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Engaging Students on a Construction Execution Course by Applying a Gamified Flipped classroom

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Engaging students on a construction execution course by applying a gamified flipped classroom

Abstract

This paper describes a case study that encourages students to prepare themselves in advance and participate actively in class activities on a construction execution course. This involved a game consisting of a group competition-based quiz, performed in four rounds and distributed through the course schedule. The students were asked about the content they had studied previously, and the first group that pushed the buzzer of a physical electronic device made specifically for this course had the right to answer. Other groups corrected the answers, considering the peer learning environment and stimulating all students to participate and show what they had learned. At the end of the course, students answered a questionnaire about their engagement in pre-activities, their satisfaction level, what they learned, and what could be improved. The results show that the engagement of the students, encouraging them to prepare before a class and participate actively in class activities, can be achieved through gamification when there is the definition of game elements, incorporation of feedback, definition of the dynamics, and the establishment of behavioral rules. This research contributes to filling the gap in understanding how flipped classrooms and gamification work together by showing that the engagement provided by designed game elements motivates the students to study before their classes. Consequently, the active participation of the students in class activities is enhanced, and thus, so is the interaction between them, promoting their learning.

1. Introduction

Active learning is becoming increasingly popular in construction education research [1]. However, as identified by Rodriguez-Largacha et. al [2], considerable effort on the part of the instructor does not guarantee that the student will be motivated or engaged to learn. The research of the cited authors, which was carried out on a civil engineering course in Spain, was motivated by the low interest of the students in learning more, low levels of self-learning and curiosity, and a lack of use of the recommended literature. The students appeared to be interested only in passing exams, and "the only motivation that students get -if any- is that the material will be important later in the curriculum or in their careers" [3].

The application of active learning methods is gaining attention and is aimed at motivating students to get involved in the learning process. One such method, known as the flipped classroom, flipped learning, or inverted learning, has been growing in popularity among engineering instructors over the past decade because it appears to be more effective than conventional teaching methods [4]. In this method, the activities carried out inside and outside the classroom are flipped or inverted [5] by combining online resources and activities inside and outside the classroom in a reverse order of content delivery [6]. Thus, the success of the flipped classroom is highly dependent on the students' prior preparation, relying on their capacity to study new material on their own [7].

Mojtahedi et.al [6] applied this method to a course on building services and found that the students felt prepared for their classes when they performed pre-class online quizzes. Although the benefits of flipped learning are recognized in the literature [4], [5],[6],[7],[8], little discussion is available on how to promote or motivate the student to participate in activities outside the classroom [8].

To address this lack of motivation of the students observed in previous studies, DeLozier and Rhodes [8] noted that "flipped classrooms may be an ideal venue for combining multiple methods of active learning". In this regard, gamification, also referred to as game-based learning or serious games, despite some conceptual differences, is another approach that is growing in relevance among engineering instructors [9],[10],[11], mainly because of its potential to engage students in study activities [5],[11].

The flipped classroom and gamification are currently trending in engineering education, but little is known about how these methods work together. Accordingly, the purpose of this paper is to address the engagement of students in activities outside and inside the classroom, when using the flipped classroom in conjunction with gamification to teach the content of a course on construction execution. The main research question can be given as follows: does gamification help engineering students to become engaged in the flipped classroom? Other specific research questions are: (1) Does a gamified flipped classroom help students to be engaged and motivated to study before the classes? (2) Does a gamified flipped classroom facilitate student learning inside the classroom?

This research involved the design of a game with four rounds as a formative component of the final course grade, using an electronic device produced specifically for this course to perform quizzes. The engagement is verified through a questionnaire survey sent to students. The following sections discuss relevant academic information based on background literature, describe the procedures of the study method, and provide details on the results. Lastly, the conclusion section highlights the main contributions of this research and the implications for future research.

