the Kolb's cycle.

*Abstract Conceptualization*

During this stage, students engaged in discussions of various strategies for modifying the conditions of a sequencing problem. Two particular scenarios of interest were examined. The first scenario involved determining the appropriate strategy when there is no economic penalty, and instead focusing on other output variables that can be measured in sequencing processes, such as makespan, average tardiness, the average number of jobs in the system, or average completion time. The second variable under consideration was the number of machines involved in a manufacturing process, and whether or not these machines were sequenced.



Player Selection

| # | PRODUCT | PROCESS TIME | DEAD LINE | PENALTY FOR TARDINESS | ORDER | TASK COMPLETION TIME | COST |
|---|---|---|---|---|---|---|---|
| 1 | P001 | 4 | 17 | 8 | 1 | 4 | 0 |
| 2 | P002 | 2 | 37 | 11 | 2 | 6 | 0 |
| 3 | P003 | 6 | 62 | 9 | 3 | 12 | 0 |
| 4 | P004 | 5 | 147 | 20 | 4 | 17 | 0 |
| 5 | P005 | 11 | 35 | 8 | 5 | 28 | 0 |
| 6 | P006 | 5 | 21 | 18 | 6 | 33 | 216 |
| 7 | P007 | 8 | 164 | 10 | 7 | 41 | 0 |
| 8 | P008 | 7 | 21 | 8 | 8 | 48 | 216 |
| 9 | P009 | 16 | 128 | 7 | 9 | 64 | 0 |
| 10 | P010 | 3 | 133 | 9 | 10 | 67 | 0 |
| 11 | P011 | 2 | 98 | 8 | 11 | 69 | 0 |
| 12 | P012 | 18 | 59 | 12 | 12 | 87 | 336 |
| 13 | P013 | 5 | 171 | 13 | 13 | 92 | 0 |
| 14 | P014 | 3 | 126 | 20 | 14 | 95 | 0 |
| 15 | P015 | 16 | 132 | 20 | 15 | 111 | 0 |
| 16 | P016 | 17 | 172 | 18 | 16 | 128 | 0 |
| 17 | P017 | 2 | 94 | 12 | 17 | 130 | 432 |
| 18 | P018 | 20 | 38 | 13 | 18 | 150 | 1456 |
| 19 | P019 | 3 | 63 | 10 | 19 | 153 | 900 |
| 20 | P020 | 19 | 72 | 18 | 20 | 172 | 1800 |

Sum CE: 5,356

Player Selection

| # | PRODUCT | PROCESS TIME | DEAD LINE | PENALTY FOR TARDINESS | ORDER | TASK COMPLETION TIME | COST |
|---|---|---|---|---|---|---|---|
| 1 | P001 | 4 | 17 | 8 | 1 | 4 | 0 |
| 2 | P006 | 5 | 21 | 18 | 2 | 9 | 0 |
| 3 | P008 | 7 | 21 | 8 | 3 | 16 | 0 |
| 4 | P005 | 11 | 35 | 8 | 4 | 27 | 0 |
| 5 | P002 | 2 | 37 | 11 | 5 | 29 | 0 |
| 6 | P018 | 20 | 38 | 13 | 6 | 49 | 143 |
| 7 | P012 | 18 | 59 | 12 | 7 | 67 | 96 |
| 8 | P003 | 6 | 62 | 9 | 8 | 73 | 99 |
| 9 | P019 | 3 | 63 | 10 | 9 | 76 | 130 |
| 10 | P020 | 19 | 72 | 18 | 10 | 95 | 414 |
| 11 | P017 | 2 | 94 | 12 | 11 | 97 | 36 |
| 12 | P011 | 2 | 98 | 8 | 12 | 99 | 8 |
| 13 | P014 | 3 | 126 | 20 | 13 | 102 | 0 |
| 14 | P009 | 16 | 128 | 7 | 14 | 118 | 0 |
| 15 | P015 | 16 | 132 | 20 | 15 | 134 | 40 |
| 16 | P010 | 3 | 133 | 9 | 16 | 137 | 36 |
| 17 | P004 | 5 | 147 | 20 | 17 | 142 | 0 |
| 18 | P007 | 8 | 164 | 10 | 18 | 150 | 0 |
| 19 | P013 | 5 | 171 | 13 | 19 | 155 | 0 |
| 20 | P016 | 17 | 172 | 18 | 20 | 172 | 0 |

Sum CE: 1,002

**Figure 7.** *Example of the heuristic applied by the students when solving the sequencing problem.*

In order to facilitate this dynamic, the instructors selected two decision variables for analysis. The first variable pertained to different output variables, such as makespan, average tardiness, average number of jobs in the system, or average completion time. The second variable revolved around the number of machines that the students were required to consider when solving a sequencing problem, ranging from one to five machines.

