Gamificación en matemáticas: una experiencia en una clase de secundaria

Gamification in mathematics: a secondary classroom experience

Adrián Bacelo [1], María García-Lojo

Didáctica de las Matemáticas, Facultad de Ciencias Matemáticas, Universidad Complutense de Madrid, 28040 Madrid, Spain [1]

abacelo@ucm.es

HTTPS://ORCID.ORG/0000-0001-8595-0256

Resumen

El siguiente trabajo se centra en el estudio de una propuesta de gamificación del proceso de enseñanza-aprendizaje y su implantación en un aula de 4º de ESO de matemáticas. Tras analizar la situación actual, se realiza un estudio pre-post test en dos grupos de alumnos que trabajan simultáneamente los mismos contenidos, con la única diferencia que un grupo trabaja con el método tradicional de enseñanza y el otro con gamificación. El objetivo es comparar ambas metodologías en cuanto a resultados, motivación e interés por las matemáticas. Los resultados de la investigación muestran que la gamificación como método innovador de enseñanza-aprendizaje tiene un impacto positivo en los alumnos ya que aumenta su motivación y, por tanto, su rendimiento. Además, la gamificación también fomenta otros aspectos como el trabajo en equipo y la participación.

Palabras clave

Gamificación

Innovación

Matemáticas

Motivación

Método de enseñanza-aprendizaje

Abstract

The following paper focuses on the study of a gamification proposal of the teaching-learning process and its implantation in a mathematics 4th year secondary school classroom. After analysing the current situation, a pre-post test study is carried out in two groups of students who work the same contents simultaneously, with the only difference that one group works with traditional teaching method and the other with gamification. The objective is to compare both methodologies in terms of results, motivation and interest in mathematics. The research results show that gamification as an innovative teaching-learning method has a positive impact on students since it increases their motivation, and thus their performance. In addition, gamification also encourages other aspects such as teamwork and participation.

Keywords

Gamification

Innovation

Mathematics

Motivation

Teaching-learning method

Recibido: 10.07.204

Aceptado: 04.11.2024

Cómo citar: Bacelo, A. & García-Lojo, M. (2024). Gamification in mathematics: a secondary classroom experience. *Indivisa, Boletín de Estudios e Investigación.* Nº 24, 76-100. DOI 10.37382/INDIVISA.VI24.105

INTRODUCTION

Mathematics is fundamental in many aspects of our daily life, from its use in everyday situations to its use in science, technology, economics, industry or commerce (Cockcroft, 1985). In the international PISA study carried out in 2018, the results obtained in mathematics by Spanish students place them below the OECD average and the EU total (OECD, 2019). Also, in the TIMSS international assessment Spanish students were below the average and the total EU (Instituto Nacional de Evaluación Educativa, 2016). These results reflect the low performance and the high number of failures that occur in this subject and that may be a consequence of the difficulties involved in the subject.

Hidalgo, Maroto and Palacios (2004) locate the increase in the number of students who have a negative attitude towards mathematics at the secondary education stage. According to this study, it is frequent that students who did not have negative attitudes towards the subject, such as that it is complicated or that they are not capable of understanding, begin to have them at this stage. These thoughts cause them to lose their liking for the subject, considering it boring and impractical. In addition, the authors establish the existence of a vicious circle that relates different factors: difficulty, boredom, suspense, fatalism, low self-concept, demotivation and rejection.

Despite the fact that motivation is essential in learning, according to studies such as Ricoy and Couto (2018), there is a huge lack of it in adolescent students.

In many other areas there have been enormous changes, however, a large part of the classrooms are still as they were years ago and the teaching method that is still most commonly used is the traditional one, in which the teacher transmits information to the students, instead of the students being the ones who construct their own knowledge (Montero, 2017; Casas et al., 2018).

There is a need, on the one hand, to reflect on didactics and the traditional method of teaching-learning mathematics and, on the other hand, the need to innovate in this field seeking to achieve methodologies or systems that manage to motivate students by making them interested in the subject and that allow a better understanding and an increase in performance.

Among the various methodologies that allow innovation in the classroom, gamification is a method that is based on the acquisition of knowledge through the game, it is shown as a useful tool for teaching mathematics (Sakai & Shiota, 2016; Pascuas et al., 2017). This work focuses on gamification and the identification of the possible advantages that its implementation could have in the subject of mathematics for different reasons.

This research was born with the intention of evaluating a classroom intervention with gamification in mathematics to see its impact compared to a traditional methodology and to discuss the influence of gamification on student motivation.

To do this, first, we analyze the current situation in this area. In the second part, we develop the research method and in the last part, we analyze the results after conducting the experiment to draw conclusions.

THEORETICAL FRAMEWORK

Emotional intelligence has turned out to be a factor that is related to academic performance, since it includes variables such as social awareness, interpersonal relationships, adaptability or adequate expression of emotions, and students who obtain high scores for these variables also obtain a high school grade point average (Buenrostro et al., 2011).

All of the above, indicates that there is a need to reflect on these results in the area of mathematics and the reasons that lead to them and also about the teaching-learning process of mathematics at different levels taking into account that, in this process, motivation is placed as an important element as indicated in various studies on the subject (Valle et al., 1997; Herrera & Zamora, 2014).

MOTIVATION AND LEARNING

Different studies over the years have established a relationship between motivation and learning (Valle et al., 2010; Carrillo et al., 2009). Several authors have stopped considering that the only factor on which learning depends is intelligence (Vázquez & Manassero, 2007), including motivation as a fundamental element in this learning process (Núñez, 2009). Some of these authors, such as Lozano et al. (2000), qualify that motivation is essential if we want the resulting learning not to be exclusively rote, i.e., a more lasting learning over time.

There are many definitions of the concept of motivation. García & Doménech (1997) state the following: "Despite the existing discrepancies, most specialists agree in defining motivation as a set of processes involved in the activation, direction and persistence of behavior" (p.1). Núñez (2009), adds that learning requires, on the one hand, what he considers as "being able", a concept with which he refers to the cognitive variable, i.e. having the knowledge and skills, and on the other hand, "wanting" or having the intention, being willing to do so, i.e. the motivational variable.

Both studies agree on the complexity of motivation and subscribe to the idea of Pintrich & De Groot (1990), who differentiate three components of school motivation that are related to each other and influence learning. These components are first, the expectancy component, which is based on the learner's own belief about his or her abilities, the learner's self-concept

of himself or herself. Secondly, the value component, which encompasses the interest in or attraction to a given task, the reasons why the learner performs that task, and thirdly, the affective or emotional component or dimension of motivation, i.e., the emotions that occur in relation to a given activity or task.

