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GAMIFICATION TO WORK ON THE NUMBERS IN A MATHEMATICS COURSE: STUDY OF EMOTIONS AND ACADEMIC PERFORMANCE IN HIGHER EDUCATION

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Abstract

The traditional approach to teach and learning mathematics has often been theoretical and teacher-centered. This tendency may be associated with students' low interest in the subject. Consequently, it is important to stimulate students' interest and motivation through active methodologies such as gamification. In recent years, escape rooms have been introduced in higher education for this purpose. In mathematics learning, the emotional dimension of students is as important as academic performance, given the strong connection between both aspects. Hence, this research aims to analyze both emotional dimension and academic performance of pre-service teachers before and after applying an escape room to work on mathematics content during two academic years. The results indicate positive effects on the emotional dimension, since all positive emotions increased significantly both academic years after completing the mathematics escape room. Negative emotions generally remained unchanged, except for uncertainty and fear, which decreased during the first academic year analyzed. Additionally, correlations emerged between emotions and academic performance, highlighting the connection between these factors. Academic performance improved significantly after the intervention in both academic years, showing that the escape room was an effective tool for enhancing the learning of mathematical content. Considering these findings across two consecutive academic years, the mathematics escape room can be regarded as valuable strategy to foster both emotional development and academic performance among pre-service teachers. These aspects are particularly relevant, given that pre-service teachers often show disinterest in, or even avoidance of, mathematics.

Keywords **–** Mathematic education, Gamification, Escape room, Emotions, Academic performance, Pre-service teachers.

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1. Introduction

Ensuring adequate mathematics comprehension in the population is a fundamental priority in the general education system (Golding, 2018). Having mathematical skills grounded helps intellectual development,

orderly reasoning and prepared for logical and critical thinking, and the capacity for abstraction (Akbasli et al., 2016; Jeong & González-Gómez, 2026; Yore & Tang, 2022). Although the link between mathematics and society is strong, international educational reports such as PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) reveal a lack of mathematics skills in students, connected to a low interest in this discipline (PISA, 2023; TIMSS, 2024). Additionally, students often begin to show disinterest in mathematics from an early age (Brown et al., 2008; Montero-Izquierdo et al., 2025). This disinterest generates a negative image and can promote students to abandon the intention of choosing university careers related to mathematics and close disciplines (Ricoy & Couto, 2018). This disinterest may be caused because the teaching of mathematics has been approached in a theoretical-centered style and an absence of practical activities (Li & Schoenfeld, 2019). This approach may not be the most suitable to promote the students' learning, because the teaching-learning process should not be considered exclusively as the simply transfer of theoretical knowledge (Strayer, 2012; van-Aalderen-Smeets & van-der-Molen, 2015). Providing a sense of achievement and autonomy to learners over their education is essential to effective learning (Zayapragassarazan & Kumar, 2012). However, effective learning could be difficult to accomplish when mathematics contents are taught. That is because of the difficulties that students might have in solving mathematical operations and understanding certain abstract contents (Sarı et al., 2018; Srikoom et al., 2018).

To reverse the students' difficulties and disinterest in mathematics teaching-learning process, active learning methodologies are introduced with the aim of involving the student as a protagonist in the teaching-learning process (Freeman et al., 2014; Jeong & González-Gómez, 2025a; Lugosi & Uribe, 2020; Vale & Barbosa, 2023). Specifically, gamification employs common game elements in non-game contexts with the objective of favoring the teaching-learning process (Deterding et al., 2011). Here, the educational escape rooms are instruments that require students to contribute to collaborative tasks designed to achieve skills and knowledge towards certain content with the aim of escaping from a room by solving puzzles in a limited amount of time (Nicholson, 2018). The use of escape rooms as a teaching strategy is related to enhancing students' engagement and motivation (Lopez-Pernas et al., 2019; Yllana-Prieto et al., 2023a). According to Kinio et al. (2019) and Jenkins and Mason (2020), using educational escape rooms foster students' abilities like problem solving are helping them to understand the content. Regarding higher education, several studies have pointed out that different learning components are promoted, highlighting the motivation, interest and fun felt by students when an educational escape room was implemented (Brown et al., 2019; Pérez-Vázquez et al., 2019; Sierra & Fernández-Sánchez, 2019). On the other hand, these authors also show that the use of educational escape rooms is very useful to foster collaborative and teamwork between students (Brown et al., 2019; Pérez-Vázquez et al., 2019; Sierra & Fernández-Sánchez, 2019).

