MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2022, 18(2), em2082
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/11707

Didactic Strategy Mediated by Games in the Teaching of Mathematics in First-Year Engineering Students

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Received 13 June 2021 ▪ Accepted 23 January 2022

Abstract

The development of mathematical skills for future engineers is essential. Game-based learning (GBL) and gamification have been widely used in elementary education, but less applied in higher education. The objective of this article was to evaluate the effect of didactic strategies mediated by games in the teaching of mathematics in first-year engineering students. A qualitative study was carried out. Five (5) teaching units were designed. Seven (7) focus groups were developed with 81 participants from the differential calculus course. The keyword in context–KWIC technique was used for the focus group analysis. The categories attention, relevance, confidence, and satisfaction (Keller's motivational model) were evaluated. An important contribution of the pedagogical strategy to student motivation, teamwork, commitment, and argumentation was verified. In conclusion, game-based learning makes it possible to strengthen the motivation of students in the educational processes of mathematics in engineering.

Keywords: game-based learning, gamification, learning strategies, motivation, math, engineering education

INTRODUCTION

Gamification has become a very popular and prominent strategy in the educational field today (Aldemir et al., 2018; Nah et al., 2014; Shemran et al., 2017). Many implementations have been developed in various areas of knowledge (Dempsey & Burke Johnson, 1998; Hamari et al., 2016; Kiili, 2005).

Several definitions are found in the academic literature on the concept of gamification. One of these definitions indicates that it consists of the use of game design elements in non-game activities (Deterding et al., 2011). Burke (2016) defines gamification as the use of game mechanics to encourage commitment and motivation to achieve their results. This definition largely coincides with that proposed by (Kapp, 2012). Gamification has created great interest in the educational field. Research on pedagogical elements using gamification has been widely used (Zainuddin et al., 2020). In gamification there are concepts such as game (broad vision of play), game elements (narrative, feedback, levels, cooperation, collaboration, and among others), design (interfaces, patterns, mechanics, dynamics, and models), and cognitive factors (Bjork & Holopainen, 2004; Crumlish & Malone, 2009; Deterding et al., 2011).

Another important topic is game-based learning (GBL). GBL refers to educational environments that implement games for the acquisition of skills, competences, and knowledge (Qian & Clark, 2016). These games can be used in training processes in multiple sectors, such as health (Arruzza & Chau, 2021; Sandrone & Carlson, 2021), manufacturing (Bilge & Severengiz, 2019; Kaczmarek, 2019), agriculture (Gómez-Prada et al., 2020; Kovács et al., 2021), and among others. GBL is a learning methodology that encourages effective learning, stimulates thought processes, allows the capture of students' attention, and increases problem solving skills (De-Marcos et al., 2016; Sousa & Rocha, 2019).

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Contribution to the literature

- This work contributes to didactic strategies based on games, which allows improving the motivation of mathematics students (particularly differential calculus) in the first year of engineering. This will promote the academic achievement of students.
- The proposal reviews the ability of games to foster student motivation within the framework of John Keller's ARCS model. They are obtained, through a qualitative mechanism, with an understanding of the dynamics in the categories Attention, Relevance, Confidence, and Satisfaction.
- The teaching units designed from multiple digital tools (games) and the recommendations for their implementation and improvement are presented.

The use of games to improve educational processes has been widely developed in the literature (Connolly et al., 2012; Hainey et al., 2016; Zabala-Vargas et al., 2020; Zainuddin et al., 2020). The categories or variables of the game that are considered more broadly are: primary purpose of the game (original intention of the game), digital or non-digital game, game genre (action games, puzzles, role-playing, other), platform (pc, video game console, and mobile phone), and game outcomes (learning and behavioral outcomes, knowledge acquisition/content understanding, perceptual and cognitive skills, motor skills, and behavior change) (Hainey et al., 2016).

The research of Partovi and Razavi (2019) relates a study where the motivation of the students is strengthened using games with an educational application. The commitment and dedication of students towards the academic process when using games is also highlighted in (Andrew et al., 2019; Hamari et al., 2016). It is also important to consider that there are researches that show less commitment of students in educational processes or no increase in motivation when using games (Hanus & Fox, 2015; Zimmerling et al., 2019).

Additionally, the concept of motivation is fundamental for the present work. Motivation is defined as what people want to do, what they decide to do, and what they commit to doing (Keller, 2010). Another definition of motivation is the impulse that human beings have to satisfy their needs in different dimensions (Maslow, 1943).