These three components or dimensions are interrelated and all are necessary for motivation. If any of them is missing, the following occurs: the student considers that he/she is incapable (expectation component) or the activity does not interest him/her (value component), or it bores him/her or produces anxiety (emotional component) (Núñez, 2009). Faced with these situations, it is difficult for the student to be motivated.

However, despite motivation being a fundamental element in the learning process (Lozano et al., 2000), we find that many students are not motivated to study and that this seems to be a recurrent problem (Fernández et al. 2010). Tapia (1992) already considers these attitudes of student apathy towards learning and education to be worrying. Furthermore, he states that the reasons for this lack of interest are due to the feeling of frustration derived from the difficulties encountered by students when learning. Years later, this lack of academic motivation among adolescents is still considered one of the main problems in education (Legault et al., 2006).

Given the importance and complexity of motivation in the learning process and the negative ideas that most students have about science and mathematics (Solbes, 2011), the importance of the affective dimension of motivation in the learning of this subject is highlighted.

Also, lack of motivation is one of the problems of current education. Specifically in the subject of mathematics, students' lack of motivation is accentuated (Farias & Pérez, 2010). For this reason, mathematics accumulates a large number of failures and even many students who do not have difficulties in other areas obtain negative results in this subject (Carbonero & Navarro, 2006; Núñez et al., 2005).

Mathematics is perceived by many students as difficult, boring, impractical, formal or very abstract (Carbonero et al., 1998; Gil et al., 2006). This perception leads many students to have doubts about their abilities with respect to mathematics, causing them to consider that their effort in this subject is useless (Blanco & Guerrero, 2002).

For Gil et al. (2006), the consequences of students doubting their own abilities are reflected in the magnification of mistakes, the attribution of failure to their own lack of ability, low expectations of success, and the ease of giving up instead of facing difficulties.

According to Borrachero (2015), although it is not easy to quantify and evaluate the affective domain it is especially necessary to study this domain in the area of science. The author,

focusing on emotions, points out that just as negative emotions prevent the student from performing the desired behavior, when the student experiences positive emotions, motivation is activated, allowing him/her to focus attention and perform the desired action. To achieve a change in perception, positive attitudes must be developed through favorable feelings and emotions, since it is impossible for the student to have a positive attitude towards mathematics if the emotions he/she feels are nerves, anxiety, worry, tension, etc., i.e., negative emotions.

These elements of the affective domain are not static but vary over time. Negative emotions, beliefs and attitudes with respect to mathematics are accentuated with age and the advancement of school years at the same time that positive emotions decrease (Borrachero, 2015). This difference is quite noticeable between Primary Education, in which the student does not seem to present negative attitudes, and Compulsory Secondary Education, when attitudes towards the subject begin to be more negative (Deieso & Fraser, 2019).

GAMIFICATION

Among all the current active methodologies focused on the learner, gamification is an innovative method that challenges learners and is motivating due to the elements that compose it (Alsawaier, 2018).

Given the existence of a multitude of definitions for the term gamification, the following is the starting point, provided by Kapp (2012), who defines gamification as the use of game mechanics, aesthetics and thinking to attract people, motivate actions, promote learning and solve problems.

Teixes (2015), considers that the ability of gamification to promote the motivation of participants is the foundation of this strategy. Based on this, he establishes that through gamification it is possible to modify the behaviors of individuals through motivation, thus achieving previously proposed objectives. This foundation of gamification in the possibility of modifying behaviors through motivation has led to the use of this strategy in various sectors of the business world such as marketing, with the aim of increasing customer engagement or worker productivity, or human resources departments (Simpson & Jenkins, 2015) and has been implemented by companies such as Nike or Volskwagen (Ortiz-Colón et al., 2018).

The success that the use of gamification has meant in other sectors, induces to think that it can give good results in the educational field since one of the pillars of gamification is motivation, an element that is fundamental in learning processes. Moreover, according to Nistor & Iacob (2018), gamification makes it possible to keep students' attention, facilitate learning by making it more fun, improve their responsiveness, make them participate actively and, in general, improve the learning experience.

When Kapp (2012) speaks of game mechanics, he refers to the set of rules and elements and how they are related so that the actions of the players have consequences. Among these mechanics stand out points, which allow directing the player to perform actions to achieve a goal; badges, which are used as indicators of progress and rankings (Teixes, 2015) that allow players to know their progress and get feedback.

Feedback is a fundamental element in learning and gamification allows this feedback or feedback to be constant (Borrás, 2015). In addition, according to Zichermann & Cunningham (2011), it allows the player, in the case of education the student, to know what their progress is and where they are at. This offers the possibility of directing his actions in the desired direction.

Following Stott & Neustaedter, (2013), in addition to those already mentioned, other important elements in the success of gamification are freedom from failure and narrative. According to these authors, the freedom to fail makes it possible to improve learning, since the incorporation of this freedom to fail in classes increases the commitment of students, increasing their efforts to try to achieve the objectives.

Finally, storytelling is also considered an important resource in gamification. Clark & Rossiter (2008) point out the effectiveness of its use in the teaching process, as well as the possibility of contextualizing different activities offered by this resource. This allows us to deduce that it can bring benefits in gamification, allowing students to be placed in any scenario through a story in which a specific challenge that arouses their interest is framed (Batlle, 2016), i.e., placing them in a motivating situation in which they need to use their skills and knowledge (Kapp 2012), thus promoting learning by competencies.

On the other hand, in relation to emotions Robson et al. (2015) point out that gamification is capable of generating positive emotions such as surprise, amazement or personal triumph, emotions that, as previously stated, are fundamental in the learning process. This research suggests that one of the biggest educational problems in the subject of mathematics is the lack of motivation and the negative emotions and attitudes that students have towards the subject and the need for innovation in mathematics education.

In these works, gamification has been applied in different ways and in subjects from various fields: from history (Gómez, 2018) or music (Palazón-Herrera, 2015) to physics and chemistry (Quintanal, 2016) or technology (Pulido, 2019). In mathematics we did not find many studies on gamification at any of the levels, although there are a few: Lo & Hew (2020), Jagušt et al. (2018), Cunha et al. (2018) and Sakai & Shiota (2016). We highlight the work done by Türkmen & Soybaş (2019) who conducted an experiment with gamification and control and experimental group where both groups have no significant differences in their achievements

and attitudes but the experimental group's growth is higher. They reflect that indeed gamification has a very positive impact on learning in favor of other methodologies.