Studying emotions is crucial to mathematics education in every educational level as well as during transitions between steps of education (Di-Martino et al., 2023). According to Schoenherr et al. (2025), understanding the variety of emotions in the teaching and learning process is an important objective of research in mathematics education. Emotions and cognitive processes are connected and difficult to separate, the cognitive domain conditions the affective domain and vice versa (Frijda, 2000). Furthermore, there is a significant correlation between emotions and the concept's retention, as information that is complemented by emotional incentives is better remembered than information that is not (Dunsmoor et al., 2015). Likewise, it is important to be careful with the balance between positive and negative emotions when carrying out a didactic intervention (Jeong et al., 2019). Positive emotions increased factors like attention, motivation to learn, memory, or performance, and negative emotions could have a diminishing effect in these factors (Li et al., 2020). Here, several studies pointed out that escape rooms used such as didactic tools in the context of gamification methodology could have beneficial effects on the emotional dimension of students, increasing their positive emotions and decreasing negative emotions about the contents taught (Brown et al., 2019; Gómez-Urquiza et al., 2019; Yllana-Prieto et al., 2023b).

Teaching mathematics requires a deep cognitive dimension that enables teachers not only to teach knowledge, but also to cultivate critical skills in students (Horzum & Duran, 2024; Jeong & González-Gómez, 2025b; Su et al., 2016). In fact, professors with a wide cognitive dimension and high performance can implement more effective pedagogical strategies regarding certain content. Likewise, a deep understanding of mathematical concepts by the teacher not only improves teaching performance but also translates into more meaningful learning for their students, a fact that benefits the educational environment (Charalambous et al., 2020). Teachers with broad cognition about the matter, especially in mathematics, can implement more effective pedagogical strategies as they can adapt their teaching methods to meet the individual needs of their students (König et al., 2021). In addition, their content knowledge allows them to explain complex concepts in a clear and accessible way, which facilitates their students' understanding and learning. Regarding the influence of the educational escape rooms on the cognitive dimension and performance, several authors such as Claudio et al. (2019) and Fuentes-Cabrera et al. (2020) work on mathematics content employing educational escape rooms. It should be noted that these studies indicate an improvement in the students' cognitive dimension throughout a higher academic performance.

Therefore, this study focuses on analyzing the pre-service teachers' emotional dimension (positive and negative emotions) and academic performance before and after completing an escape room designed to work on mathematics content.

2. Methodology

With the aim of improving the students' interest and motivation towards mathematics, an escape room to work on mathematics content was designed and implemented. To measure the effects of this escape room in the pre-service teachers' emotions and performance, a quantitative study was conducted. Here, the answers compiled in the pre-test and post-tests were compared. Moreover, the correlation between these variables was assessed. The study was conducted during two academic years.

2.1. Sample

The sample consists of 119 students enrolled in the subject "Mathematics and its Didactics" in the second year of the Primary Education degree. Thus, the participants are pre-service teachers at Teaching Training College of Authors' University. Data were collected over two academic years. Of the total, most were women (65.6%) and the rest were men (34.4%). The average age was 20 years. Regarding their pre-university background, 55.5% of the pre-service teachers had studied non-scientific track, while 44.5% had followed a scientific track. The sociodemographic characteristics disaggregated by academic year are presented in Table 1.

Year	n	Gender		Background	
		Women	Men	Non-science	Science
First	65	46	19	35	30
Second	54	32	22	31	23
Total	119	78	41	66	53

Table 1. Participants (n), gender, and preuniversity background of the sample

2.2. Instrument

To analyze the influence of the mathematics escape room in the emotional dimension and academic performance of students a two-sections questionnaire was designed (Appendix I).

The first part analyzes the students' emotions. This section studies a total of 14 emotions (7 positive and 7 negative ones). Particularly, the positive emotions analyzed are joy, satisfaction, enthusiasm, fun, confidence, hope, and pride. Likewise, the negative emotions are uncertainty, nervousness, worry, frustration, boredom, fear, and anxiety. The students were asked to evaluate on a 5-point Likert scale the

intensity of each emotion that they felt before and after its development. This part of the instrument derives from the Achievement Emotions Questionnaire (AEQ) of Pekrun et al. (2011). Recently, the AEQ has been revised, updated, and its internal consistency validated through robust statistical analyses by different researchers (Goetz et al., 2016). The emotions were chosen based on their frequency among students (Pekrun et al., 2011).

The second part of the questionnaire aims to examine the academic performance of students with 10 multi-choice questions about contents worked in previous theoretical classes and reviewed in the mathematics escape room. The questions in this part consist of content of the first three topics in the subject "Mathematics and its Didactics." These topics cover concepts of natural numbers, arithmetic operations, and divisibility of numbers. The grades in this section follow a scale of 1 to 10 points. The questions are elaborated by the authors and were reviewed and modified by a panel of experts consisting of researchers of the topic and experienced professors of didactics of mathematics.

The different sections of this questionnaire have been tested and employed in previous studies (Jeong et al., 2019; Jeong & González-Gómez, 2025a; Yllana-Prieto et al., 2023b). Likewise, the instrument and its procedures were authorized by the Bioethics Committee of University of Extremadura (94/2018 and 200/2024) to gather the pre-service teachers' data before commencing the research. Here, participants consented to use this questionnaire to collect data.