There are different frames of reference for motivation in learning. Maslow's hierarchy of needs is centered on a hierarchy of factors that motivate individuals, which declares five categories: physiological, safety, love/belonging, esteem, and self-actualization (Maslow, 1943). Alderfer's ERF Theory that groups in the categories (existence, relatedness, and growth), the needs proposed by Maslow (Alderfer, 1969), McClelland's Human Motivation Theory that describes three important motivations for the individual: the need for achievement, affiliation or power (McClelland et al., 1953). Finally, for instructional design based on motivation, Jhon Keller's ARCS motivation model (Keller, 2010) has been widely used in the literature.

The ARCS model of Keller (2010), which is one of the most widely mentioned models of motivation in education and which has been suggested should become the standard by which a game increases learning motivation (Di Serio et al., 2013; Galbis Córdova et al., 2017; Keller, 2010).

The ARCS model of Keller (2010) establishes as dimensions' attention (stimulate and maintain the student's curiosity), relevance (convince the student of the importance of the training process), confidence (belief that success can be achieved in the academic process), and satisfaction (the motivation to keep learning). There is also evidence of the use of the ARCS model with gamification and GBL (Cheng & Su, 2012; Dempsey & Burke Johnson, 1998; Hamizul & Rahimi, 2015; Hao & Lee, 2019; Klein, 1992; Su & Cheng, 2015; Wu, 2018).

Multiple investigations show that game-based learning and gamification increase motivation and academic performance (Chen & Law, 2016; Galbis Córdova et al., 2017; Hämäläinen et al., 2006; Ke & Hsu, 2015; Kiili, 2005; Plass et al., 2015).

In this paper, the interest is focused on first-year engineering students from the Universidad Santo Tomás (Bucaramanga-Colombia) where there was a considerable dropout from the engineering programs (>40%). It was evidenced that there are two important factors for this dropout: low levels of both student motivations in the learning processes and academic performance, mainly in first-year mathematics courses (Castaño et al., 2006; SPADIES, 2019).

This work strengthens the investigations of the UNITEL, ESPIRAL, and GICIBAYA research groups of the Santo Tomas University (Zabala-Vargas et al., 2020, 2021, 2022) to which the authors of this article belong.

Specific experiences of the use of gamification or game-based learning in engineering learning are presented in (Alami & Dalpiaz, 2017; Alhammad & Moreno, 2018; Hakak et al., 2019; Priyaadharshini et al., 2020; Song et al., 2017). There is also a relationship between the use of Keller's ARCS model and the development of STEM competencies in engineering courses (Alekhya & Prabhu Kishore, 2018; Hsia et al., 2021; Karampa & Paraskeva, 2018; Laurens Arredondo & Valdés Riquelme, 2021). These works highlight positive effects on student engagement, academic performance, and motivation, among others.

In this sense, the research question was: Is there a relationship between the use of a gamification/GBL-based didactic strategy and student motivation? Finally, the purpose of this research is to develop a didactic strategy, mediated by games, for the teaching of mathematics in first-year engineering students, which was validated in the framework of Keller's ARCS model.

METHODOLOGY

The selected paradigm is qualitative. A categorical analysis was performed based on the ARCS model (Keller, 2010) to measure the main output variable: the student's motivation. The focus group was the tool used. No control group was used in the design.

Participants

The sample consisted of 81 male and/or female first-year engineering students from the Santo Tomas University. The age of the population was between 17 and 22. All students belonged to the differential calculus course 2019-2020. This course was selected for having the highest failure rate of first-year engineering students. For the 2019-2020 academic year, the total number of engineering students at the Santo Tomás University was 81, the same ones who participated in this research. The assignment of the groups was not random.

Procedure

The first step was the design of the didactic strategy. Five activities were developed:

1. Space Gem–Part I (exam),
2. Mind Gem–Part I (debate),
3. Space Gem–Part II (solving basic math problems),
4. Mind Gem–Part II (collaborative work), and
5. Reality Gem (solve advanced math problems).

The main tool used was Classcraft (a web platform oriented to role-playing games with specific challenges). Other tools used were: Kahoot, Socrative, and Wolfram Mathematica. These were selected based on the experiences of the authors of this work (Zabala-Vargas et al., 2021), and complement the proposed didactic units. The storyline focused on a superhero adventure, making adaptations to the educational environment. This theme was selected because of the students' interest in fantasy stories.

The second step was the adaptation of an interview protocol for the focus group. This is an adaptation of the one proposed in the Keller ARCS model (Keller, 2010).