The reasons that lead us to choose gamification for this work are, on the one hand, the aforementioned elements, characteristic of this methodology, together with the fact that it is based on motivation through game mechanics, and on the other hand, the existence of other studies on gamification in secondary education that have had successful results. The success that has been obtained in these studies, together with the above, reflects that gamification can provide a solution to some of the existing problems in current mathematics education.
In view of the above, the aim of this article is to carry out a pre-post test study with two groups: an experimental group working with gamification and a control group working with traditional teaching. The objective is to check if this methodology effectively increases the motivation of the students, leading to an improvement in their learning. Thus, the following questions were posed:

RQ1: Does significant learning occur after the development of the proposal?

RQ2: Does motivation increase with the use of gamification in the classroom based on their participation?

RQ3: Is there more learning with the use of the gamification proposal than with the traditional methodology?

METHODS

STUDY DESIGN

With a quantitative approach, a pre- and post-test study is designed with intervention in two groups of students: a control group and an experimental group. Both are defined by the educational center itself without being possible for the distribution to be completely random. Therefore, this is a quasi-experimental study for which the variables studied are defined below and the research hypotheses are established.

Since it is assumed that learning depends on whether or not gamification is applied, this is defined as the dependent variable and the use of gamification is defined as the independent variable, which is the variable that can be manipulated and which will be implemented in the experimental group, while the control group works with the traditional method.

PARTICIPANTS

The sample is made up of two groups of students in the 4th year of secondary school in a public high school in the Community of Madrid, located in Fuenlabrada during scholar year 2019/2020. In both groups, they are studying Mathematics oriented to applied education.

On the one hand, the control group is composed of 23 students, 10 girls and 13 boys, aged 15-16 years. Four of them are repeaters and are 17 years old. On the other hand, the experimental group is composed of 24 students, also 15-16 years old, among whom there are 13 girls and 11 boys. There are 5 repeaters, aged 17. There are no students with special educational needs in either group.

Both groups are made up of students who have known each other for years and whose participation in the classes is quite low, which is generally reflected in their academic performance.

PROCEDURES

The study consisted of two clearly differentiated phases: on the one hand, preparation and, on the other, the intervention itself.

During the preparation phase, meetings were held with the educational center to inform about the study and its objectives. In these meetings it was decided that the topic chosen for the study would be equations. All the intervention sessions and activities were also prepared for the experimental group and the teacher in charge of this group during the course participated in their design. In the same way, the pre-post-test was designed with the collaboration of the teachers of both groups.

The intervention was carried out at the center during five sessions of 50 minutes each, during the mathematics subject timetable. As the mathematics subject has 4 weekly sessions, in both groups, four sessions were held on Monday, Tuesday, Thursday and Friday of one week, and the last session on Monday of the following week. In addition, the week prior to the development of these five sessions, the initial evaluation was carried out by means of the pre-test. For this purpose, the first 15 minutes of a mathematics subject session were taken. The post-test, in the same way, was carried out during the first 15 minutes of the session following the end of the intervention.

INSTRUMENTS

Measurement instruments

Both groups are given the same pre-test and post-test (and both are the same between them), the content of which is the one being worked on during the intervention, i.e., equations. It is a test consisting of ten questions to which the students must respond by marking one of the three possible options for each question and which they must complete in a time of 15 minutes. The maximum score is 10 points, one per question, and incorrect answers will not subtract points.

In addition to the pre- and post-test, direct observation is used in the experimental group, with the objective of evaluating the attitudes and participation of the students in this group. In each session, the teacher in charge of the subject during the course will take notes about the students by means of a checklist (Figure 1), where the presence of active and participative attitudes is marked.

Figure 1
Annotation table for direct observation

	Participates actively	Asks questions	Interacts with others	Do tasks correctly
Student 1				
…				
Student x				

Intervention instruments

Methodology

The intervention is carried out in parallel and simultaneously in the control and intervention groups, and in both the same didactic unit is worked on: equations, belonging to the algebra block. In both groups, the same contents are worked on in each session, with a difference in the methodology used in each one.

In the control group, the instruments of the traditional teaching method are used, the teacher explicitly exposes and explains the contents on the blackboard and different activities are carried out in the textbook or notes to practice them. The sessions always follow the structure of the teacher's explanation-resolution of activities proposed in the textbook. In this group, the intervention is carried out by the teacher in charge of the subject during the course.

In the experimental group, work is done through gamification. Through the narration of a story, which serves as a guiding thread throughout the intervention, different activities are introduced, based on the game, through which it is intended that without the teacher's prior explanation of the contents to be worked on, the students discover and internalize these contents by themselves through the activities.

Activities.

The contents to be worked on are the following and their distribution in the different sessions is as shown in Figure 2:

Figure 2
Distribution of contents in sessions

Session	Contents
1	First degree equations: form, resolution and differentiation of algebraic identity.
2	Second degree equations: form, resolution and discriminant use.
3	Solving problems with first and second degree equations.
4	Equations of degree greater than two I: factored form, factorization of equations, biquadratic equations.
5	Equations of degree greater than two II: factored form, factorization of equations, biquadratic equations / Review of the complete theme

We are going to see the distribution of the sessions in both groups:

- Control group.

In this group the sessions are standard sessions and follow the structure in Figure 3:

Figure 3
Structure of sessions in traditional methodology

Activities	Time	Description of the activity.
1. Introduction	10'	Presentation of what is going to be explained. Resolution of doubts about what has been previously explained, if any.
2. Explanation on blackboard	25-30'	The teacher explains the content that corresponds to that session following the textbook of the subject.
3. Exercises	10-15'	The teacher sends exercises from the book. They are started in class and finished at home.

- Experimental group.

At the beginning of the first session, the methodology to be followed is explained through the narration of the story that will be used as a guiding thread throughout the intervention. In each session, called training or mission, students score points by performing different activities and attitudes. If they achieve a certain number of points, established at the beginning, they pass the mission and obtain geographical coordinates that allow them to access the next mission. In order for them to make an effort in each session, it is explained to them that it is necessary to pass each one of them in order to continue, since the only way to access the next one is by obtaining the geographical coordinates that indicate the place where the next mission takes place, so they must make an effort because otherwise they cannot continue to the next one.

Therefore, at the beginning of each session, after having looked up the coordinates, they must know in which city they are and enter the name of the city in an interactive presentation, which only allows them to advance if this name is correct. After doing this, the same presentation

specifies how to get points and the maximum number of points that can be achieved, as well as a minimum required to pass the mission. In this way they will add points together, so that the goal is common to the whole class. At the end of each session, the points obtained are counted and recorded in a table that students can access to see their individual progress, as well as the total for the class.