2. Background Literature

2.1. Flipped classroom and active learning methods

As mentioned earlier in this paper, the use of the flipped classroom method is currently increasing in engineering education. This approach has been described as follows: "through the use of computer technology and the Internet [...], the information-transmission component of a traditional lecture is moved out of class time and replaced by a range of interactive activities designed to entice active learning" [5]. Thus, the basic content is published online, allowing the students to prepare themselves in advance, freeing up time in the classroom that can be dedicated to other activities, such as those that promote student participation in active and collaborative tasks [12],[13]. This better use of the time in the classroom allows for student-centered learning activities [10], encouraging students to become autonomous learners [14].

In this context, among other studies, Kim et al. [15] identify nine principles to optimize the achievement of student results in flipped classrooms. These include the following: the second principle, which establishes that incentives should be created for students to prepare before classes; the fourth principle, which states that clear connections must be provided between activities outside and inside the classroom; and the eighth principle, which states that rapid feedback on individual or team tasks should be provided.

Nevertheless, the effectiveness of the flipped learning method has been questioned [6],[12]. The research of DeLozier and Rhodes [8] showed that flipped learning needs to be associated with other methods to achieve successful student learning. Thus, in some cases, the use of the flipped classroom shows an increase in student performance [12] that may be related to the

additional time provided in classrooms when adopting active learning tools [8]. Of the tools available, quizzes have more robust benefits and are likely to increase student performance, regardless of how the quizzes are delivered [8],[14].

2.2. Student engagement through gamification

Gamification is related to game-based learning, which "is a type of gameplay with defined learning outcomes" [16]. It includes activities with electronic games, as well as the application of game logic in different contexts, including the educational arena [11]. Among its benefits, gamification promotes learning, motivates action, engages people, and solves problems [17]. These benefits, according to Hegazy et al. [18], allow the "students [to] advance to high cognitive levels by critiquing others, experimenting with different methods, judging their own performance and the practicality of their knowledge".

In this regard, one of the main ways to achieve the benefits of gamification is to work with the emotions of the students [17]. This is because emotions are inseparable from thoughts and should be present during learning [19]. Another main feature of gamification is that it includes incentive systems to motivate students to become involved in a task that would otherwise not be attractive [16]. Also, Burguillo [20] believes that friendly competition among groups of students, considering extra points as a reward, motivates students. Thus, these gamification features are core to motivating the students to learn.

Al-Jibouri et al. [21] found that with the application of a game in a course on construction project management, students acquired skills including cost control and teamwork. It was noted that interactions between players positively influenced the development of social skills [22]. However, Burguillo [20] notes that to obtain better results, the games must be carefully planned to improve interaction and active participation, instead of just providing entertainment.

The literature review on gamification performed by Subhash and Cudney [11] found that the most used game design elements are levels, points, leaderboards, and badges. The use of these elements in education presents benefits to students [23]. Although no definitive set of game design elements or attributes has been established, a useful set was proposed by Alshammari [24], who identified seven top elements of gamification: (1) badges, (2) rewards, (3) points, (4) timer, (5) feedback, (6) levels and (7) leaderboard. After defining the elements, analysis needs to be carried out to "describe the interplay of those game elements" [25], using a framework known as MDA: mechanics (rules), dynamics (behavior), and aesthetics (emotions) [25]. According to these authors, mechanics is related to the functioning components of a game, dynamics to the interactions between the mechanics and the players, and aesthetics to how players feel while playing.

Motivation and engagement are two desired effects of game design. According to Kim et al. [26], motivation is the "desire to be involved with learning activities/tasks". In the context of gamification, engagement refers to the "active participation of the players throughout the game. If a player is engaged in the game, he will be motivated to address the challenges ahead and will not think of dropping out" [27]. Additionally, according to Plass et al. [16], engagement should be based on the interaction between the student and the activity, which has been classified into four main types: (1) cognitive; (2) affective; (3) behavioral; and (4) sociocultural. A more in-depth discussion of these concepts lies outside the scope of this paper. However, the socio-cultural aspect of the engagement implies, according to Vygotsky [28], that playing, especially with a more capable pair, allows students to succeed in activities

beyond their individual capacities. As is known culturally, “people learn through their interactions with those who surround them” [29]. Therefore, the use of games can promote group work, which is considered a skill required of civil engineers [30].

