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Research article

Influence of two educational Escape Room– Breakout tools in PSTs' affective and cognitive domain in STEM (science and mathematics) courses

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ABSTRACT

During the last decade, there has been a strong emphasis on developing new instruction methodologies for the effective teaching of different contents. Here, it is important to teach Science, Technology, Engineering and Mathematics (STEM) education, specially, in scientific and mathematical concepts. In the context of active learning and gamification, educational Escape Room – Breakout (ERB) could be a useful strategy to improve students' affective and cognitive domain towards STEM (science and mathematics). Thus, two didactic tools, based on an ERB, have been designed to teach science and mathematics contents. This research compares the influence of two ERBs (Science ERB and Mathematics ERB) in Pre-Service Teachers' (PSTs) affective domain (emotions, attitudes, and self-efficacy towards STEM) and cognitive domain (performance). Non-parametric statistical tests were used, the Mann-Whitney *U* test was applied to measure significant differences between the variables in the two ERBs. Spearman correlation coefficient was implemented to measure the correlations between the study variables. The results show that there is a significant increase in positive emotions in both ERBs. The emotions "joy", "fun", and "nervousness" are significantly higher after the Science ERB, and the emotion "fear" is lower with respect to the Mathematics ERB. In the self-efficacy and attitudes analysis, a significant increase of 8 items of the questionnaire is observed in the Mathematics ERB with respect to the Science ERB. According to performance analysis, PST grades have been increased after each ERB. Finally, the correlation analysis between variables indicates that positive emotions, high self-efficacy, and positive attitudes increase the PSTs' performance. Here, high values of these variables are related to high values on the theoretical content test after both ERBs. According to these results, the two ERBs used could have several advantages in the PSTs' affective and cognitive domain.

1. Introduction

Science, Technology, Engineering and Mathematics (STEM) education has gained attention in the educational field [1,2]. The National Science Foundation (NSF) introduced the term "STEM" in 1990 as an acronym for Science, Technology, Engineering and Mathematics although it was not until decades later that the concept gained the importance it has today [3]. According to Ref. [4]; STEM education proposes the integration of various scientific disciplines as a cohesive entity whose teaching is integrated and

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synchronized as they are used in problem solving in ordinary situations. STEM education has been able to involve its fields, as well as interdisciplinary or cross-disciplinary combinations of individual STEM disciplines [5]. Various authors [2,6] have pointed out that a STEM approach could positively influence Pre-Service Teachers' (PSTs) performance in science and mathematics courses. Some educational skills such as creativity, critical thinking, problem solving or collaborative working cannot be acquired by the students with the traditional education approach, but STEM education could help students to develop these abilities [2,7]. Particularly, students' disinterest has been one of the principal causes of negative attitudes toward STEM contents in science and mathematics fields. The application of STEM methodologies, specifically science and mathematics disciplines, could be useful to promoting scientific and mathematic knowledge for students [6,8]. However, in general, the teaching of STEM contents has generated disinterest or apathy due to its difficulty and to the fact that this content has generally been taught by focusing on theoretical content, letting practice content in the background [9,10].

Active learning is a learner-centered teaching strategy that requires the students' participation in activities designed to engage students in their learning. These activities involve answering questions, solving problems, discussing content, teaching others, and externalization of cognitive processes to achieve a meaningful learning [11,12]. Recently, active learning has gained importance in university teaching, especially in STEM contents on science and mathematics [13]. Different research studies [14–16] have shown that active learning has important advantages that can influence students' achievement like the improvement of their performance, interpersonal and social skills, motivation, teamwork, or a better understanding of some concepts. Related to active learning, gamification is a learning methodology inside active learning approach [17]. This learning strategy involves the use of game design elements in non-game contexts, especially in the educational field, to promote different skills [18]. The use of gamification strategies in a classroom could increase students' positive emotions or performance [19,20]. Here, the design of gamified tools or strategies have been providing the opportunity to work with a multi-disciplinary approach, considering the importance to promote this in STEM environment [21–23].

According to the problems in the learning of STEM courses and the use of active learning strategies and gamification to improve this learning, this paper tries to answer whether there are any differences and similarities between two didactic tools for teaching science and mathematics contents based on gamifying Escape Room and Breakout in PSTs' affective domain (emotions, attitudes, and self-efficacy towards STEM) and cognitive domain (performance). To answer these questions, it is necessary to examine and clarify the concepts of Escape Room and Breakout in the educational context, as well as their possible effects on the study variables.