The didactic strategy required the training of teachers in didactic tools, as well as in gamification strategies and game-based learning (GBL). The third step was to train the teachers of the differential calculus course. The topics covered were gamification, GBL, game elements, avatars, motivation, implementation trajectories, technological tools, and repositories of digital and non-digital games. The above was done so that the teachers can develop the didactic strategy with the target population. Ten teachers participated in the training process. This activity was carried out in 3 sessions with a total duration of 12 hours.

The fourth step consisted of training students in the use of the technological tools required for the development of teaching strategies. Before the training, the research group socialized the scope of the research with the target population. An informed consent was delivered and signed by each participant. This made it possible to consolidate the research sample. The training took place during class hours in the classrooms of the university campus. The research had the approval of the university authorities for the development of all the proposed activities.

The didactic strategy was implemented (fifth step). The five activities developed in step one was executed in two months. Activities on the university campus were combined with autonomous work workshops (extra-class).

The sixth step was the application of the interview protocol to the focus group after the development of the previous steps. This tool was the one created in step 2. The number of members per focus group should not exceed 12 (Baumgartner et al., 2005). Seven focus groups were formed: 4 with 12 participants and 3 with 11 participants. A single session was held for each focus group of approximately 1 hour each. Each focus group had a moderator and an assistant (support). The analysis was carried out using the categories of the ARCS model: Attention, relevance, confidence, and satisfaction (Keller, 2010; Li & Keller, 2018). Atlas.ti was used to analyze the information.

The last step was a qualitative analysis of the data associated with the focus group, as proposed in (Baumgartner et al., 2005; Krueger & Casey, 2014; Onwuegbuzie et al., 2011). Deductive data analysis was used. The initial categories were attention, confidence, relevance, satisfaction and motivation. To ensure the validity of the qualitative analysis and to avoid rater bias, a second rater participated in the process. Inter-rater reliability was evaluated by comparing both rater's ratings on all categories; a value (Cohen's Kappa coefficient) of 0.79 was found. The differences were resolved through dialogue and subsequent agreement between the appraisers. Discussion and conclusions were made.

INSTRUMENTS AND MATERIALS

This section has two parts: description of the didactic strategy and focus group as a strategy for qualitative analysis.

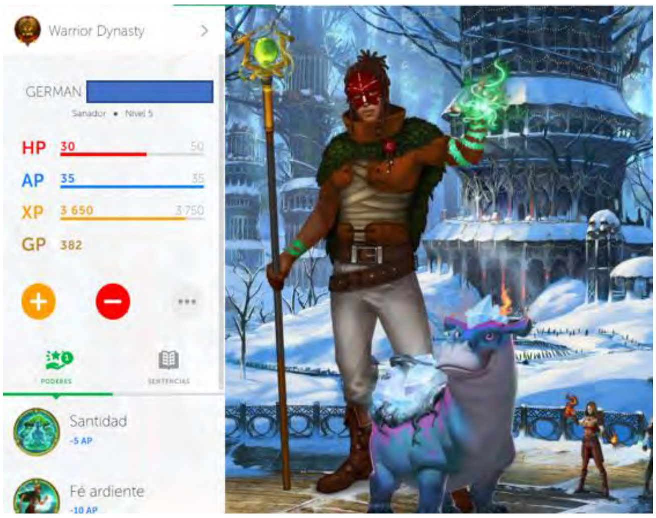

Figure 1. Example of Avatar with abilities & characteristics

Table 1. Negative behavior health points discount list

Health points discount	Negative behaviors
-15 HP	Being rude to classmate
-5 HP	Handing in work late
-10 HP	Being off task
-5 HP	Use mobile phone when it is not allowed
-10 HP	Being late to class
-20 HP	Plagiarize an activity

Description of the Didactic Strategy

The didactic strategy is composed of five (5) activities. The main technological tool was Classcraft (gaming environment), Kahoot (synchronous tests), Socrative (asynchronous tests) and Wolfram Mathematica (simulations and graphing). Classcraft tool allows the generation of a map wherein the different points represent specific learning activities of the didactic strategy.