At the end of the last session the total points obtained in all sessions are counted, if they have reached the objective set at the beginning the training is passed and they receive a final message. In the Figure 4,5,6,7 and 8 is shown the scheme of each day:

Figure 4

Structure of the first session

Activities	Time	Description of the activity.
Presentation	15'	Presentation of the methodology to be followed. Narration of the story that will be used as the thread of the intervention.
Sudoku	15'	Students have a blank Sudoku, and they must solve equations in order to get some numbers and complete it.
UNO	15'	Each student has cards with equations, they have to be the first to run out of cards, to be able to throw a card it has to be worth one more or one less than the one on the table.
Closing session	5'	Closing of the session: counting of points and obtaining the final digit

Figure 5

Structure of the second session

Activities	Time	Description of the activity.
Introduction	5'	Presentation of the activities and the theme of the session.
Cooperative puzzles	25'	Each student has cards on the sides of which are written different equations, solutions or the type of equation it is. They must find the partner who has the cards that correspond to theirs.
Zero, one, two	15'	Second degree equations are shown, and should read ZERO, ONE or TWO, this being the number of solutions of the equation calculated according to the discriminant.
Closing session	5'	Closing of the session: counting of points and obtaining the final digit

Figure 6

Structure of the third session

Activities	Time	Description of the activity.
Introduction	5'	Presentation of the activities and the theme of the session.
Relay race	20'	In teams they must solve problems. To read the statement they must answer questions posed. If they get it right a member of the team can read it and come back.
Wheel of problems	20'	In a circle, each person must pose a problem to the person on his right and solve the problem posed by the person on his left.
Closing session	5'	Closing of the session: counting of points and obtaining the final digit

Figure 7

Structure of the fourth session

Activities	Time	Description of the activity.
Introduction	5'	Presentation of the activities and the theme of the session.
Algebraic Memory	20'	The game is played in groups. A series of cards are placed face down and each student, in turn, picks up two cards. If the ones picked up form a pair, he/she keeps them, if not, he/she leaves them face down again. The pairs will be two-square equations in their general form, and the equation written after the change of variable.
Touch the solution	20'	Equations of degree greater than two, in their factored form, are posed and students must touch the solutions to the equation.
Closing session	5'	Closing of the session: counting of points and obtaining the final digit

Figure 8

Structure of the fifth session

Activities	Time	Description of the activity.
Introduction	5'	Presentation of the activities and the theme of the session.
Red Light, Green Light	20'	They must fill in the missing gaps to know the factorization of a polynomial using Ruffini's rule. Only the first person to reach the board and place a number will be able to do so by playing Red Light, Green Light
Mathematical contest	20'	They must answer questions that will be asked through the Quizizz app.
Closing session	5'	Closing of the session: counting of points and obtaining the final digit

All the activities are developed by the authors in collaboration with the team of teachers, always from the perspective of gamification. In Figure 9 and 10 we can see examples of the activities that have been made in the experimental group.

Figure 9
Example of activity developed: Sudoku

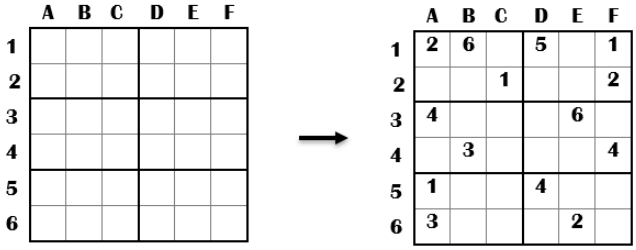
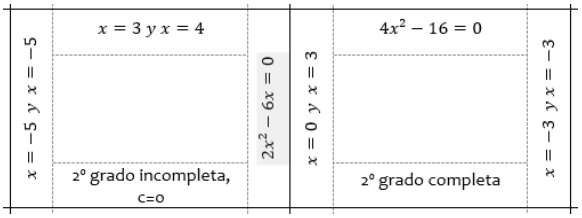


Figure 10
Example of activity developed: Cooperative Puzzle



RESULTS

This section shows the pre- and post-test results obtained by both groups, out of a maximum of 10 points. Figure 11 shows the points obtained by each student in the control group in the pre-test and post-test, while Figure 12 shows those obtained by the students in the intervention group.

Due to the number of subjects, the Shaphiro-Wilks test is performed to check whether the results obtained in the pre-test and post-test follow a normal distribution in both groups. The null hypothesis is that the data are normally distributed, since, in all cases, a value of $p>0.05$ is obtained, and therefore, the null hypothesis is accepted.

Once the normal distribution is accepted, we analyze whether or not there are significant differences in learning through cross-sectional and longitudinal comparisons of the data.

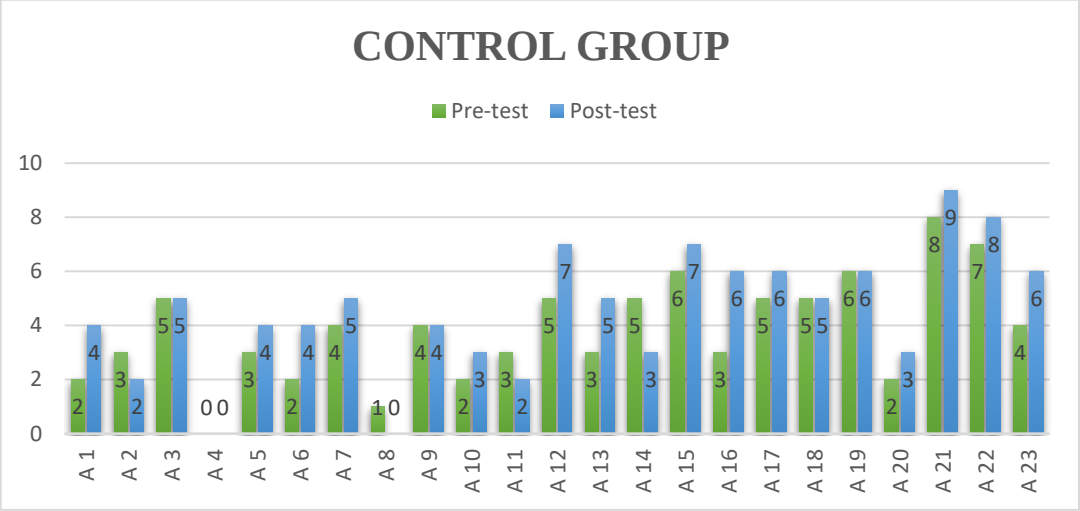
Using the T-Student test, a comparison was made of the results obtained in the pre-test in both groups and a value of $p>0.05$ was obtained, so there was no significant difference in learning between the control group and the intervention group before the intervention.