In this respect, Cohen and Lotan [31] perceived that the interaction, especially in group work, is not necessarily verbal and requires more attentive behavior from the student. These same authors defended that learning occurs through interaction with peers, instructors, and real objects. In the report “The vision for civil engineering in 2025” [30], it is defended that skills are developed through on-the-job work experience, focused training, and formal education. Thus, game-based learning is a way to improve teaching success in engineering and construction courses, as it encourages exposure to and interaction with real-world problems, which require multidisciplinary skills [32].

3. Study Method

A case study was carried out to answer the research questions. One of the authors, referred to herein as the instructor, collected the data. Further details on the data collection and analysis, in this case study can be found in the next three sections: Course background, The gamified flipped classroom, and The game: a designed competition-based quiz.

3.1. Course Background

The course called ‘Construction Execution’ is taught in the sixth semester of a six-year civil engineering course at a private university located in São Paulo, SP, Brazil. This university has existed for more than 50 years, attracting middle-class students. They mostly work during the day to be able to pay for their studies and attend evening classes. The course addresses general concepts related to construction product development, construction site layout, earthmoving, shoring, foundations, structures, masonry/partitions, floors and ceilings, waterproofing, internal coating, façades, and roofing. The main learning objective of the course is to ensure that the students can identify the activities related to a construction project and gain knowledge of the various phases involved. In addition, they should be able to distinguish between the characteristics of the different construction methods and techniques available.

The course comprises 16 classes, 100 minutes each, delivered once a week. All of the material, including subject slides, used in the classroom was made available through an online system provided by the university. The instructor gave lectures for the semesters 2018-1 and 2018-2 classes using the traditional classroom method. At that time, an evident weariness of the students at the beginning of the class due to their daytime jobs was identified. This difficulty, added to those resulting from the traditional classroom strategy, motivated the instructor to seek alternatives in order to encourage the students to be attentive. Thus, the instructor made the class material available before classes. However, only a few students studied in advance, and the classes became boring, with the lecturing of content for more than 90% of the time, resulting in the students losing interest.

At the end of 2018, an institute related to this university opened a competition for grants in order to promote innovations in university teaching. Due to the fact that the university had the infrastructure, including both physical and information technology assets, the instructor identified the flipped learning approach as a viable option for the competition. However, flipped classrooms rely on students studying the class material in advance, which did not work with this course. In this context, gamification was identified as a method that could

provide this motivation. With a view to facilitating the implementation of this idea, the instructor was awarded one of the above-mentioned grants after developing a proposal. The proposal was implemented in a class with 59 students in the second semester of 2019. The details of this implementation are described below.

3.2. The gamified flipped classroom

In the flipped learning context, to allow more time for instructors and students to interact in the classroom, prior study by the students is essential. Thus, changes in the course were implemented considering features from the flipped classroom approach [5]. These changes included: a) pre-class activities, watching short videos in addition to studying the class material; b) in-class activities, answering questions about pre-class activities, using quizzes in groups, and administering feedback to students; and c) post-class activities, including student feedback questionnaire. These elements were enabled by the use of online resources, such as Google Forms, to perform the survey, Google Classroom, to upload class materials and exercises and to receive their solutions, and the IT infrastructure of the university to share communications and to post student grades.

3.3. The game: A designed competition-based quiz

Regarding the previously noted reluctance of students to study and their signs of weariness due to daytime jobs, options that offer dynamism were sought. Specifically, the search included options that allow in-class competition, using some physical features to trigger the students' emotions during the activity, mixed with electronic features. Consequently, the game proposed was a competition-based quiz using a physical, electronic device, as shown in Figure 1. Quizzes were selected because they are widely used and recommended for active learning methods [6], [8], [14], [33]. Instructors and students are familiar with quiz structures.

a) Electronic Panel, links to the receptor

b) Signal receptor, links to the panel with the buzzer

c) Buzzer with a cable that connects to the receptor

Figure 1. Components of the electronic device manufactured for this game.