2.3. Intervention

The escape room developed focuses on the study of numbers and was employed as a review to emphasize the contents taught in theoretical classes. Specifically, the nature of numbers, numerical systems, base changes, simplification methodologies, multiples and divisors, and arithmetic operations are worked on. This intervention was designed to be solved in groups. At all times the teachers of the subject assumed a guiding role and were attentive to the doubts of each pair of students, as well as checking the correct resolution of some challenges.

The first 10 minutes were dedicated to explaining what an escape room consists of, and several rules and tips were specified to face the activity correctly. As this is an activity that works on mathematical content, it was contextualized around the writer and communicator Ian Nicholas Stewart. At each workstation, each group of students found a big box closed by a padlock and a letter. The letter contained a message from Dr. Stewart in which he is angry about the lack of knowledge and interest of today's young people in mathematics, so he has locked them in the classroom, and they must solve challenges for their supporters, the professors, to give them the key to escape. The escape room has a linear design, which means that the different challenges must be solved in order with the objective of opening 3 boxes locked by different padlocks (Wiemker et al., 2016). To ensure the linear format, the big box contained the medium box and a challenge. Likewise, the medium box contained the small box and a challenge.

The first challenge to obtain the combination that opens the first box consisted of two tasks. In the first task, students had to fill in a base-4 addition table to discover the first two digits of the combination (they were in a specified position of the table). In the second task, they had to find out how many prime numbers there are from 0 to 120 using the Eratosthenes Sieve method (this provided the last two digits of the padlock). To open the second box, students had to complete a triple challenge. First, they solved a word search about general concepts of numbers and their properties. Each word had a Roman number associated, and they had to use these numbers to do a calculation (this task gave them the first number of the combination). The second task consisted of solving a multiplication problem using the ABN method (Open Number Based Algorithm), and the sum of the results gave them the second digit of the padlock. In the third task, they had to find the GCD (Greatest Common Divisor) of two groups of numbers and divide the results to obtain the third digit of the padlock and open the second box. The students found plastic pieces and instructions inside the box. In this challenge, they had to build a cube with the instructions provided to subsequently find its capacity and obtain the key of the last padlock. Inside the third box, they found different Cuisenaire rods. In the last challenge, they had to express the capacity of

the cube in milliliters using the rods. If the completion of this last challenge was approved by the professors, the students obtained the key to the laboratory and were able to escape. Figure 1 shows a general outline of the developed intervention.

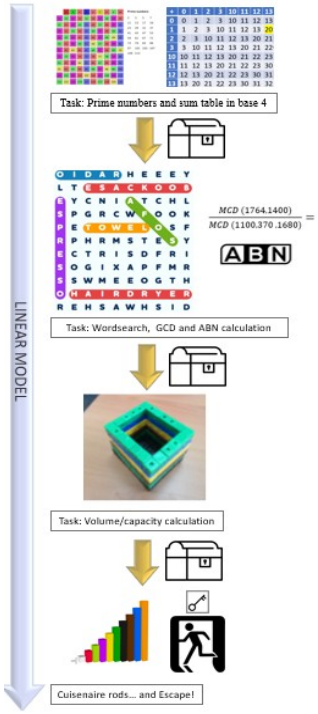

Figure 1. General outline of mathematics escape room

3. Results

The results compiled during two academic years were analyzed separated by academic cohort to observe if the results were maintained over time. Particularly, a study of emotional dimension (examined for each emotion individually) and average values of students' academic performance were analyzed. With the scope of testing the connection between emotional dimension and academic performance, the correlations between emotions and performance were examined.

3.1. Statistical Data Analysis and Internal Consistency of Questionnaire

With the aim of achieving a quantitative analysis of the data compiled, different statistical analyses were applied. Although the instrument has been tested in other studies, Cronbach's α test has been performed to test if the Likert questionnaire has internal consistency. The Cronbach's α values for each construct of emotional dimension instrument are: 0.93 for positive emotions, and 0.84 for negative emotions. The values of Cronbach's α are higher than 0.7 so the instrument is robust.

Then, the Kolmogorov-Smirnov normality test was performed to establish whether the data were normally distributed or not. Data were not normally distributed ($p<0.05$ in all the variables after implementing Kolmogorov-Smirnov test), thus non-parametric statistical tests were used. Since the data are not paired, they were statistically analyzed as independent groups. Therefore, the Mann-Whitney U-test was employed to establish the existence of significant differences between the values of the pre- and post-test. To assess the differences size between the mean values of pre- and post-test, the Rank Biserial Correlation test (effect size) was employed. According to López-Martín and Ardura-Martínez (2023), this value is equivalent to different effect sizes: < 0.1 (very small–no significant), 0.1-0.29 (small), 0.3-0.5 (medium), and ≥ 0.5 (large). With the aim of examine the correlations between variables, Spearman Coefficient test was implemented. Statistical software Jamovi (2.6.26 version) and JASP (0.19.3 version) have been employed.