After the intervention, the data collected from the pre- and post-test for both the control and intervention groups were analyzed longitudinally. In the control group (Figure 11) the T-Student

between the pre- and post-test returns a value p<0.05, so it is determined that there is a significant statistical difference.

Figure 11

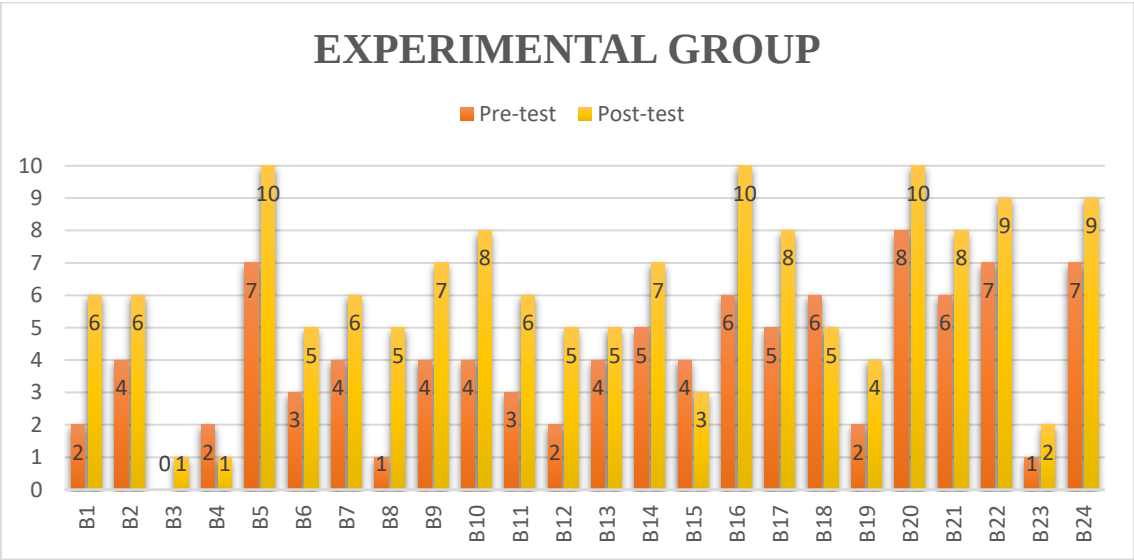
Control group results



Similarly, the longitudinal analysis of the results of the intervention group is performed (Figure 12). In this case, the p value obtained in the T-Student test is p<0.05, which also determines the existence of a significant statistical difference. It should be noted that in the control group the p-value obtained is p=0.01224, while in the intervention group the value is p=0.0000007448, i.e., much lower for the intervention group, being a much more significant difference for the group in which gamification is used.

Figure 12

Experimental group results



Finally, a cross-sectional comparison was also made between the post-test results of both groups. The result of the T-Student test in this case, is a value $p<0.05$. It is also observed that there is a significant statistical difference between both groups, also favoring the intervention group.

If we calculate the Intraclass Correlation Coefficient, associated to a multilevel model, of a two-level structure, the formula would be: $ICC = \frac{S^2_{nivel\ 2}}{S^2_{nivel\ 1}+S^2_{nivel\ 2}}$

The result after intervention is an ICC of 0.0526241 and a 95% confidence interval of (0.0016, 0.65). The result before intervention is an ICC of $1.44 * 10^{-23}$ and a 95% confidence interval of $(1.44 * 10^{-23}, 1.44 * 10^{-23})$.

DISCUSSION

The study starts from two groups with very similar levels, since the data reveal that at the time prior to the intervention there is no significant statistical difference between them. The results also show that in both groups there has been an improvement with respect to baseline and that learning has occurred in both groups after the intervention. However, the improvements are not equal in both groups, like Türkmen & Soybaş (2019) said.

Considering the multilevel analysis model, we have to take into account that the ICC provides us with information about the agreement between different measurements of a variable. A low ICC will mean that subjects within the same group are as different from each other as those belonging to other groups. In that case, the groups are not internally homogeneous and the observations are independent.

Regarding the results in the multilevel model, we calculate the null model in order to check if we have enough evidence of clusters. The ICC after intervention is low not concluding the existence of differences among the groups and therefore clustering and multilevel analysis cannot be executed. It can be seen how the ICC before the intervention was clearly 0 and now the value has risen up to having a CI of (0.0016, 0.65). Both ICC do not overlap and therefore, they are not the same at a 95% CL. As the only existing difference is being exposed to the proposed intervention therefore, it can be stated that it caused an effect and different scores are not related to luck. Furthermore, we are aware of the limitations, specially data limitations, which do not allow us to reach further level analysis.

The intervention in the two groups developed, in general terms, as expected. In the control group, in which the traditional teaching method was used, the improvements were not as significant as in the experimental group and the attitude of the students did not vary much during the intervention. The teacher of this group stated that the development was like that of other subjects already worked on previously. In the control group, the students who obtained the best results in the post-test (A12, A15, A21 and A22) coincided with those who

participated the most in the sessions and asked the most questions during the sessions. In contrast, the lowest results (A4, A8, A2 and A11) were those of the students who showed practically no interest in the explanations and did not carry out the proposed activities. The teacher in charge of this group, who worked with the traditional method, affirms that in general the students who obtained the best results are those who usually make an effort and show more interest, so their results are generally good. This fact is observable since, among these four students whose results were the best, two of them (A21 and A22), obtained a high score in the pre-test.

All this, leads the teacher in charge of the control group to suggest that the motivation of the students for the study of this subject is low, as assured by studies such as that of Fernández et. al (2010) and that the traditional method used, which involves low student participation and in which most of the interventions are made by the teacher, may influence the apathy and demotivation shown by the students as pointed out by Montero (2017).

In the experimental group, the number of students who obtained high scores in the post-test is considerably higher than in the control group. Through the annotations made in the checklist, it can be observed that the participation of the students, in general, was quite high.

If we pay attention to the learning process experienced by the students in the groups we have to distinguish several aspects. In the control group, the evolution was similar to that experienced in other units. Moreover, it is expected that with these concepts it takes some time for the students to assimilate the material and use it autonomously, as the teacher's experience indicates. In particular, the use of the formula for second degree equations was difficult for them and it was not until almost the final exam that they had the fluency to use it in exercises and problems. This shows that traditional teaching is associated with what we could call traditional learning, where some concepts and formulas are difficult for students in general to learn.

In contrast, the experimental group showed very different and faster processes than the control group. By using the game as a learning tool, the students were fluent in using several advanced concepts from the very beginning. In fact, the students' own interest in assimilating the content, encouraged by its possible use in later activities and games, is remarkable. Compared to other years, other classes of the same year and the control group, the experimental group progressed at a faster pace and understood better everything that was explained. Therefore, we can say that gamification stimulates the students' learning process and the assimilation of the contents explained with it.