Also, it was necessary to structure and select the game elements that would be used: rewards, points, timer, feedback, levels, and leaderboard. These elements are detailed below.

1. **The competition produced an accumulation of points at each game round.** In this regard, in each class where the game was held, a representative was chosen by the group to answer the questions. All students had to study the available class material previously published by the instructor. Eight groups had to answer eight questions related to the theme of each class, so that each group could answer at least one question. The points earned by each group in all rounds were transformed into a grade for formative assessment. The questions were previously prepared by the instructor, printed on separate papers, folded, and placed in a bag to be randomly selected. The

instructor then randomly chose a student to select a question, and subsequently, the instructor read the question. The degree of difficulty of the question was first informed to generate expectations in the students, increasing the emotion of the moment.

2. **The questions had levels of difficulty.** Each of the 8 questions was allocated a score, according to its degree of difficulty, as follows: Three "Easy" level questions: 1 game point each (e.g. What is a construction site? What are its main phases?); three "Medium" level questions: 2 game points each (e.g. What are the types of deep foundations?); and two "Hard" level questions: 3 game points each (e.g. Explain in detail how the reinforced concrete structure is executed, covering all its production cycle). Thus, the groups could obtain a maximum of 15 game points in each class, accumulating over the five rounds to 75 game points. However, if one group obtained the maximum score, the other groups would obtain zero. To avoid this, the formula to transform the game points into the formative assessment grade included an augmentation factor.

3. **The right to answer by using an electronic device, given one minute to reply**. Each group representative sat individually at a desk in the front of the classroom. Each desk had a custom-made buzzer with the group number on its front. The instructor stood up close to them, and the other students were seated in a circular arrangement, clustered in groups. The representatives sat with their hands in the air, close to their heads, to ensure none of them had an advantage by being closer to the buzzer. Immediately after the instructor read a question, a representative who knew the answer pressed the buzzer. By doing this quickly, the group whose number was displayed on the electronic panel got the right to answer. This group would then have one minute to debate among themselves and for the representative to answer the question.

4. **The students gave feedback after each question, after each round, and at the end of the course**. After the awarded group responded, students from groups who did not get the right to answer had to say whether the answer was right or wrong. In the case of a wrong answer, the group that identified this had to provide the correct answer. This group would then earn the game points. After each correct answer the instructor could give feedback and a wider explanation to the class regarding the answer, when necessary. At the end of the course, the Student Final Questionnaire (SFQ) was sent to the students, using Google Forms with anonymous responses. The SFQ was sent to identify the engagement and the learning of the students as well as the level of satisfaction with the entire course, including 9 questions about the perception of the gamified flipped classes, 5 questions related to the seminars, 4 questions about the content of the course and another 4 questions related to general issues.

5. **Students could see the results of the competition on a leaderboard. At the end, this competition delivered a reward:** In each class the rankings of the groups were calculated and displayed, as well as the accumulated ranking of the rounds played so far. The group that accumulated the highest score at the end of the five games was the winner, earning a t-shirt with a university logo.

4. Results

This section reports the responses to the SFQ questionnaire administered at the end of the course. Although the link to the questionnaires was made available to all students at Google Classroom, in general, low rates of student responses were observed: 13 out of 59 (22%). Nevertheless, this is relatively frequent when surveying student perceptions [34],[35], and it does not affect the reliability of the results [34]. In this case, the lack of time for the students to respond was a contributing factor because the SFQ was sent during the final assessment period of the semester. Thus, the results for students´ perception are restricted to those who responded to the SFQ questionnaire.