3.2. Analysis of Emotional Dimension

To analyze the change that students may have felt in their emotional dimension, the average values of their responses for each emotion before (pre-test) and after (post-test) completing the mathematics escape room were analyzed, splitting the data by year to see if the effect was maintained.

Firstly, to analyze which differences were statistically significant, the Mann-Whitney U-test and the Rank Biserial Correlation test (effect size) were performed. Of the 14 emotions analyzed, the 7 positive emotions had a statistically significant change between pre- and post-test in both academic years. Regarding the negative emotions, only two emotions (uncertainty and fear) had significant differences between pre- and post-test in the data of the first academic year and none in the second academic year. Table 2 shows the results of the p-value in Mann-Whitney U-test and the effect size values, as well as the average values of the data, split by academic year.

Emotion	Year	Pre-test	Post-test	p-value	Effect size
Joy	First	3.86	4.25	0.02	0.22
	Second	3.52	4.09	0.01	0.29
Satisfaction	First	3.63	4.29	0.00	0.34
	Second	3.46	4.20	0.00	0.39
Enthusiasm	First	4.11	4.43	0.02	0.21
	Second	3.50	4.16	0.00	0.32
Fun	First	4.11	4.48	0.02	0.21
	Second	3.69	4.13	0.04	0.22
Confidence	First	3.37	4.03	0.00	0.34
	Second	3.24	3.89	0.00	0.33
Hope	First	3.58	4.00	0.02	0.23
	Second	3.52	3.98	0.02	0.26
Pride	First	3.42	4.10	0.00	0.32
	Second	3.19	4.11	0.00	0.47
Uncertainty	First	3.68	3.16	0.03	0.22
	Second	3.41	3.42	0.96	0.01
Nervousness	First	3.18	3.25	0.77	0.03
	Second	3.11	3.05	0.84	0.02
Worry	First	2.46	2.24	0.35	0.09
	Second	2.59	2.40	0.36	0.10
Frustration	First	2.00	2.46	0.06	0.19
	Second	2.07	2.20	0.70	0.04
Boredom	First	1.23	1.32	0.58	0.04
	Second	1.57	1.60	0.76	0.03
Fear	First	1.92	1.57	0.03	0.20
	Second	1.94	1.76	0.34	0.10
Anxiety	First	2.05	2.03	0.59	0.05
	Second	2.09	2.16	0.71	0.04

Table 2. Average values of pre- and post-test, p-value of Mann-Whitney U-test and effect size by year

According to Mann-Whitney U-test, there are several significant differences between the pre- and post-test average values. Concerning positive emotions, all of them increased significantly after pre-service teachers performed the intervention. These results are significant in both academic years. Related to effect size analysis, most emotions with significant differences have a small effect size, except for satisfaction (both years), enthusiasm (second year), confidence (both years), and pride (both years), which have a medium effect size. Moreover, the negative emotions, uncertainty, and fear had a decrease after

implementing the escape room in the first academic year. These findings were not maintained the following academic year. To visualize the results in a general overview, Figure 2 shows the medians of emotions with significant differences before and after the intervention for each academic year.