The students selected their own avatar and participated in the activities. An example of an avatar is presented in Figure 1. Avatars have the following characteristics:

1. Health points (HP): It is understood as the character's energy and must be greater than 0 to be able to play. It is what is needed to remain successful and active in the game. The way to lose these points is for the student to display behaviors that are not desirable in class (negative behaviors). Table 1 shows the negative behaviors and the corresponding discount on health points. The course teacher performs this assignment daily.
2. Action points (AP): What students spend to use powers in the game. Powers help the educational process, can save teammates, avoid exams, allow turning in activities late, among others. These points are recovered automatically (4 AP each day) and can also be recovered by the wizard avatar. There is no teacher intervention.
3. Experience point (XP): The main way to earn XP is by completing the didactic units. Each didactic unit had a maximum score of 1,000. These points were used to generate a partial grade for the differential calculus course (30%). This score was obtained by dividing XP/1,000 (scale used 0.0 to 5.0). XP allows the avatar to level up in the game. An additional way to earn XP is by showing good behavior. Table 2 presents the additional points that can be earned by the student based on their behavior. Teacher performs this assignment.
4. Gold pieces (GP): Students earn gold pieces which allow them to upgrade their avatars (clothing, pets, and accessories). GPs complement the game experience to make it more fun. 1,000 GP were assigned for each activity completed (1. Space Gem–Part I, 2. Mind Gem–Part I, 3. Space Gem–Part, 4. Mind Gem–Part II, and 5. Reality Gem). Also, for each of the behaviors shown in Table 2, 50 GP will be added. The teacher assigns these points.

Table 2. List of additional experience points for positive behaviors

Increase in experience points	Positive behaviors
+125 XP	Completing online activities
+100 XP	Helping another student with their work
+100 XP	Being respectful to others
+100 XP	Being positive and hard-working
+50 XP	Answering a question correctly in class
+75 XP	Being the first to complete an activity

The didactic strategy, as already mentioned, has 5 learning activities. These activities are presented in Table 3 and are available in full at https://bit.ly/3IcOax1.

Each of the learning activities was registered in the instructional design scheme called Gamification Canvas, presented in (Instituto Tecnológico y de Estudios Superiores de Monterrey [Monterrey Institute of Technology and Higher Studies], 2015). This format has nine fields: objective, player profile, expected behaviors, components, dynamics, mechanics, management, potential risks, and aesthetics.

The main elements of the GBL considered were: rules, competitiveness, collaboration, visible status, immediate feedback, narrative, multiple options, possibility of failure, and others (Observatorio de Innovación Educativa del Tecnológico de Monterrey [Observatory of Educational Innovation of the Technological of Monterrey], 2018).

Table 3. Didactic units implemented in the educational proposal

Didactic unit	Description	ABET student outcomes	Course specific learning outcomes	Support technology tool
Space gem–Part I (exam)	Activity consisted of an exam with 15 differential calculus questions. Question type was multiple choice with a single answer. Graphs, videos, & equations were used to support questions. Test ran asynchronously. Approximate duration of test was 60 minutes. Students could use personal computer or mobile device to participate. Objective of this activity was to evaluate previous knowledge.	a-) An ability to apply knowledge of mathematics, science, and engineering.	I-Solve problem situations that require application of polynomial functions. II-Use methods analytics & graphics for calculation of limits & continuity of functions. III-Use derivative to get slope of tangent line of any type of curve in Cartesian plane.	Socrative (online tool to create questionnaires/ exams)
Mind gem–Part I (debate)	This activity was a debate among students. Topic was concept of limits & its relationship with its application in real contexts. Each student was required to make a minimum of three entries to Classcraft discussion module. Activity had an estimated duration of 90 minutes distributed over three days. Objective was to generate discussion on a central theme of differential calculus course.	b-) An ability to design & conduct experiments, as well as to analyze & interpret data. d-) An ability to function on multidisciplinary teams. g-) An ability to communicate effectively.	II-Use methods analytics & graphics for calculation of limits & continuity of functions. III-Demonstrates communication skills in development of collaborative activities.	Classcraft discussion module
Space gem–Part II (solving basic math problems)	Activity was a class workshop. Students had to solve problems about limits & derivatives. Analysis of equations & construction of graphs uses computational software support. Problem-based learning strategy was used. Activity had an estimated duration of 120 minutes. Goal was problem solving in context.	a-) An ability to apply knowledge of mathematics, science, & engineering. e-) An ability to identify, formulate, & solve engineering problems.	II-Use methods analytics & graphics for calculation of limits & continuity of functions. III-Use derivative to get slope of tangent line of any type of curve in Cartesian plane. IV- Solve limit & derivative problems using simulation tools.	Wolfram Mathematica (programming & simulation language with applications in mathematics, engineering, & science).
Mind gem–Part II (collaborative work)	Activity consisted of a high difficulty mathematical question. First, students seek to answer this question individually. A discussion was generated among all without giving correct answer. Then a group work was carried out to arrive at correct answer. This strategy was based on peer instruction proposal (Mazur, 1997). Applications in financial & economic area were used. Activity is synchronous. Teacher provided support as a mediator for solution of question. Duration of session was 120 minutes & objective was team problem solving.	a-) An ability to apply knowledge of mathematics, science, & engineering. d-) An ability to function on multidisciplinary teams. e-) An ability to identify, formulate, & solve engineering problems. g-) An ability to communicate effectively.	I-Solve problem situations that require application of polynomial functions. II-Use methods analytics & graphics for calculation of limits & continuity of functions. III-Use derivative to get slope of tangent line of any type of curve in Cartesian plane.	Kahoot (platform to create evaluation questionnaires/ exams).
Reality gem (solve advanced math problems)	Activity consisted of solving a problem (determining area of an irregular figure) & presenting results in a video of maximum 3 minutes where student argued proposed solution. Activity is asynchronous & has a duration of 120 minutes. Objective of this activity was to present solutions to mathematical problems before other students.	a-) An ability to apply knowledge of mathematics, science, & engineering. b-) An ability to design & conduct experiments, as well as to analyze & interpret data. e-) An ability to identify, formulate, & solve engineering problems.	II-Uses methods analytics & graphics for calculation of limits & continuity of functions. III-Use derivative to get slope of tangent line of any type of curve in Cartesian plane. IV-Solve limit & derivative problems using simulation tools.	Wolfram Mathematica (simulation & calculations) & Camtasia (video creation).