There are different procedures, strategies or tools that could be applied within the context of gamification methodology [24]. Here, the use of Escape Room – Breakout (ERB) games as educational tools has increased in recent years [25,26]. Escape Rooms are live-action and team-based games where participants discover clues, solve puzzles, and accomplish challenges in one or more rooms to escape from the room in a certain amount of time [27,28]. Educational Escape Rooms usually combine with Breakout games [29,30]. Breakout games are similar to Escape Room games. Breakout is a game in which the aim is to open one or more boxes locked with different types of padlocks. To get the codes that open them, it is necessary to solve problems, quizzes or clues, in order to reach to reach a final challenge that is found inside the last box [31,32]. These educational games generally have challenges that integrate the use of technological tools such as mobiles. In this sense, a correct integration of these tools with the contents, duration and difficulty of the intervention is important [33,34]. Various research studies have highlighted the effective application of Escape Room – Breakout as a didactic tool in university teaching [25,35,36]. By using Escape Room and Breakout as a didactic tool, students solved problems for themselves that required them to apply reason, sensation, and reflection, and it could improve averages and understanding of concepts [37,38]. Active learning, gamification in general, and Escape Room – Breakout games can improve the cognitive and affective domains of students [22,39,40]. Here, several studies highlighted that following an active methodology using educational ERB generated positive emotions such as joy, enthusiasm, or fun, as well as more positive attitudes and greater student self-efficacy towards STEM content [41–43]. However, it is possible that some negative emotions, such as anxiety or frustration, may appear during a gamifying ERB due to the difficulty of a task, the time taken to solve it or the participant's lack of knowledge [40,44,45].

Traditionally, STEM courses, especially science and mathematics contents courses, have caused disinterest and negative emotions at an early age, producing students to have a negative image of STEM contents in general [46]. Thus, the affective domain in STEM teaching and learning has been played an essential role due to emotional component is directly related to the cognitive domain [47]. Fostering positive emotions and attitudes towards STEM could be especially useful for PSTs, who feel competent, interest and qualified for STEM teaching [47,48]. The term self-efficacy, introduced by Bandura, is a subjective judgement of person's level of competence in executing certain behaviors or achieving certain outcomes in the future. That is, the belief a person has to think that they can do what they have to do [49]. In a teaching and learning process, self-efficacy should be considered because it has been related to the students' motivation, performance, and ability to develop their academic and professional interests, especially in PSTs [50,51]. Specifically, it is important to generate positive emotions, high self-efficacy, and better attitudes towards STEM in PSTs, because if they feel competent and qualified to teach STEM, they will generate more STEM interest in future generations [48,52].

According to the bibliography found, it was decided to design a tool based on the combination of Escape Room and Breakout because it was a methodology that adapted well to the contents taught. Therefore, the main objective of this research is to compare the effects of two didactic tools based on gamifying ERB in PSTs' affective domain (emotions, attitudes, and self-efficacy towards STEM) and cognitive domain (performance). Specifically, two didactic tools have been designed, an ERB to teach science contents (Science ERB) and an ERB to teach mathematics contents (Mathematics ERB).

2. Methodology

To analyze the influence of the ERBs in the PSTs' affective domain, a comparative study was conducted between the responses of the post-tests in the two ERBs. To study the effects of the ERBs in the PSTs' cognitive domain, it was analyzed the results of the pre- and post-test in the two ERBs.

2.1. Sample and courses context

The research has been developed in two courses of experimental sciences and mathematics in the second year of the Primary Education degree in a Spanish University during the 2020/2021 course. Specifically, these courses were "Teaching of matter and energy" and "Mathematics and its Didactics". The Science ERB was implemented in the course "Teaching of matter and energy" and the Mathematics ERB was developed in the course "Mathematics and its Didactics". The questionnaire as an instrument and its protocols were permitted by the bioethics committee of University of Extremadura (94/2018) to gather the PSTs' data before commencing the research. In the actual survey, respondents consented for using questionnaire to collect data.

The sample consists of 65 PSTs and all of them were enrolled in both courses. The PSTs who participated in the research had an average age of 20 years old. Approximately two thirds of the sample were women, and most of them had studied Humanities or Social Sciences (50.77%), or Sciences (38.46%) during their pre-university education. Almost all of them had studied in a High School (96.92%) before accessing to the university. Fig. 1 provides more complete demographic information about the sample. No constraints were imposed, and the PSTs freely choose whether they wanted to participate in this research.