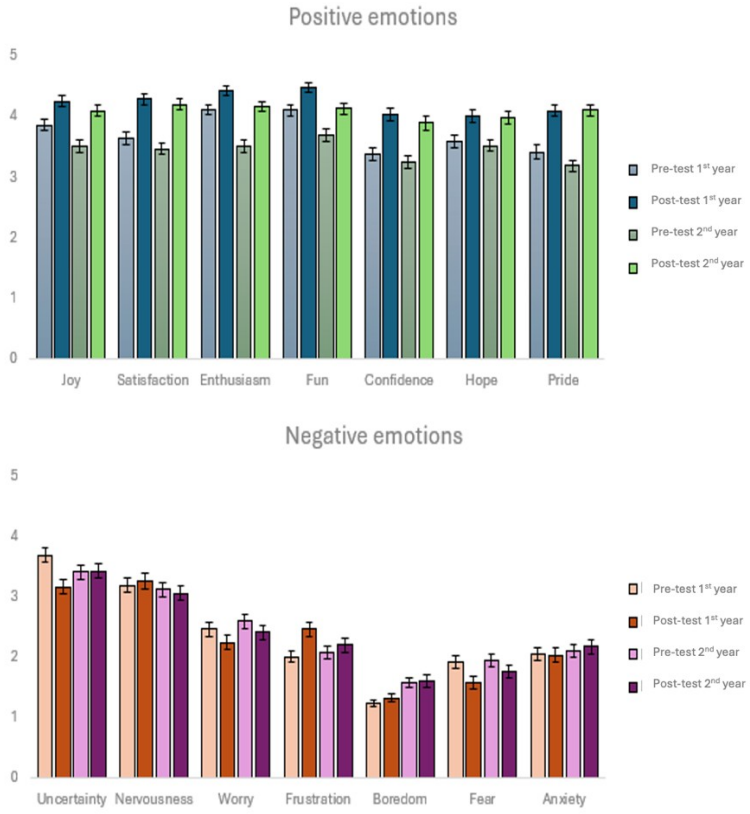

Figure 2. Emotions before and after the escape room split by academic years

As can be seen in the data represented in Figure 2, most of the means increase positive emotions after students complete the escape room with a small and medium effect. Regarding the negative emotions with significant differences, the means decrease after the escape room with a small effect (except for the uncertainty of the first academic year, where they have the same mean value). These graphs are also useful to understand the distribution of the data (above the boxes). It can be observed that there is a greater distribution of the data in higher values of positive emotions than in lower values after implementing the escape room. Likewise, the data distribution is higher in low values of negative emotions after pre-service teachers performing the escape room.

3.3. Analysis of Academic Performance

This study also aims to analyze the effect of the mathematics escape room in the academic performance of the pre-service teachers. After employing the Mann-Whitney U-test, a p-value<0.01 is observed in both academic years, which means that there are significant differences between the pre- and post-test responses. Moreover, the effect size test indicates that the effect of the designed intervention was medium, with effect size values of 0.45 in first academic year and 0.44 in second academic year.

Specifically, the average values after the intervention were higher in both academic years. During the first academic year, students obtained an average of 6.58 (1 to 10 scale) in the pre-test. After implementing the mathematics escape room, pre-service teachers had an average of 7.94. That is an increment of 1.36 points in the content test. Figure 3 shows a box plot indicating the median (line), the mean (point), and the data distribution (violin plot) of these results.

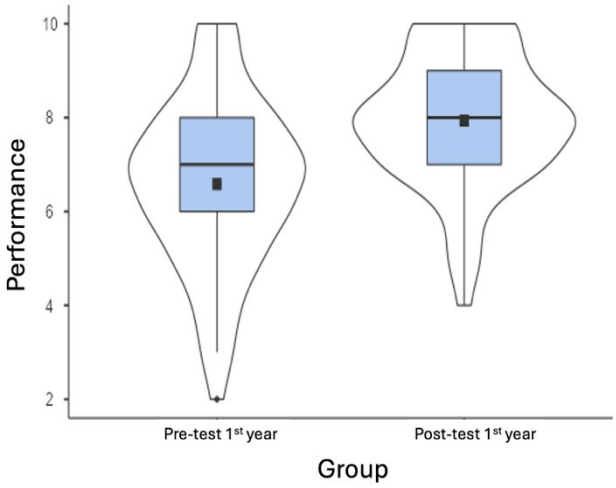

Figure 3. Performance results in the first academic year

Likewise, the average values after the intervention were higher in first academic year. Here, pre-service teachers had an average of 6.35 (1 to 10 scale) in the pre-test. After implementing the mathematics escape room, participants had an average of 7.67. That is an increment of 1.32 points in the content test. Figure 4 shows a box plot indicating the median (line), the mean (point), and the data distribution (violin plot) of these data.

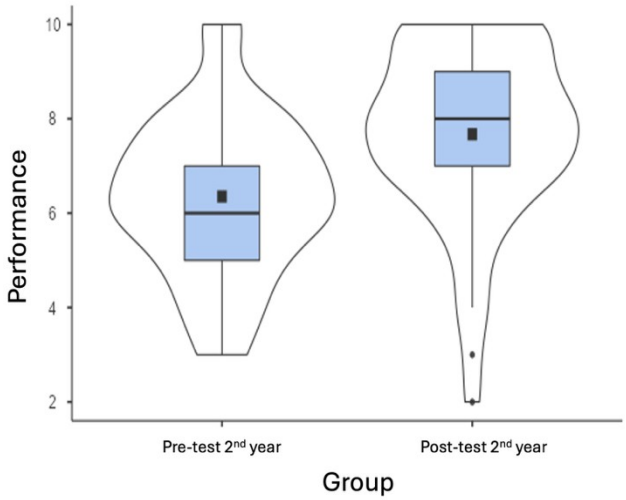

Figure 4. Performance results in the second academic year

Although there were certain differences between the initial and final level of knowledge between academic years, the increment of the students' grades was very similar (1.36 and 1.32). This fact demonstrates the efficacy of the intervention on students' performance, which has been maintained over time for two consecutive academic years.

3.4. Correlations between Emotional Dimension and Academic Performance

With the aim of completing the study of the students' academic performance in mathematics content, a correlation analysis was carried out to observe if emotions have influenced in the academic performance of pre-service teachers and how these relationships are. This correlation analysis complements the research. The previous analyses have been carried out to observe specific changes in the study variables before and after the escape room, and the global analysis of correlations has been carried out to identify general patterns of association between variables that may be useful for future research or educational interventions.