Table 4. Focus group questions by category

ID	Category	Question
A_1	Attention	What aspects kept you motivated and attentive to the activity?
R_1	Relevance	Do you think this will help you to perform in this area or in the development of your career? Why?
C_1	Confidence	Did you feel that you could carry out the exercise or was there any doubt at some point? When did you have it? What was this doubt?
S_1	Satisfaction	Were you satisfied with the way you did the exercise? Was there something you did not feel comfortable with?
CS_1	Cross-sectional	How did you feel during the activity?
CS_2	Cross-sectional	What were the positive aspects and which ones to improve in the activity?
CS_3	Cross-sectional	From 1 (little value) to 5 (great value), what value would you give to learning experience carried out?

The Focus Groups

For the collection of data, the focus group technique was used. One question was used for each category of the ARCS model and three cross-sectional questions. The reference framework for the design of the interview protocol is the proposal presented in (Keller, 2010).

The focus group technique was selected because it creates less concern for participants and fosters a better environment for brainstorming. (Krueger & Casey, 2014). Keyword in context–KWIC Glaser (1992) were used. The source of data analysis was the full-text transcription of what each participant did and the video recording of each session. An analysis of emerging issues was carried out, as well as dissidents (members who disagree with the group in general) were considered. Table 4 shows the questions used, as well as the initial categories proposed for the focus group (associated with the ARCS model). The questions in the cross-sectional category seek to generate other emerging categories of interest for the study. Finally, the focus group technique complements the quantitative analysis performed previously with the Synthesized Instructional Materials Motivation Survey (SIMMS) proposed in Zabala-Vargas et al. (2021), adapted from the categories of Keller's ARCS model (Keller, 2010).

RESULTS AND ANALYSIS

Table 5 presents examples of the responses of the participants in the focus groups. These are presented according to the nomenclature in Table 4. The categories that emerge from the analysis are presented in Table 6. In addition to the original categories (motivation, attention, confidence, relevance, and satisfaction), another nine (9) categories were found that were coded. Figure 2 shows the category map that results from the focus group.

Table 5. Most frequent answers for each question of the focus group

Question	Examples of focus group responses
A_1	*Being the first to answer correctly was very motivating.* *Competition is a very motivating factor since it allows us to measure our results.* *It is very positive to know if the answer is correct or incorrect quickly.* *Work under pressure motivated the development of the activity.* *It was very useful to apply the development of the exercises to topics of interest, such as engineering and economics.* *The exercises were interesting, and the implementation correct. It is observed that we must apply.* *Though he did not remember complete procedure to solve an exercise, collaborative work allowed achieving an adequate result.* *Changing the learning environment using the GBL was a lot of fun.* *Discussing responses among peers is valuable. Having teacher's experience in the subject motivates us to continue learning.*
R_1	*I think so since it is a very applied topic. Other times I had studied it was monotonous & boring, whereas now I very enjoyed it.* *The application of simulations and computer calculations are very valuable to my profession.* *The practical sessions carried out are used for the development of subjects for the rest of the degree.* *When we perform in our work, in many aspects if we are going to need this pre-knowledge.* *Yes, because we are advancing more and more every day and technology should not be left behind, new things must be implemented to attract attention.* *The integration between career topics, differential calculus and technological tools is very interesting.* *Yes. I feel that it is useful to me both in my career and in my professional life.* *Statistics showed that group work showed better results. So, there is an important point.*
C_1	*Some exercises were complicated because I did not master the subject, but then I felt confident.* *The application of derivatives seems very interesting to me, and I was confident that I would be able to develop the exercises successfully.* *I was not clear about the procedure to carry out some of the proposed challenges, however the support of the teacher and my classmates was important to achieve it.* *At the beginning of the exercises I was a little confused and was afraid of not being able to achieve the goal. After analyzing and deepening the subject, I achieved my goals.* *In some exercises I felt insecure for the time necessary to achieve it, however the dialogue with the teacher and the proposed methodology allowed me to fully develop the activities.*