2.2. Instruments

A questionnaire was designed to be used as an instrument to measure the different studied variables. The questionnaire consisted of three sections, and it was applied before and after each intervention (pre- and post-test).

The first section contained 14 items about the emotions that PSTs felt about the ERB. Precisely, 7 positive emotions (joy, satisfaction, enthusiasm, fun, confidence, hope, and pride) and 7 negative emotions (uncertainty, nervousness, worry, frustration, boredom, fear, and anxiety) were assessed.

The second part of the questionnaire aimed to analyze self-efficacy and attitudes that PSTs have towards STEM (science and mathematics), this part consisted of 28 items.

These two sections of the questionnaire were based on quantitative items that were measured by a five-point Likert scale from 1 to 5. The validity of the first section was tested in previous research [48,53]. The second section was adapted from the Science Teacher Efficacy Belief Instrument (STEBI-B) and validity by Ref. [54]. The questionnaire about attitudes of [55] was also used to make this second section.

The third section evaluated the PSTs' performance of the theoretical contents included during the ERB. It consisted of different questions with four possible answers. This section has been designed by the authors with the specific contents that are taught during the theory classes and in each of the interventions. Then, the questions were reviewed by several experts in the field of didactics of experimental sciences and mathematics.

To compare the effects that the Science ERB and Mathematics ERB may have on the PSTs' emotions, self-efficacy, and attitudes, the answers after each intervention were analyzed (post-test comparison in first and second section). Due to the difference in theoretical knowledge of the sample before the development of both ERBs (more knowledge about the lesson before the Mathematics ERB than before the Science ERB), the performance of the PSTs has been studied by means of the pre-test and post-test difference of both interventions (pre-test and post-test comparison in third section).

2.3. ERB designed

Each ERB was repeated three times in a laboratory session (around 22 PSTs per session of 2 h, for a total of 65 PSTs). In the laboratory, PSTs were distributed in pairs and placed at each workspace. During the ERB, participants could use their mobile phones to scan QR codes and look up information, when necessary. All the theoretical contents included in each Escape Room have been taught in theory classes, which means that the PSTs started from a previous knowledge and these activities had been designed with the aim of

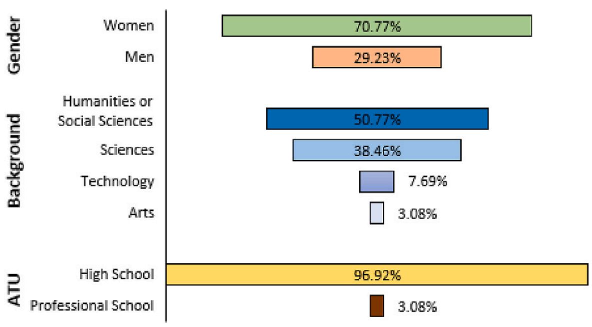

Fig. 1. Graph about gender, background, and Access To University (ATU) of the sample.

reviewing and reinforcing this knowledge.

Each ERB was carried out at the end of the lesson corresponding to the contents taught (around 2 weeks after the end of the theoretical classes pertaining to the contents). To measure the effects of the ERBs on the variables studied, the pre-test was taken at the end of the theoretical classes and the post-test was taken at the end of each ERB. The Science ERB was administered first and then the Mathematics ERB (about one month in between). The sample performed the ERBs approximately 2 months apart.

Both ERBs had a similar structure and consisted of several boxes with number or key locks that the PSTs must open by passing different tasks to reach a final challenge to obtain the key to escape from the laboratory. A linear model was followed in which students had to solve each task sequentially in order. There were 6 tasks in each ERB. Occasionally participants were interacted with the instructor to validate a task or challenge. During each ERB, collaboration between groups was not allowed.

Science ERB covered contents related to the Universe. Specifically, contents about solar system, the Sun, planets, asteroids, satellites, movements of planets, and general concepts such as density, perimeter, radius, and diameter were studied. The first task consisted of solving a puzzle to obtain the next task. Second challenge involved filling a table with information about the order, composition, satellites, and perimeter of each planet in the Solar System. In the third task, participants had to watch short videos and answer questions about them to open several locks. The fourth challenge consisted of a crossword about general definitions of the lesson. In the fifth task the students had to calculate average densities and how much they would weigh on each planet to open the final box. The final challenge consisted of building a model of the Solar System using materials and objects that they found throughout the activity.