Although the descriptive and comparative analysis of emotions and academic performance has been carried out separating the data by academic years to observe the specific effects of the mathematics escape room on each of the variables, the analysis of correlations between these variables has been carried out using the complete data set. This has been done because both academic years share a similar educational, curricular and methodological context. By combining the data from both academic years, the sample size is increased, which facilitates obtaining more reliable results of the correlations between variables. In addition, the correlation analysis aims to explore the general relationship between emotions and academic performance in the context of the study, regardless of the academic year.

As previously analyzed, the data do not have a normal distribution, thus nonparametric statistical tests were selected. Spearman Coefficient was employed to analyze the correlations between the 14 emotions and academic performance. This coefficient compares each variable pairwise and provides a value between -1 and 1 depending on whether there is a positive or negative correlation. These correlations, even if they have low values, are statistically significant when p-value<0.05. According to Spearman Coefficient results, there are positive and negative emotions that have significant correlations with students' performance. Table 3 shows the Spearman Coefficient value of every emotion with academic performance and their p-value.

Emotion	Spearman Coefficient	p-value
Joy	+0.20**	0.002
Satisfaction	+0.29***	< 0.001
Enthusiasm	+0.21**	0.001
Fun	+0.22***	< 0.001
Confidence	+0.20**	0.002
Hope	+0.18**	0.005
Pride	+0.23***	< 0.001
Uncertainty	-0.15*	0.018
Nervousness	-0.09	0.195
Worry	-0.12	0.073
Frustration	-0.10	0.127
Boredom	-0.21**	0.001
Fear	-0.19**	0.003
Anxiety	-0.13*	0.049

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 3. Correlation results between emotions and academic performance

Although correlation analysis provides an overview of the connections between emotions and academic performance, it is interesting to observe the impact of each emotion individually. The p-value indicates that effects of all positive emotions and several negative emotions (uncertainty, boredom, fear, and anxiety) are statistically significant. Particularly, positive emotions had positive correlation and negative emotions had negative correlation with performance. The emotions that have the greatest influence on pre-service teachers' performance are satisfaction, pride and fun. In the case of negative emotions, the ones that most negatively influence students' academic performance are boredom and fear. Thus, it is important to consider not only positive emotions but also negative emotions, especially uncertainty, boredom, fear, and anxiety. Emotions such as nervousness, worry and frustration do not seem to have a significant influence on students' academic performance in this intervention.

4. Discussion and Conclusion

To address the increasing disinterest of students in mathematics, innovative approaches have been explored to enhance the engagement with mathematics content. Among these approaches, gamification

and educational escape rooms have emerged as promising tools to foster motivation and improve the teaching and learning of complex concepts. The present study examines the effects of implementing a mathematics escape room on pre-service teachers' emotional responses and academic performance.

Findings on mathematics-related emotions and motivation are still too scarce to derive firm conclusions based on cumulative, consistent evidence across studies (Schukajlow et al., 2017). However, the results of the students' emotional dimension found in this research are generally positive. Most positive emotions are increased after completing the escape room during the two academic years. Concerning negative emotions, only uncertainty and fear had a significant decrease after students perform the escape room. According to the effect size analysis, the mathematics escape room has had small and medium effects on emotions with significant differences. Several authors have pointed out that, in education, small effect sizes are common due to the complexity of teaching-learning processes and the simultaneous influence of multiple contextual variables (Kraft, 2020; Lipsey et al., 2012). In this context, even small effects can be considered relevant from an educational perspective, especially when it involves affective variables that are more resistant to change than cognitive outcomes (Pekrun et al., 2017). Furthermore, the fact that several emotions have medium effect sizes reinforces the potential of the designed intervention, in line with previous studies, that emphasize that modest but consistent improvements in emotional domain can have a relevant cumulative impact on motivation and mathematical learning in the medium and long term (Hattie, 2008; Pekrun et al., 2017).

According to Kanefke and Schukajlow (2024), the emotional dimension is especially relevant in the teaching and learning of mathematics due to its difficulty and the general students' disinterest. Therefore, identifying how emotions influence and their connection with the teaching and learning process in higher education is an important aspect for teacher training and the educational system (Del-Rosal & Bermejo, 2017). Results about an overall significant increase in emotions have been described in other research using escape room-based activities to teaching mathematical concepts (Glavaš & Staščik, 2017; Sánchez-Ruíz et al., 2022). Here, different authors (Jeong & Mateos-Serrano, 2025; Saleh-Alabdulaziz, 2023) demonstrated the positive effect on the students' positive emotions after completing escape room games to work on mathematics contents. Fostering a positive emotional dimension is especially relevant in pre-service teachers because they could transfer their emotions to their students (Jeong et al., 2019). In fact, according to several studies, not only does the emotional dimension help to improve students' attention in the teaching and learning process, but high academic grades also predict positive emotions (Hayat et al., 2020; Todd et al., 2020). On the other hand, negative emotions like frustration and nervousness could be found in escape room games, but this is typical in this type of activity due to the game components (Clauson et al., 2019).