The instructors provided the students with random values for each of these variables in order to recreate a scenario that the students could theorize and strategize about. The project report for this activity was to be carried out in teams of four students, and upon submission, the students were required to make a presentation to the course group regarding the case scenario they had to solve. This presentation needed to include a justification for the relevant variables they considered, an explanation of the interrelations between these variables, and a presentation of their strategies to solve the problem. Additionally, the students were also required to write an essay in which they argued their solution strategies.

*Active Experimentation*

In this phase, a visit was arranged for the owner of a woodworking shop to share insights on how his company approached sequencing problems. The businessman engaged in discussions with the students, elaborating on how his company reached agreements with customers, managed tasks related to furniture production, and employed strategies to prioritize different tasks. Furthermore, the owner highlighted that certain element of the production process exhibited variability in times, making them non-deterministic. He also mentioned that penalties for late deliveries were infrequent occurrences.

Following this visit, the students were tasked with designing strategies that could aid the entrepreneur in improving response times with his customers. This provided an opportunity for the students to apply the knowledge and insights gleaned from the visit to formulate effective strategies aligned with real-world scenarios.

### 4.3 Surveys

#### 4.3.1 Game Evaluation Survey

A survey was conducted to the students to gather their feedback on various aspects of the simulator. The questionnaire was administered after the players had submitted their first report with their game results. The survey was designed based on established literature [45] and included statements related to game features, which the students rated on a scale of 1 to 10. The game rating was calculated as the average of responses to each statement. Table 3 presents the comprehensive survey, encompassing a total of 16 questions.

**Table 3.** *Evaluation Game Survey.*

| Characteristic | Questions |
|---|---|
| **Concentration** | 1. The game provides content that stimulates my attention.<br>2. The game grabs my attention. |
| **Goal Clarity** | 1. Overall game goals were presented clearly.<br>2. Overall game goals were presented in the beginning of the game. |
| **Feedback** | 1. I receive information on my status, such as score or level.<br>2. The indicators in the game provide me with relevant information. |
| **Challenge** | 1. I enjoy the game without feeling bored or anxious.<br>2. I am encouraged by the improvement of my skills. |
| **Autonomy** | 1. I feel that I can use strategies freely.<br>2. I know the next step in the game. |
| **Immersion** | 1. I forget about time passing while playing the game.<br>2. I can become involved in the game. |
| **Social Interaction** | 1. I feel cooperative toward other classmates.<br>2. I strongly collaborate with other classmates. |
| **Knowledge Improvement** | 1. The game increases my knowledge.<br>2. I try to apply the knowledge in the game. |

### *4.3.1 Motivation Survey*

The students were requested to complete a motivation survey, which was based on established literature on this topic [46]. The survey was administered at the end of the course. A 7-point Likert scale was used for the survey. Table 4 displays the survey, which comprised 10 questions related to lack of motivation, intrinsic motivation, and extrinsic motivation.

**Table 4.** *Motivation Survey.*

| Type of Motivation | Questions |
|---|---|
| Lack of Motivation | 1. When I'm playing the simulator, I have the impression that I am wasting my time.<br>2. I cannot understand why playing the simulator is important for this class. |
| Intrinsic Motivation | 1. I like to play the simulator because it presents new information or makes me reflect on essential aspects of my career.<br>2. I like to play the simulator because it presents me with new information on a topic that I enjoy.<br>3. I like to play the simulator because it allows me to continue learning subjects that are interesting to me.<br>4. I like to play the simulator because of the challenge of learning things on my own. |
| Extrinsic Motivation | 1. I like to play the simulator because the information can help me eliminate some of the questions that I had in the classroom.<br>2. I think playing the simulator can help me improve my grades in this subject.<br>3. I like to play the simulator because it allows me to learn some subjects that are relevant to my career.<br>4. I like to play the simulator because it helps me to have better preparation for when I will look for some work opportunity. |

## 5. Results

Herein, we provide a summary of the outcomes attained in various components of the course. Section 5.1 presents the findings on Simulator Scores, Final Exam, and Final Grade, while Section 5.2 elucidates the results obtained from the surveys.

### 5.1 Simulator Scores, Final Exam and Final Grade

Table 5 presents the mean and standard deviation of students' results in relation to their final exam, final grade, and their final score in the simulator. The final exam is evaluated on a scale of 1 to 100. The final grade for the course is also assessed on a scale of 1 to 100 and is calculated as a weighted average, taking into consideration various components such as homework, reports, simulator score, and final exam.