Table 1 shows the perception of the students and the satisfaction levels for some aspects of the gamified flipped classroom concerning the overall course. It contains numerical responses to 'yes/no' questions and responses on a Likert scale. Thus, closed questions with the answer 'Yes' had a value of 5, and the value for 'No' was 1. Responses to questions based on a Likert scale from 1 to 5 were allocated values: Terrible = 1, Bad = 2, Good = 3, Very good = 4, and Great = 5. For questions related to agreement, the following values were allocated to the responses: I totally disagree = 1, I disagree = 2, I don't know = 3, I agree = 4 and I totally agree = 5. The percentage of positive perception was calculated considering only the responses with scales of 4 or 5.

The following sections are organized around the two specific research questions stated in the introduction section, in order to answer the main question of this research: does gamification help engineering students to become engaged in the flipped classroom?

Table 1. SFQ answers

Questions about students' perceptions and satisfaction levels	Average ± Standard Deviation	Positive Perception
(1) GAMES		
What was your general perception of the classes with the games?	4.15 ± 0.66	84.62%
Did games make you prepare / study before classes?	4.38 ± *	69.23%
Did games make you research more about the themes of the classes?	3.15 ± *	53.85%
Satisfaction level: Educational material available	3.62 ± 0.62	53.85%
Satisfaction level: Equipment	3.54 ± 0.63	46.15%
Satisfaction level: The way the instructor conducted the class	3.46 ± 0.75	46.15%
Satisfaction level: Evaluation criteria	3.23 ± 0.97	46.15%
Satisfaction level: Class dynamics	3.15 ± 0.86	30.77%
(2) SEMINARS		
What was your general perception of the classes with the seminars?	3.85 ± 0.86	69.23%
Satisfaction level: Your own learning / engagement	3.77 ± 0.89	46.15%
Satisfaction level: The way the instructor conducted the class	3.69 ± 0.72	53.85%
Satisfaction level: Evaluation criteria	3.62 ± 0.92	46.15%
Satisfaction level: Class dynamics	3.15 ± 0.86	23.08%
(3) SUBJECT CONTENT		
Was the course organized to allow the participation of all students?	4.08 ± 0.83	84.62%
Was the course load appropriate?	3.92 ± 0.62	76.92%
Were the objectives clear?	3.85 ± 0.77	76.92%
Was the course content organized and well planned?	3.77 ± 0.8	69.23%

* question with" yes" or "no" answer (discrete variable).

4.1. Does a gamified flipped classroom help students to be engaged and motivated to study before the classes?

As recommended by Kim et al. [15], Abeysekera and Dawson [5], Mojtahedi et al. [6], and Ling and Gan [12] inverting in-class and out-of-class work, adding post-class activities and adaptations to the class materials are necessary when flipping a traditional classroom. However, these actions alone did not motivate the students to study the class materials prior to the class. Thus, gamification was introduced in this course.

Table 1 shows that the higher average (4.38) refers to the question of whether the games prompted students to prepare/study before the classes. Additionally, the positive perception of this question is 69.23%, and 53.85% of the respondents agreed that the games made them research more about the themes of the classes. These numbers show that the gamified flipped classroom helps students to be engaged and motivated to study before the classes.

It is also clear from the results in Table 1 that the educational material made available in the games was the aspect students liked the most, with an average of 3.62. This material was adapted with the insertion of short construction videos produced by construction companies, suppliers, or even other instructors, which were posted on the internet. This average shows that this feature is important to engage students to study prior to classes.

4.2. Does a gamified flipped classroom facilitate student learning inside the classroom?

Using a physical electronic device in the game stimulates emotions in the students, and according to Vygotsky [19], emotions should be considered for learning to occur. Also, Barbosa and Moura [36] stated that students need to feel what they are doing in order to retain the knowledge. Table 1 shows that the equipment was the second aspect that students liked the most in the games, with an average of 3.54.

Cohen and Lotan [31] defended that interaction promotes learning. As seen in Table 1, 84.62% of the respondents agreed that the course was organized to allow the participation of all students, fostering interaction and enabling peer learning. Therefore, the design of the game was responsible for promoting a high level of interaction among the students and peer learning inside the classroom.