Mathematics ERB was about numbers and arithmetic, where concepts such as the nature of numbers, numerical systems and arithmetic operations were studied. The first task involved looking for a hidden link in a text about the lesson. The second and third challenge was to fill in tables by applying different methods of decomposing numbers. In the fourth task the students had to solve a wordsearch about general contents of the lesson. The fifth challenge consisted in deciphering a code by solving different numerical problems. The final task consisted of constructing a cube with Lego pieces to measure the volume and capacity to obtain the laboratory's key. The general structure of the two ERBs can be seen in Fig. 2.

2.4. Data analysis

In this research, the variables were analyzed through various statistical analyses: descriptive statistics, comparison of means, and correlations. First, the homogeneity of the sample was tested to obtain consistent results about the comparison of the two ERBs. The Kolmogorov-Smirnov normality test was performed to establish whether the data were normally distributed or not. Data were not normally distributed (p-value = .000 for all study variables), thus non-parametric statistical tests were applied. Thus, the Mann-Whitney *U* test was used to establish the existence of significant differences between the values of the variables in the pre- and post-tests employed in the two ERBs. Furthermore, Spearman correlation coefficient was used to analyze the correlations between the variables studied. Statistical software SPSS (SPSS statistics 22.0) has been used to perform these analyses.

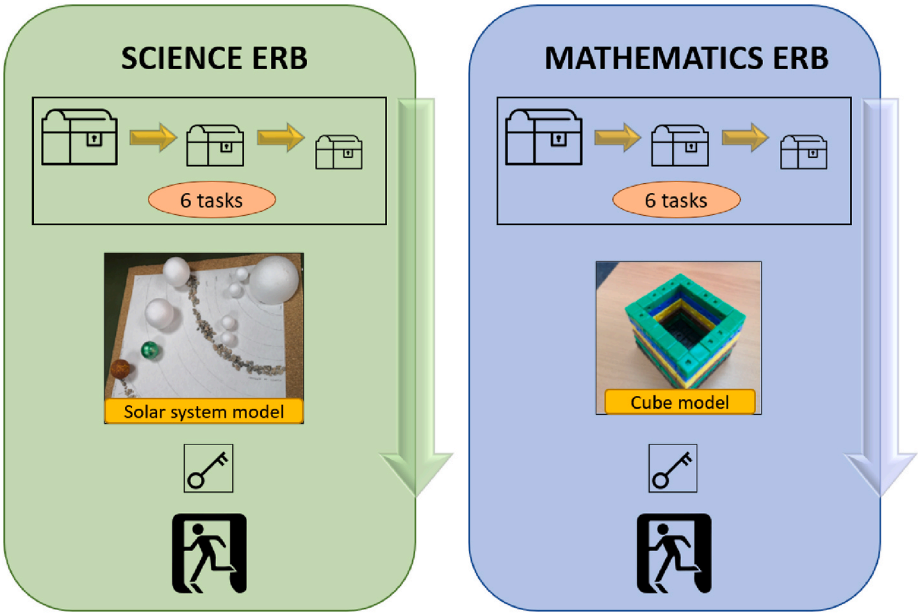

Fig. 2. General structure of Science Escape Room – Breakout (ERB) and Mathematics ERB.

3. Results

During the development of the two ERBs every PST completed all tasks and interventions. Here, there were pairs that finished before the estimated time and others that finished later. The faster pairs were asked, when completing the ERB, to help the groups that had more difficulties without saying the answers to the tasks. The aim of this was to keep the attention of the pairs who had already finished and to help all the groups finish all the tasks. However, the delay between groups was not usually very long.

The data compiled through the questionnaire were analyzed according to four general groups: emotions, self-efficacy and attitudes, performance, and correlation between some study variables. To evaluate the effects on the PSTs' affective domain of the Science ERB and Mathematics ERB, the results of the post-tests carried out after each intervention were compared. To study the effects of both ERBs in the PSTs' cognitive domain, the results of pre- and post-test conducted in both interventions were evaluated.

3.1. Emotions analysis

To compare the effects that the proposed ERBs may have on the affective domain of the PSTs, the answers given by the participants in the questionnaire on the 14 emotions measured with a Likert scale from 1 to 5 points after each intervention were analyzed (post-test comparison). The responses had been statistically compared using non-parametric tests (Mann-Whitney *U* test), as shown in Table 1.