**Table 5.** *Mean and Standard Deviation of Final Exam, Final Grade and Simulation Score*

| | *January to May 2021 semester* | | *August to December 2021 semester* | |
|---|---|---|---|---|
| | *Mean* | *St. Dev.* | *Mean* | *St. Dev.* |
| *Final Exam* | 78.43 | 7.39 | 78.43 | 7.39 |
| *Final Grade* | 88.64 | 5.62 | 88.64 | 5.62 |
| *Simulator Score* | 848 327 | 63 123 | 848 327 | 63 123 |

### 5.2 Evaluation Game and Motivation Surveys

Table 6 presents the mean and standard deviation of students' opinions regarding the different features of the simulator, as well as their opinions about the various types of motivation. The survey concerning their opinions about simulation games was administered after their first report, while the survey on motivation was conducted at the end of the course. It is important to note that the surveys utilized a 7-point Likert Scale for evaluation.

**Table 6.** *Mean and Standard Deviation for Evaluation Game and Motivation Survey*

| | *January to May 2021 semester LOST* | | *August to December 2021 semester PRO Game* | |
|---|---|---|---|---|
| *Features of Game* | *Mean* | *St. Dev.* | *Mean* | *St. Dev.* |
| Concentration | 9.63 | 0.96 | 9.23 | 1.17 |
| Goal Clarity | 9.50 | 1.16 | 9.76 | 0.66 |
| Feedback | 9.18 | 1.32 | 8.73 | 1.41 |
| Challenge | 9.52 | 0.84 | 9.02 | 1.03 |
| Autonomy | 9.55 | 1.12 | 9.57 | 0.61 |
| Immersion | 9.36 | 1.11 | 8.82 | 1.23 |
| Social Interaction | 9.24 | 1.23 | 9.01 | 1.32 |
| Knowledge Improvement | 9.76 | 0.62 | 9.33 | 0.53 |
| **GAME EVALUATION** | **9.47** | **1.07** | **9.18** | **1.05** |
| *Motivation* | *Mean* | *St. Dev.* | *Mean* | *St. Dev.* |
| Lack of Motivation | 2.16 | 0.92 | 1.98 | 0.91 |
| Intrinsic Motivation | 6.22 | 0.81 | 6.13 | 0.94 |
| Extrinsic Motivation | 6.31 | 1.05 | 6.16 | 1.11 |

Table 7 presents the results of a correlation study conducted during the January to May semester. The variables included in Table 7 are the Final Exam, Final Grade, Simulator Score, Game Evaluation, Lack of Motivation, Intrinsic Motivation, and Extrinsic Motivation. The coefficients of correlation generally indicate a high degree of correlation among these variables.

**Table 7.** *Correlation Coefficients in January to May Semester*

| | FE | FG | S Sim | G Ev | LM | IM | EM |
|---|---|---|---|---|---|---|---|
| FE | 1.000 | | | | | | |
| FG | 0.283 | 1.000 | | | | | |
| S Sim | 0.712 | -0.034 | 1.000 | | | | |
| G Ev | 0.689 | 0.209 | 0.864 | 1.000 | | | |
| LM | -0.233 | -0.031 | -0.132 | -0.221 | 1.000 | | |
| IM | 0.431 | -0.192 | 0.821 | 0.526 | -0.257 | 1.000 | |
| EM | 0.522 | 0.197 | 0.723 | 0.671 | -0.321 | 0.765 | 1.000 |

Table 8 presents the results of a correlation study conducted during the August to December semester, specifically when students utilized the PRO Game Simulator.

**Table 8.** *Correlation coefficients in August to December Semester*

| | FE | FG | S Sim | G Ev | LM | IM | EM |
|---|---|---|---|---|---|---|---|
| FE | 1.000 | | | | | | |
| FG | 0.179 | 1.000 | | | | | |
| S Sim | 0.623 | -0.121 | 1.000 | | | | |
| G Ev | 0.328 | -0.203 | 0.721 | 1.000 | | | |
| LM | -0.428 | 0.301 | -0.523 | -0.431 | 1.000 | | |
| IM | 0.521 | -0.152 | 0.713 | 0.567 | -0.457 | 1.000 | |
| EM | 0.531 | -0.097 | 0.642 | 0.483 | -0.521 | 0.811 | 1.000 |

## 6. Discussion

The results of this research study highlight the potential of using simulation games to recreate the Concrete Experience (CE) stage of Kolb's Experiential Learning Cycle in the context of logistics education. The use of simulation games as tools for active learning and problem-solving has been previously utilized in other areas of engineering, such as aerodynamics, to generate concepts and promote engagement among students (reference [11]). The CE stage, which aims to capture participants' attention through elements of conflict and motivation to participate in problem-solving [12], is facilitated through the use of simulation games that present situations where students can identify and engage in finding solutions.