In relation to the motivation and attitude of the members of this group, on the one hand, there are students B3, B4 and B23 who normally did not show interest in the activities and whose participation was quite low, a fact that may be the reason for their low results in the post-test.

On some occasions, in activities in which there was more movement, such as Zero, one, two or Red Light, Green Light, they participated and asked some questions.

On the other hand, students B7, B12, B18 and B19 showed a progressive change of attitude during the intervention and were initially reluctant to participate. However, after observing that the group obtained 408 points in this first session, thus achieving the objective, they began to show greater interest. In the case of student B13, a change of attitude in the same sense was also observed, with the difference that his really active participation began with the Relay Race activity, later than that of the previously mentioned students, which suggests that he could have obtained a better result in the post-test if he had actively participated in all the sessions.

Also, the students who obtained better results showed high participation in the activities. In particular, students B5, B20, B24 and B22, showed a very good attitude from the beginning that had a positive influence on the functioning of the group. From the first activity, which they finished first, they offered help to their classmates ('To find out if 3 is the solution to this equation you have to substitute x for 3 and see if it is satisfied', 'If you multiply zero by any number it always gives zero, so it is satisfied for any value you give to x'). This information was collected in the annotations through direct observation.

Students B1, B6, B8 and B10, whose results improved greatly after the intervention, also had a remarkable change in attitude between the beginning and the end of the intervention. In the activity Zero, one, two, students B1 and B6 were able to obtain points for reasoning correctly because they had placed themselves on one side or the other, depending on the result obtained with the discriminant ('You have to move to this side because it gives -11 and there is no root because it is negative, it has no solution', 'It gives zero, it has only one'). As they became aware that they were capable of understanding the subject and helping to add points for the group, their self-confidence improved and their participation increased, a fact that seems to corroborate that, as Gil et al. (2006) affirm, the beliefs and emotions that students have influence their motivation.

The group in general showed high interest and even, at times, concern, especially at the beginning ('We don't know how to do it, we won't get the points and we won't be able to move on to the next one', 'But how are we going to do this, if we haven't given it'). However, as the intervention progressed and they were scoring points, they realized their ability and the importance of helping each other and working as a team. Thus, in Touch the solution, they realized that if they worked as a team and made sure which were the solutions to the equations they touched the correct ones and could give the explanation, thus adding more points than if they worked individually, and they achieved the maximum possible in the activity. Therefore, it would be good to rethink activities in which they worked in a more individualized way, since the results were better when working as a team. In this way, the Sudoku activity could be

rethought in such a way that the questions were on cards that they had to share among all of them, instead of on the activity sheet of each student.

All of the above can be translated into the fact that the motivation of the students in this group was higher than in the control group, which suggests that, as stated by Teixes (2015), gamification and the use of game elements such as points promote motivation and allow modifying behaviors through such motivation.

With respect to the objective of creating a proposal that improves and also facilitates the learning of mathematics, most of the students in the experimental group assured, at the end of the intervention, that the gamification method had seemed much more interesting to them than the traditional one ('And can't we do the rest of the course like this?'). In this regard, after the end of the intervention, we have been in contact with the teacher of this group who assures that they continue to talk about it and ask for more work to be done in this way, and that they continue to remember what they have worked on with gamification better than content they have worked on more recently.

In line with Nistor & Iacob's (2018) statements, which state that gamification increases attention and facilitates learning, students such as B1, B8 and B12 assured that they had learned more this way because they had found it easier to pay attention and be active during the whole session than when working with the traditional method ('With the points thing, In the end I get more serious and I learn', 'This way the classes go by quickly and I don't get lazy because I don't get bored') which, after a short period of time, causes them boredom, with the consequent loss of attention.

Others, such as B5 and B20, who usually obtain good results, also stated that they had found it easier to learn in this way despite the fact that their participation in the classes is usually high regardless of the method. Student B16, noted that he did not believe he was capable of getting the best score in math ('It seems impossible for me to get an A in math and studying at home even less') and that working with his classmates to achieve a common goal had helped him to do so.

In addition, at the end of several sessions, they asked for more time ('Just a moment teacher!', 'Wait five minutes, we are going to finish it now'), statements that surprised the teacher in charge of the group as this group normally used to pick up before ringing the bell and get up quickly.

The above statements and attitudes, together with the results obtained by the students in this group, allow us to establish that gamification seems to generate, in most cases, positive emotions conducive to student motivation as stated by Robson et al. (2015).

From what has been presented so far, it can be deduced that although both groups improved, gamification achieved more significant improvements and in more varied aspects, such as

collaboration and teamwork. Therefore, the need to innovate raised among others by the OECD (2016) and, in this case, the implementation of an active methodology, such as gamification, has proved to be an advantageous proposal that brings benefits in learning and motivation of students.

CONCLUSIONS

After the design of activities based on gamification and its subsequent application in a 4th course of secondary school mathematics classroom, several advantages of this method with respect to the traditional method, used quite frequently, can be established.

First, with respect to the objective of achieving an improvement in attitudes towards the subject, gamification produces a decrease in the negative attitudes that students acquire towards mathematics as the courses progress (Deieso & Fraser, 2019), which, on the other hand, confirms the importance of attitude and its relationship with motivation (Solbes, 2011).

Secondly, and in relation to the above, the use of gamification as an innovative teaching method increases student motivation through its elements and also manages to maintain it (Teixes, 2015) by encouraging their participation and teamwork, thus achieving the stated objective of increasing motivation towards mathematical learning.

Thirdly, the results obtained in this study allow us to affirm that through the implementation of gamification the objective of producing an improvement in the interest in solving mathematical tasks. The increase in participation and motivation in turn favors interest in learning, which indicates that student motivation is a very important element in the teaching-learning process (Valle et al., 2010; Carrillo et al., 2009; Núñez, 2009) a fact that can be observed in the results obtained by students working with gamification.

Despite the fact that with the traditional method there are also improvements in the interest in solving mathematical tasks, the motivation of students working with this method is lower than when working with gamification, so the use of this traditional method may be one of the reasons that influence this low participation of students, who find the learning process boring (Montero, 2017), which is reflected in the results obtained in this research. Moreover, in the control group, the results reveal that the students who have fewer difficulties and already had good results before the intervention, continue to have them afterwards but that the students who find more difficulty do not manage to improve too much.

Therefore, we can conclude that gamification as an innovative method in the mathematics classroom has a positive impact and that with its application there is an improvement in the interest in performing mathematical tasks and in attitudes towards mathematics, as well as offering the possibility of working on other competencies other than mathematics, such as teamwork.