Table 5 (Continued).

Question	Examples of focus group responses
S_1	*The time dedicated to the activity was sufficient, however I think that more extra-class training activities can be carried out.* *Getting out of traditional daily class routine made me feel great. I managed to increase my knowledge & have fun at the same time.* *I felt that the learning process was more active and participatory.* *In general, I felt very good.* *The proposed problems may be more complex or increase in difficulty with greater intensity.* *The quality of the graphs can be improved to facilitate the analysis requested in the questions.*
CS_1	*I felt comfortable with the activity and the subject. The work with my colleagues was very motivating.* *Answering questions and challenges with time limits is very interesting. I consider that the adrenaline, in my case, increased.* *I felt very good, although I suggest that the questions not be multiple-choice with a single answer since I consider it monotonous.* *This type of activity changes the monotony of the classes, especially in the early hours of the day.* *It is an interesting mix between learning and fun.* *Deepening the subject in a fun way, I really liked it.
CS_2	*Positive aspects:* *Excellent strategy to expand knowledge about calculus and apply it in real exercises.* *The activities are innovative and fun.* *These types of strategies are helpful in preparing for state knowledge tests.* *It is easier to appropriate knowledge with the proper use of technologies.* *The dynamics of the activity is very good and allows reinforcing the learning of mathematics.* *Aspects to improve:* *The time to answer the questions in many cases was sufficient but using the cell phone is sometimes a distraction.* *I do not like that there are new guidelines or rules in the development of synchronous activities.* *The activities carried out are specific and are not reflected in the entire curriculum of the degree.* *Single-answer multiple-choice questions are tedious and reduce the possibility of discussion.
CS_3	*The average response in the students' evaluation was: 4.4 / 5.0.*

Table 6. Relationship of frequency of appearance of the categories resulting from the focus group

Name	Grounded	Density
Activity difficulty	20	1
Attention	30	3
Competition	10	1
Competitiveness	10	2
Confidence	45	2
Emotion	10	1
Extra-class work	5	1
Mechanics of activity	60	3
Novelty	20	1
Relevance	55	2
Satisfaction	40	3
Team work	45	1
Time	10	1

Attention Category

According to the results obtained from the focus group, both competitiveness and obtaining a high evaluation, are very motivating factors for the student. The novelty factor is another important element to promote attention. The students emphasize that the activity reduced the monotony of the classes. The use of games as an educational strategy is highlighted as very positive. The participants highlighted the importance of interaction with teachers and the preparation of teaching units.

The satisfaction of carrying out the educational process correctly and correcting mistakes are important aspects as well. The use of everyday or quite