However, there was also some dissatisfaction among the students, as shown in Table 1, as class dynamics is the aspect that students liked least, with an average of 3.15. Additionally, low rates were found to the questions: What are your dissatisfactions, and what do we need to improve? Five students (38%) stated that there was a lack of greater collaboration or organization by the students themselves. It happened because some students cheated and used their smartphones to check the answers. As the competition relied on a physical device, there wasn't a need to use smartphones, and so it was forbidden in the game classes. Three students (23%) responded that there was a lack of rules. Even though the instructor created the rule of forbidding the use of smartphones in the second round, the bad classroom environment led the instructor to cancel the third round, so the competition was run with four rounds. The other answers mentioned the evaluation criteria (8%) and that there was no need to improve anything (8%).

Furthermore, answers to the question: Did the changes made during the semester improve your learning? Why? Eleven students (85%) agreed that the changes made during the semester improved their learning. With regard to the answers related to the question 'why?',

the answers included ‘I tried harder’ and ‘students started to respect more’ the dynamics of the game. Therefore, these changes helped students engage with their learning process.

Evidence for student learning can be seen in the answers to the question, which was not mandatory: Which aspects of the gamified flipped classroom were most useful or valuable? This received seven answers, and two of them (28%) stated that the combination of methods, gamification, and the flipped classroom made students more interested in learning. Also, 76.92% of the respondents had a positive perception of the clarity of the objectives and the appropriate load of the course. With regard to the course content, organization, and planning, the positive perception was 69.23%. These high percentages indicated that the students perceived the contributions of the game to the learning objectives of the course, and the course organization and planning were well received, considering peer learning.

In addition, the percentage of positive perception for the game classes was 84.62%, and for the seminar classes was 69.23%. However, considering the way in which the instructor conducted both types of classes, the positive perception for the seminars was 53.85%, and for the games was 46.15%. Considering the class dynamics, the positive perception for the games was 30.77%, and for seminars, 23.08%. These numbers show that, despite the conduction of the instructor, mainly because of the troubled game environment, the students generally preferred game classes over seminar classes.

Moreover, 46.15% of the students positively perceived the evaluation criteria for both games and seminars. However, the average for the seminar evaluation criteria (3.62) was slightly higher than the game evaluation criteria (3.23). This shows that the students perceived that the grades of the game activity assessment were defined with less appropriate evaluation criteria.

Likewise, the aspect that the students liked the most about the seminar classes was their own learning/engagement (3.77). In gamified flipped classroom classes, the students had to study every week to participate in the games, creating the habit of studying. The students created the seminars and were now used to studying, some even researching beyond the materials made available. This shows that the gamified flipped classroom also promoted more engagement and a better quality of learning in the seminar classes.

5. Conclusions

This paper describes a gamified flipped classroom aimed at using gamification to help engineering students engage in the flipped classroom on a construction execution course. A game consisting of a competition-based quiz was performed in four rounds, distributed throughout the course schedule. The first group that pushed the button of a physical electronic device manufactured especially for the game had the right to answer. This case study gathered data from SFQ responses. Its main finding is that, through a gamified competition, the students were engaged and motivated to study before the class and actively participate in class activities.

This research contributes to filling the gap in understanding how the flipped classroom and gamification work together by showing that the engagement provided by designed game elements motivates the students to study before their classes. Consequently, the participation of the students in class activities is enhanced, and thus, so is the interaction between them, promoting peer learning. The results are limited to this unique implementation, and this research should be replicated to be validated. Moreover, although the results are presented

quantitatively, this research was carried out to figure out the qualitative impact of the gamified flipped classroom, which will be presented in a future paper. Additionally, given the findings of this study, research could be done to identify specific causes of the engagement provided by the gamified flipped classroom.

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Data Availability Statement

Data gathered, and analysis results are available upon request from the corresponding author.

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