The findings suggest that using simulation games for a constructivist approach, under certain conditions, may be more effective in enabling students to experiment with different scenarios compared to using real-world situations. In the initial sessions of the activity, students were encouraged to explore the system, experiment with variables, and understand their relationships without the pressure of obtaining high scores. This approach is consistent with the view presented in reference [12], which argues that simulations in a constructivist educational model allow for "what if" analysis with multiple solutions that may not be feasible in reality. As students gain a better understanding of the system and develop strategies that they can articulate and put into practice, their engagement in the game and their learning become more evident.

The study also acknowledges that the meaningfulness of the CE stage is crucial for student motivation and engagement in the learning process. The researchers encountered challenges in the first stage of the activity related to students' training in using the simulator, particularly in decision-making using LOST. Interestingly, the students' ratings of the simulator and the scores obtained in the simulator were found to be highly correlated, suggesting that a better understanding of the system and improved results in the game led to higher ratings of the simulator. This finding is consistent with reference [30], which argues that emotions and engagement are important factors for students' motivation in game-based learning, particularly when favorable scores are obtained. However, the study also acknowledges that the intensity of this engagement may vary depending on cultural, content, instructor, and previous experience factors, as highlighted in reference [32]. The study also concurs with the notion presented in reference [30] that emotions can act as both motivators and inhibitors of learning.

In terms of student learning outcomes, the study suggests that the use of simulation games as learning tools has a positive impact on student motivation and engagement, but the evidence is not conclusive in terms of improving student learning. We have applied motivation surveys for other groups in previous semesters, as well as a similar final exam. When we compare the motivation of the groups that have used the simulators, we find a significant increase in motivation ($p = 0.031$). However, the results in the final exam only show a small increase, which is not significant. These findings align with the conclusions drawn in references [5] and [35], which suggest that games are effective tools for learning in terms of motivation and observable behavior changes but may not necessarily result in significant improvements in student learning. The study emphasizes the need for further research to determine whether there are statistically significant differences in student learning outcomes using different teaching methodologies.

One of the main advantages of using simulation games in logistics education, as highlighted in the study, is the opportunity for students to make decisions, experiment with different strategies, and observe the consequences of their choices. This feature is considered a strong advantage of simulation games, as not all systems allow for such experimentation. The study also points out that the ability to observe the relationship between decisions and outcomes is more apparent in the PRO Game compared to LOST, as the former has a deterministic scenario where the consequences of decisions are immediately reflected. This enhances students' understanding of the game and the interaction of variables, which is consistent with the views presented in references [3] and [4] regarding the importance of providing immediate feedback, clear goals, and challenges to players that matches their skill level. The efficacy of feedback directly correlates with the depth of the student's comprehension of the educational system, their ability to articulate their learning, and their levels of motivation and engagement.

## 7. Concluding Remarks and Future Works

The analysis of the two cases, namely the LOST simulator and PRO game simulator, revealed several interesting findings. First, simulation games with challenging problems have the potential to recreate a concrete experience, enabling students to immerse themselves in practical scenarios. Second, simulation games facilitate experimentation with different scenarios, allowing students to test their decision-making skills in a risk-free environment. Third, the degree of motivation and engagement of students correlates with the concrete experience gained through simulators. However, while the results obtained from the simulator were correlated with student motivation and engagement, the study was not conclusive in terms of student learning.

These findings highlight the significance of employing strategies that motivate students and support their deepening of learning, thereby facilitating their ability to apply and transfer knowledge to new situations. A key focus of this research is the potential of simulation games in logistics education, as they enable students to comprehend the essential factors involved in decision-making in this field in a faster and more enjoyable manner. Furthermore, the use of simulation games allows for experimentation without any associated risks. Although conclusive evidence demonstrating the superiority of this learning strategy over other methodologies is lacking, substantial evidence suggests that it enhances student motivation, commitment, and strategy adaptation in the context of the game.

It is important to acknowledge certain limitations of this study. Foremost among these is the small sample size in both cases, which restricts the ability to make broad generalizations about student learning and motivation when combining game-based learning and experiential learning. Additionally, sociodemographic factors were not considered in the baseline survey, but their inclusion in future research may yield more reliable findings regarding the specific needs of students.

Finally, the authors suggest that it is necessary to create a better understanding of how the games contribute to learning and motivation. It seems that there is an important correlation between the score obtained in the simulator, the motivation of the student and the evaluation of the game. However, the correlation seems stronger in LOST, but is interesting that evaluation of the game is higher that in PRO Game, even when some students did not reach the minimum required score. Authors consider that the motivation of students and the game evaluation are linked to the learning challenge this represents, and to the learning benefits students perceive they obtain when using the simulation game. On the other hand, the authors consider it important to survey instructors to verify if an increase in the student motivation could influence the learning process, the use of the games, and their learning opinion.

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## Conflicts of interest

The authors have no conflicts of interest to declare.

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