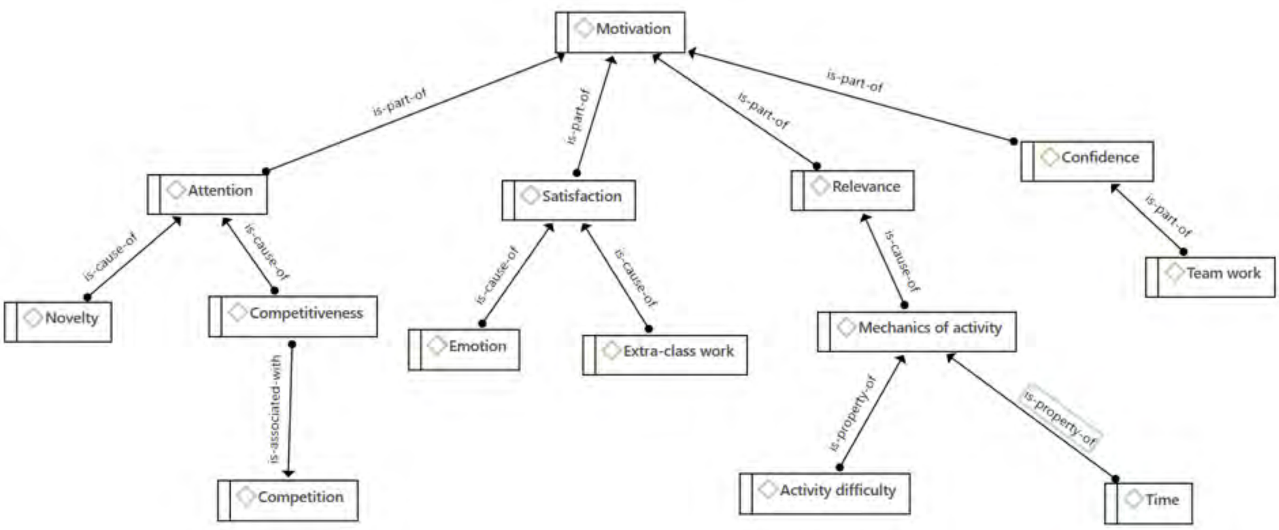

Figure 2. Map of categories resulting from the focus group

contextualized aspects in the activities is another factor that increases the attention of the students. This contrasts with the use of a fantastic narrative (superheroes) with exercises that are easily adapted and understood to the context of the student. Collaborative work in some didactic units is also highlighted by students as a strategy that encourages attention to the educational process. The didactic strategy motivated the students to have a greater commitment to their learning process. The activities acting as triggers of curiosity to generate more inquiry was an aspect that is also highlighted.

Relevance Category

All the students made positive references to the contribution of these recreational activities in their training process. Students recognize the application of the knowledge developed in their professional life. The articulation of the topics with technology and teamwork were also relevant aspects for the students in this category since they provide the students with more comprehensive training.

The difficulty in the activities was highlighted. In this sense, the students emphasize that in the development of the activity this generated frustration, which was attenuated with the fulfillment of the proposed challenges. Time (counter for the development of the activity) emerged as a challenging characteristic. This was a factor of concern for several students. The use of computer equipment, mobile phones, and games is recognized by students as an adaptation of the educational process to their tastes and context. The creation of an avatar that represents the participant in the game is highlighted as a very motivating aspect. The ability to improve the character with new attachments and characteristics is highlighted by most of the participants as valid. Several participants indicated that as an option to improve, the avatar could be a character with greater animation and interactivity.

Confidence Category

Many participants literally indicated that from the beginning they had confidence in the success of the development of the activity because the strategy was presented clearly and with a defined context. These agreements were observed in both verbal statements and non-verbal participation.

Some participants indicated that at the beginning of the activity they were afraid or worried due to the complexity of the mathematical exercise, which decreased with the progress of the activity. Time and not remembering the issues were aspects that made them feel insecure, but group work helped them regain confidence. The teachers' explanation made it possible to reduce anxiety.

There was a great consensus that activities with gamification are more motivating than traditional ones. Setting up the pedagogical proposal with specific activities that were being achieved, step by step, was highlighted by the participants as a positive aspect.

Teamwork was a deciding factor for the participants, building trust (confidence) in an important way. Non-verbal language during the group activities of some participants shows that they are self-conscious or repressed from giving their opinion openly.

Some participants emphasize that their previous experience in video games made them think that the exercise would be very simple. The diversity in the training actions and the way of tackling complex topics made the process interesting and motivating. Collaborative work was a very important factor in generating cohesion in the students and motivation when developing the activities.

Satisfaction Category

The main elements highlighted in this category were associated with the recreational and technological resources used. All the participants highlighted being satisfied with the educational process. They have highlighted that the emotion produced by the game produces high satisfaction. Some students indicated that they found in the didactic strategy new ways of learning and developing their skills.

Several participants indicated that the motivation associated with additional score points was attractive, however it does not define interest in the activity. They consider that the use of the game generates, by itself, a high degree of motivation. Teachers who participated in the intervention indicated that students demonstrate better levels of argumentation in solving mathematical problems. The quick feedback and the quality of the multimedia resources used were highlighted by the participants.

Finally, extra-class work is a factor that students recommend improving the training process. Participants recommend applying the games for homework as well.

Emerging Categories

The mechanics of activity emerge as a very important category. The planning of these in the activities and the way to execute it is an important factor for the participants. The use of multiple-choice questions is not very well received, and they suggest conducting exercises with open questions. Time (another category) emerges as a concern and a source of stress for several participants. The difficulty of the activities was another category that emerged from the focus group. Several participants highlighted their concern about the proposed mathematical exercises and the difficulty of solving them. Pre-knowledge are important aspects to consider when designing activities.