LIMITATIONS AND PROSPECTS

The main limitations encountered in the development of this research work are, on the one hand, the time limitation established to carry out the intervention, which only consists of five sessions. On the other hand, we found that the sample size with which the research is carried out is quite small. These factors prevent the results and conclusions obtained in the study from being applicable to the entire population. And, finally, the impossibility of the interventions being carried out by the same person in both groups, the person in charge of the control group being a different teacher from that of the experimental group.

In view of this, the following lines of future research are proposed, which will allow us to learn more about this topic:

First, to continue studying gamification as an educational methodology using larger samples and for longer periods of time.

Secondly, it is possible to extend research on this method to different educational levels and populations with different socioeconomic characteristics.

Finally, it is also proposed to investigate the use of this methodology in subjects other than mathematics to see if the results are similar in other subjects or if, on the contrary, it only produces a positive impact in specific subjects with specific characteristics.

ACKNOWLEDGMENTS

This study was partially support by the Science and Innovation Minister under project PID2021-122752NB-I00.

All the people involved in this paper have contributed equally.

REFERENCIAS

Alsawaier, R.S. (2018). *The effect of gamification on motivation and engagement.* International Journal of Information and Learning Technology, Vol. 35 No. 1, pp. 56-79.

Batlle, J. (2016). *Gamificación para el desarrollo de la comunicación intercultural en el aula de Español como Lengua Extranjera [Gamification for the development of intercultural communication in the Spanish as a Foreign Language classroom].* Roig Vila, R.(ed.) (2016) Tecnología, innovación e investigación en los procesos de enseñanza-aprendizaje. Barcelona: Octaedro, pp. 114-120.

Blanco, L. J. y Guerrero, E. (2002). *Profesores de matemáticas y psicopedagogos. Un encuentro necesario [Mathematics teachers and educational psychologists. A necessary meeting].* Aportaciones de la didáctica de la matemática a diferentes perfiles profesionales, 121-142.

Borrachero, A. B. (2015). *Las emociones en la enseñanza y el aprendizaje de las ciencias en educación secundaria [Emotions in science teaching and learning in secondary education]* (PhD thesis). Departamento de Didáctica de las Ciencias Experimentales y de las Matemáticas, Universidad de Extremadura.

Borrás, O. (2015). *Fundamentos de la Gamificación [Gamification Basics].* Universidad Politécnica de Madrid.

Buenrostro A.E., Valadez M.D., Soltero, R., Nava, G., Zambrano, R. y García A. (2012). *Inteligencia emocional y rendimiento académico en adolescentes [Emotional intelligence and academic performance in adolescents].* Revista de Educación y Desarrollo, 20, 29-37.

Carbonero, M. Á, y Navarro, J. C. (2006). *Entrenamiento de alumnos de Educación Superior en estrategias de aprendizaje en matemáticas [Training Higher Education students in learning strategies in mathematics].* Psicothema, 18(3), 348-352.

Carbonero, M. Á, Martín, L. J. y Arranz, E. (1998). *Expectativas ante las matemáticas de alumnos de primer ciclo de Educación Secundaria [Expectations of lower secondary school pupils towards mathematics].* Revista de psicodidáctica, (6), 69-78.

Carrillo, M., Padilla, J., Rosero, T. y Villagómez, M. S. (2009). *La motivación y el aprendizaje [Motivation and learning].* Alteridad, 4(1), 20-33.

Casas N., Ballesteros, D. y Etxeandia, E. (2018). *Math Mystery Box: Gamificando el aprendizaje de las matemáticas [Math Mystery Box: Gamifying Mathematics Learning].* Pensamiento Matemático, 8(2), 101-108.

Clark, M. C. & Rossiter, M. (2008). *Narrative Learning in Adulthood.* New Directions for Adult and Continuing Education, 2008: 61–70.

Cockcroft, W. H. (1985). *Las matemáticas sí cuentan: informe Cockcroft [Mathematics does count: Cockcroft report]* (Vol. 20). Ministerio de Educación.

Cunha, G. C. A., Barraqui, L. P. & de Freitas, S. A. A. (2018). *Evaluating the use of gamification in mathematics learning in primary school children.* IEEE Frontiers in Education Conference (FIE), pp. 1-4.

Deieso, D. & Fraser, B. J. (2019). *Learning environment, attitudes and anxiety across the transition from primary to secondary school*

mathematics. Learning Environments Research, 22(1), 133-152.

Farias, D. y Pérez, J. (2010). *Motivación en la Enseñanza de las Matemáticas y la Administración [Motivation in Mathematics Teaching and Administration]*. Formación universitaria 3(6), 33-40.

Fernández, M., Riviére, J. y Mena, L. (2010). *Desenganchados de la educación: Procesos, experiencias, motivaciones y estrategias del abandono y del fracaso escolar [Disengaged from education: Processes, experiences, motivations and strategies of school dropout and failure]*. Revista De Educación, (1), 119-145.

García, F. J. y Doménech, F. (1997). *Motivación, aprendizaje y rendimiento escolar [Motivation, learning and school performance]*. REME, vol. 1, n. 0. ISSN 1138-493X.

Gil, N., Guerrero, E. y Blanco, L. (2006). *El dominio afectivo en el aprendizaje de las Matemáticas [The affective domain in mathematics learning]*. Electronic Journal of Research in Educational Psychology, 4(1),47-72.

Gómez, I. M. (2018). *Gamificación y tecnologías como recursos y estrategias innovadores para la enseñanza y aprendizaje de la historia [Gamification and technologies as innovative resources and strategies for teaching and learning history.]*. Educação & Formação, 3(8), 3-16.

Herrera, J. y Zamora, N. (2014). *¿Sabemos realmente que es la motivación? [Do we really know what motivation is?]*. Correo Científico Médico, 18(1), 126-128.

Hidalgo, S., Maroto, A. y Palacios A. (2004). *¿Por qué se rechazan las matemáticas? Análisis evolutivo y multivariante de actitudes relevantes hacia las matemáticas [Why is mathematics rejected? Evolutionary and multivariate analysis of relevant attitudes towards mathematics]*. Revista de Educación, 334, 75-95.

Instituto Nacional de Evaluación Educativa (2016). *TIMSS 2015. Estudio internacional de tendencias en Matemáticas y Ciencias. IEA. Informe español: resultados y contexto [TIMSS 2015. Trends in International Mathematics and Science Study. IEA. Spanish report: results and context]*. Madrid, Ministerio de Educación, Cultura y Deporte.