The study also shows that pre-service teachers' performance increased after escape room. Related with these results, several studies highlight successful practices through a gamification approach in higher education and even reveal that students who participate often achieve better academic performance (González, 2014; González-Gómez & Jeong, 2022; Wiggins, 2018). Here, according to Clark et al. (2010) and Jenkins and Mason (2020), gamification helps working memory, which is fostered by motivation and meaningful engagement during the teaching and learning process. In the designed escape room, the pre-service teachers had to solve problems for themselves that require them to apply reason (Jenkins & Mason, 2020). Particularly, the research results are in line with recent studies, indicating that students achieve better academic performance when mathematical content is worked through educational escape rooms (García-Tudela et al., 2020; Saleh-Alabdulaziz, 2023). These findings are significant in education because the main objective of every teaching methodology is to promote better learning for students (Miller et al., 2020). As previously mentioned, teaching mathematics involves a deep development of cognitive dimension that allows pre-teachers not only to teach content, but also to cultivate critical skills in students (Horzum & Duran, 2024; Su et al., 2016). Thus, according to Charalambous et al. (2020), a complete knowledge of mathematical contents by the teacher not only improves teaching performance but also implies more meaningful learning for their students, a fact that benefits the teaching and learning process.

Related to the correlation analysis, it is important to clarify that the presence of significant correlations between variables does not necessarily imply causality and that these variables are interdependent, but it is a useful analysis for making a general interpretation that emotions influence academic performance (Cohen et al., 2013; Pekrun et al., 2017). In this context, several research pointed out the close relationship between emotions and academic performance (Eldar & Niv, 2015; Frijda, 2000). Research in achievement-emotion theory demonstrates that positive emotions are consistently associated with academic engagement and improved academic outcomes, even if the connections are modest (Pekrun et al., 2017). According to Iqbal et al. (2024), although these correlations do not imply direct causality, fostering positive emotional experiences in educational interventions can create conditions that indirectly enhance students' academic performance. In fact, according to Dunsmoor et al. (2015), information that is supplemented by positive emotional incentives is better remembered and saved in memory. In this sense, several authors highlighted that emotional dimension has a significant role in teaching and learning process due to it is directly connected to the academic performance (Méndez-Aguado et al., 2020; Schenk et al., 2021). Here, emotional dimension benefits to enhance students' attention in class, and it supports the meaningful knowledge (Mora, 2016). The positive emotions that students feel are essential due to their influence in their deep learning and high motivation to study a particular content (Aydogan et al., 2015; Jeong & González-Gómez, 2022). Similarly, emotional rejection is one of the main causes of student failure, especially in mathematics, because they usually feel negative emotions, such as fear, nervousness or worry (Eynde et al., 2006; Sutter-Brandenberger, 2018). Also, previous studies have indicated that high students' academic performance predict positive emotions such as joy, enthusiasm, and pride (Hayat et al., 2020; Todd et al., 2020).

The findings of the present research highlight significant positive effects in the emotions and performance of the pre-service teachers who participated in the study. Regarding the pre-service teachers' emotional dimension, the results reveal a general improvement of emotional dimension. Specifically, there was a general significant increase in all positive emotions analyzed after pre-service teachers finished the mathematics escape room. This improvement in positive emotions is observed in the two academic years. Therefore, it can be concluded that the mathematics escape room is successful in its purpose to improve and foster pre-service teachers' positive emotions. However, most negative emotions did not have significant variation. Here, a decrease of uncertainty and fear was observed during the first academic year, but this decrease was not continued in the successive academic year. Moreover, negative emotions can function as learning activators in certain conditions such as gamification activities where the player is immersed in the task. Related to academic performance of participants, it was observed that the average values of pre-service teachers' grades had a significant increase after completing the mathematics escape room. The performance results are in line with other studies that point out the success of mathematical contents worked with mathematics escape room in higher education. These findings are maintained during two academic years, which demonstrate that escape rooms employed as educational tools to work on mathematics content can be effective and beneficial for pre-service teachers.

Despite the generally positive outcomes, some limitations should be acknowledged. The results of the study may not be easily generalizable to other disciplines or groups of students, as it focused on mathematics pre-service teachers. The sample size may limit the representativeness of the results, and the subjective nature of the emotional assessments may affect the accuracy of the emotional data. Here, it could be interesting to have a long-term analysis and an addition of control group to compare effects between a traditional and an active methodology. Specifically, the absence of control group does not allow strong causal relationships to be established and prevents comparison with traditional methodologies (this is one of the lines of future work). However, even though there is no control group, it can be ruled out that the effects are due to intrinsic characteristics of the sample, as the intervention has been implemented over two academic years with similar results. Including a control group was not possible without affecting teaching planning. Furthermore, as this was an innovative intervention, the study was conceived as an exploratory phase aimed at assessing its feasibility and

impact in a real environment. Consequently, a pre- and post-test design was chosen, supplemented by comparisons with previous studies.