Teamwork and competitiveness are aspects that the participants highlight as positive. The possibility of solving doubts as a team fostered confidence and motivation.

Another category is the emotion that the game produces in the classroom, which stimulated attention and confidence. This category appears connected with the novelty of having games as pedagogical strategies, which was also cited as a positive element.

Finally, several participants highlight extra class work as a strategy that can also be gamified. This would give continuity to the pedagogical strategy throughout the course.

DISCUSSION

The results of the applied qualitative instrument (interview protocol) show that the different categories of the ARCS model (Keller, 2010) are positively promoted by the educational intervention that uses games and IT tools. This allows inferring that motivation increases with the use of GBL and gamification. The foregoing is in accordance with what is presented in (Aslan & Zhu, 2018; Barata et al., 2013; Li & Keller, 2018).

The relationship that exists between the different dimensions of the ARCS model and collaborative work complements what is stated in (Zabala-Vargas et al., 2021). The qualitative aspects exposed in the present work allow strengthening the previously exposed results; mainly limiting the improvement options for a future instructional design.

The pedagogical proposal made allows exploring motivational, cognitive, and affective aspects, which makes this a comprehensive educational process. These aspects are fundamental in the incorporation of games in education, coinciding with (Plass et al., 2015). The attention and commitment of the students are increased, and this facilitates the learning process. This last aspect coincides with what was stated by the investigation of (Di Serio et al., 2013; Keller, 2010; Partovi & Razavi, 2019).

Among other important aspects are the sense of commitment to the educational process and teamwork that are evident in the participants, the high perception of the game as an innovative strategy that enhances the educational process, and the use of a narrative is attractive to students which encourages competitiveness and collaboration. These elements are consistent with the results obtained in (Díaz-Ramírez, 2020; Jagušt et al., 2018).

Regarding the use of technological resources (mainly computer equipment and mobile phones), it is widely highlighted by students as a strategy that generates commitment. However, as indicated (Kebritchi et al., 2010), rules and conditions of use must be established to prevent the mobile phone from becoming a distraction.

The research results also show the importance of continuing to promote the quality of the materials used in the activities. Among the improvement options that are most highlighted by the students are:

A. strengthen the activities using open-ended questions, which differ from the traditional multiple-choice questions with a single answer (test),
B. incorporate images, videos, and others multimedia to facilitate the visualization and interpretation of the proposed activities, and
C. better adjust the time of the activities to achieve the full development of these. These design aspects and their relevance to the success of the intervention are consistent with what is indicated by (Castaño Garrido et al., 2015).

The use of challenges or problems that use the context of the students (everyday situations) becomes an important aspect in educational interventions. This allows generating the necessary scaffolding for solving mathematical problems, consistent with what was stated in (Chen, 2017).

In summary, the use of an educational strategy mediated by games, collaborative work between students, and the use of problems in the real context are the most positive aspects highlighted by students. On the other hand, the aspects to be improved focus on the quality of the multimedia support elements, the speed of feedback, the use of multiple-choice questions with only one answer, and the distractions that cellphones can generate.

CONCLUSIONS

This work contributes to measuring the effect that gamification and game-based learning-GBL has had to improve learning processes in higher education, specifically in the teaching of mathematics in engineering. The findings indicate that the participants (first-year engineering mathematics students) who participated in the game-based pedagogical intervention have high levels of motivation for the learning process. The dimensions of attention, relevance, confidence, and satisfaction, associated with motivation, have been strengthened, thus generating commitment from the participants.

The use of gamification and game-based learning also encourages the development of activities with tools and strategies of high interest to students. Properly using resources such as computer equipment or cell phones in the academic process is another important result.

The categorical analysis carried out from the focus group has made it possible to establish improvement actions for the instructional design of a new proposal of didactic units. The improvement of the materials and supported resources, the revision of the duration times of each test, the updating of the type of questions proposed (to encourage further discussion) and the incorporation of new games and challenges are part of the most important results.

In conclusion, gamification and game-based learning can be used to strengthen educational processes in engineering with very promising results in terms of motivation. Extending this research to other areas, such as physics and applied engineering, may be relevant. It is expected that in the long term this type of training action will result in the improvement of the academic performance of students and the minimization of student dropout

Author contributions: All authors have sufficiently contributed to the study, and agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Acknowledgements: The authors of this study thank the financial support of the Universidad Santo Tomas–Colombia and the academic support of the Universidad de las Islas Baleares–Spain.

Declaration of interest: No conflict of interest is declared by authors.

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