Jagušt, T., Botički, I. & So, H.-J. (2018). *Examining competitive, collaborative and adaptive gamification in young learners' math learning*, Computers & Education, Volume 125, Pages 444-457.

Kapp, K. (2012). *The gamification of learning and instruction: game-based methods and strategies for training and education*. John Wiley & Sons.

Legault, L., Pelletier, L. & Green-Demers, I. (2006). *Why Do High School Students Lack Motivation in the Classroom? Toward an Understanding of Academic Amotivation and the Role of Social Support*. Journal of Educational Psychology, 98(3), 567-582.

Lo, C.K. & Hew, K. F. (2020). *A comparison of flipped learning with gamification, traditional learning, and online independent study: the effects on students' mathematics achievement and cognitive engagement*. Interactive Learning Environments, 28, 4, 464-481.

Lozano, L. M., García-Cueto E. y Gallo, P. (2000). *Relación entre motivación y aprendizaje [Relationship between motivation and learning]*. Psicothema, 12(Su2), 344-347.

Montero, B. (2017). *Aplicación de juegos didácticos como metodología de enseñanza: Una Revisión de la Literatura [The Application of*

Educational Games as a Teaching Methodology: A Review of the Literature]. Pensamiento Matemático, 7(1), 75-92.

Nistor, G. C., & Iacob, A. (2018). *The advantages of gamification and game-based learning and their benefits in the development of education*. In The 14th International Scientific Conference eLearning and Software for Education (Vol. 1, pp. 308-312). "Carol I" National Defence University, Bucarest, Romania.

Núñez, J. C. (2009). *Motivación, aprendizaje y rendimiento académico [Motivation, learning and academic performance]*. X Congresso Internacional Galego-Português de Psicopedagogía. Braga, Portugal.

Núñez, J. C., González-Pienda, J. A., Álvarez, L., González, P., González-Pumariega, S., Roces, C. y Rodrigues, L.S. (2005). *Las actitudes hacia las matemáticas: perspectiva evolutiva [Attitudes towards mathematics: a developmental perspective]*. Actas do VIII Congreso Galaico-Portugués de Psicopedagoxía (pp. 2389-2396).

OECD (2016). *Innovating Education and Educating for Innovation: The Power of Digital Technologies and Skills*. OECD Publishing, Paris.

OECD (2019). *PISA 2018 Results (Volume I): What Students Know and Can Do*. OECD Publishing, Paris.

Ortiz-Colón, A.M., Jordán, J. y Agredal, M. (2018). *Gamificación en educación: una panorámica sobre el estado de la cuestión [Gamification in education: an overview of the state of the art]*. Educaçao e Pesquisa: Revista da Faculdade de Educação da Universidade de São Paulo, 44, 74.

Palazón-Herrera, J. (2015). *Motivación del alumnado de educación secundaria a través del uso de insignias digitales [Motivating secondary school students through the use of digital badges]*. Opción, 31(1), 1059-1079.

Pascuas, Y. S., Vargas, E. O. y Muñoz Zapata, J. I. (2017). *Experiencias motivacionales gamificadas: una revisión sistemática de literatura [Gamified motivational experiences: a systematic literature review]*. Innovación educativa (México, DF), 17(75), 63-80.

Pintrich, P. R. & De Groot, E. V. (1990). *Motivational and self-regulated learning components of classroom academic performance*. Journal of educational psychology, 82(1), 33.

Pulido, B. (2019). *Gamificación de la asignatura de Tecnología de 3º de la ESO [Gamification of the 3rd year ESO Technology subject]*. UVA, http://uvadoc.uva.es/handle/10324/38993.

Quintanal, F. (2016). *Gamificación y la Física–Química de Secundaria [Gamification and Physics-Chemistry in secondary schools]*. Education in the Knowledge Society, 17(3), 13-28.

Ricoy, M.C. y Couto, M. J. (2018). *Desmotivación del alumnado de secundaria en la materia de matemáticas [Demotivation of secondary school students in the subject of mathematics]*. Revista Electrónica de Investigación Educativa, 20(3), 69-79.

Robson, K., Plangger, K., Kietzmann, J.H., McCarthy, I. & Pitt, L. (2015). *Game on: Engaging Customers and Employees through gamification*. Business Horizons, 59(1), 29-36.

Sakai, K. & Shiota, S. (2016). *A Practical Study of Mathematics Education Using Gamification*. International Association for Development of the Information Society.

Simpson, P. & Jenkins, P. (2015). *Gamification and Human Resources: an overview*. Brighton: Brighton Business School.

Solbes, J. (2011). *¿Por qué disminuye el alumnado de ciencias? [Why is the number of science students decreasing?]* Alambique, 67, 53-61.

Stott, A. & Neustaedter, C. (2013). *Analysis of gamification in education.* Surrey, BC, Canada, 8, 36.

Tapia, J. A. (1992). *Motivar en la adolescencia: Teoría, evaluación e intervención [Motivating adolescents: Theory, assessment and intervention].* Ediciones de la Universidad Autónoma de Madrid.

Teixes, F. (2015). *Gamificación: Motivar jugando [Gamification: Motivate through play].* Editorial UOC.

Türkmen, G. P. & Soybaş, D. (2019). *The Effect Of Gamification Methodology On Students' Achievements and Attitudes Towards Mathematics.* Bartın University. Journal of Faculty of Education, 8(1), 258-298.

Valle, A., González R., Barca A. y Núñez, J.C. (1997). *Motivación, cognición y aprendizaje autorregulado [Motivation, cognition and self-regulated learning].* Revista Española de Pedagogía, 137-164.

Valle, A., Rodríguez, S., Núñez, J.C., Cabanach, R. G., González-Pienda, J.A. y Rosario, P. (2010). *Motivación y Aprendizaje Autorregulado [Motivation and Self-Regulated Learning].* Interamerican Journal of Psychology, 44(1),86-97.

Vázquez, Á. y Manassero, M.A. (2007). *En defensa de las actitudes y emociones en la educación científica (II): evidencias empíricas derivadas de la investigación [In defence of attitudes and emotions in science education (II): empirical research evidence].* Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 4(3),417-441.

Zichermann, G. & Cunningham, C. (2011). *Gamification by design: Implementing game mechanics in web and mobile apps.* O'Reilly Media, Inc.

Correspondencia:

Adrián Bacelo

Profesor Permanente laboral en la Facultad de Ciencias Matemáticas (UCM)

abacelo@ucm.es

https://orcid.org/0000-0001-8595-0256

Departamento de Álgebra, Geometría y Topología, Facultad de Ciencias Matemáticas, Universidad Complutense de Madrid, Plaza de las Ciencias 3, 28040 Madrid, España.