It is important to mention that during the development of educational interventions, there are factors that the instructor cannot control. In this context, several authors (Atteberry & McEachin, 2021; Hattie, 2008; Kunter et al., 2013) point out that variables such as the characteristics, motivation, and previous experiences of the students, the center environment, varying performance depending on the time of year, and even the intrinsic characteristics of the teacher (experience, motivation, training, and pedagogical skills) can influence the students' experience during educational activities.

In addition, several implications and future work are proposed. The results suggest that fostering positive emotions in learning environments can lead to better outcomes. This approach could be integrated into the teaching and learning process to improve both students' emotional dimension and pedagogical skills. Thus, this research offers a tool for employing an active pedagogical approach to address students' disengagement with mathematics, especially among future educators.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Authors' contributions

Jin Su Jeong, Félix Yllana-Prieto and David González-Gómez: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing—original draft, Writing—review & editing, Visualization,

Jin Su Jeong and David González-Gómez: Supervision, Project administration, Funding acquisition.

Data availability

Data available upon request

Use of Artificial Intelligence

The authors declare that the content of the article has not been developed using Artificial Intelligence.

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Appendix: Research instrument

Confidentiality of your data

According to current legal regulations, the results of the information obtained will be treated with total confidentiality. The data collection protocol will be archived, and each participant will be assigned a password so that the information obtained cannot be related to the identity of the subject. The data will be anonymized, ensuring the impossibility of inferring their identity, for further study and potential analysis.

For everything not provided for in this document, the current legislation on personal data protection will be applied (Law 41/2002 of November 14, 2002, basic regulating patient autonomy and rights and obligations regarding information and clinical documentation, BOE 274 of November 15, 2002; Organic Law 3/2018 of December 5 on Personal Data Protection and guarantee of digital rights, BOE 294 of December 6, 2018), on biomedical research (Law 14/2007, of July 3, on Biomedical Research; BOE 159 of July 4, 2007) and any other that may be applicable.

The results of the study may be published in scientific journals or general publications. However, the information concerning your participation will be kept confidential.

Participation in the questionnaire:

I AGREE TO PARTICIPATE IN THIS STUDY _____

I DO NOT AGREE TO PARTICIPATE IN THIS STUDY _____

Part 1: Emotions questionnaire

We are going to do a practical activity about learning concepts of mathematics through an Escape Room-Breakout. Indicate the emotions you feel BEFORE/AFTER this practice (from 1 -not at all- to 5 -very much or intensely-).

Joy: _____ Uncertainty: _____

Satisfaction: _____ Nervousness: _____

Enthusiasm: _____ Concern: _____

Fun: _____ Frustration: _____

Confidence: _____ Boredom: _____

Hope: _____ Fear: _____

Pride: _____ Anxiety:

Part 2: Academic performance questionnaire

Answer the following questions by ticking the option you think is correct (there is only one correct answer):

1. A natural number...
    a) can only be a multiple of two others.
    b) can be a multiple of only one number.
    c) can be a multiple of more than two numbers.
    d) all statements are correct.

2. An algorithm for finding prime numbers is...

    a) the filter of Eratosthenes.
    b) the method of Eratosthenes.
    c) the filter of Euclides.
    d) the method of Euclides.

3. For (X) to be divisible by (Y), it must be the case that...

    a) X by Y is an exact division.
    b) X by Y is an integer division.
    c) depends on X and Y.
    d) X by Y is a split division.

4. What is the name of the technique of decomposing an algebraic expression into factors in a product form?

    a) simplification.
    b) fraction.
    c) commutation.
    d) factorization.

5. Manipulative material for learning mathematics through experimentation, especially in Primary School:

    a) Pasteur rods.
    b) Euclides rods.
    c) Cuisenaire rods.
    d) Arquimedes rods.

6. Method for multiplying or dividing that allows the correct solution to be given in different ways decomposing the numbers without applying a certain rule.

    a) Greatest Common Multiple.
    b) ABN method.
    c) Least Common Multiple.
    d) Greatest Common Divisor.

7. The Greatest Common Divisor (GCD) of several numbers is...

    a) the biggest number that divides them leaving remainder 0.
    b) the smallest number that divides them leaving remainder 0.
    c) the greatest common multiple of all of them that is not 0.
    d) the least divisor multiplied by the greatest divisor of these numbers.

8. Regarding volume and capacity:

    a) capacity is the amount of space a body occupies.
    b) volume is the amount of space that occupies inside a body.
    c) capacity is the amount of space that occupies inside a body.
    d) none of the above is correct.

9. The volume of a sphere is...

   a) 1/2 x π x r2.
   b) 2 x π x r.
   c) π x r2.
   d) 4/3 x π x r3.

10. If a sphere of volume 5 ml is inside a bucket with a capacity of 10 ml, the amount of water that will occupy if we put it inside is...

   a) 5 ml.
   b) 10 ml.
   c) 15 ml.
   d) No more water can fit inside.

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