After performing both ERBs, most of the positive emotions had been increased and most of the negative emotions had been diminished. However, there were differences between the values achieved in each ERB. Precisely, statistically significant differences were observed in the emotions joy, fun, nervousness, and boredom (p-value <.05). Specifically, significantly higher values were observed in the emotions joy, fun, and nervousness, and lower values of boredom in the Science ERB with respect to the Mathematics ERB.

3.2. Self-efficacy and attitudes analysis

Concerning to self-efficacy and attitudes towards STEM (science and mathematics), the answers given by the PSTs after each ERB in the 28-item section of the questionnaire were analyzed. In this questionnaire there are mixed questions about self-efficacy and attitudes. Items Q1-5, Q10, Q12, Q14-15, Q18, and Q19 pertain to questions related to self-efficacy. The remaining items of the questionnaire correspond to questions about attitudes towards science and mathematics. Here, statistically significant differences were observed in 8 items (see Table 2).

These items correspond to positive values of self-efficacy (Q1, Q2, Q4, Q5, Q10, and Q12) and attitudes towards STEM (science and mathematics) (Q13 and Q28). Although individually all values increased after each ERB, in these 8 items it was observed that the values of means were significantly higher after the Mathematics ERB than after the Science ERB (Fig. 3).

3.3. Performance analysis

The performance of PSTs has been measured with the third section of the instrument (questions of theoretical contents) to observe whether the PSTs had acquired the theoretical knowledge imparted during the ERB.

In both interventions, the PSTs' performance increased to almost 1.5 points. Specifically, a 7.64 out of 10 was reached for science contents and a 7.94 out of 10 for mathematics contents (see Fig. 4). However, it is important to mention that, according to the pre-test average results, PSTs started from a higher theoretical knowledge in mathematics contents than in science contents (5.62 in Science ERB and 6.58 in Mathematics ERB). Here, statistically significant differences were found between pre- and post-test of both ERBs (p-value = .000 for both ERBs). Specifically, a difference of 2.03 points was observed in the science theoretical content test and a

Table 1
Comparison between the post-test of two ERBs.

Positive emotion	Means of post-test science ERB	Means of post-test mathematics ERB	*P*-Value
Joy	4.59	4.25	.045[a]
Satisfaction	4.56	4.29	.055
Enthusiasm	4.68	4.43	.125
Fun	4.74	4.48	.036[a]
Confidence	4.11	4.03	.653
Hope	3.98	4.00	.970
Pride	4.33	4.10	.166
Negative emotion	Means of post-test Science ERB	Means of post-test Mathematics ERB	*p*-value
Uncertainty	3.35	3.16	.338
Nervousness	3.68	3.25	.045[a]
Worry	2.48	2.24	.381
Frustration	2.55	2.46	.695
Boredom	1.14	1.32	.043[a]
Fear	1.41	1.57	.211
Anxiety	1.79	2.03	.262

[a] Note: Differences are statistically significant when p-value <.05.

Table 2
Items with differences statistically significant between ERBs of self-efficacy and attitudes section.

Item	Item statement	*P*-Value
Q1	I understand scientific-mathematic concepts well enough to teach science-mathematics at lower educational levels.	.000[a]
Q2	I am typically able to answer students' science-mathematic questions.	.000[a]
Q4	I believe I have the required skills to teach scientific-mathematic content.	.003[a]
Q5	I will be very effective in monitoring science-mathematic experiments.	.002[a]
Q10	I know the steps necessary to teach science concepts effectively.	.001[a]
Q12	I am comfortable in science-mathematics class.	.040[a]
Q13	Science-Mathematics is easy for me.	.009[a]
Q28	Solving scientific-mathematic problems is fun for me.	.005[a]

[a] Note: Differences are statistically significant when *p*-value $<.05$.

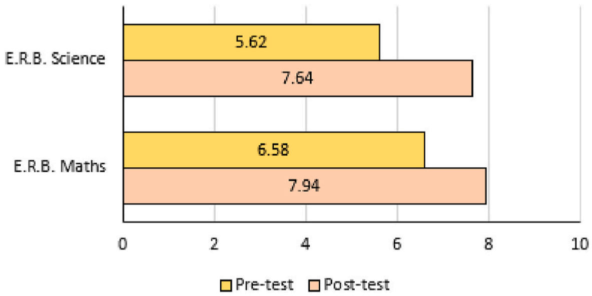

Fig. 3. Differences of means about self-efficacy and attitudes questions in both ERBs.

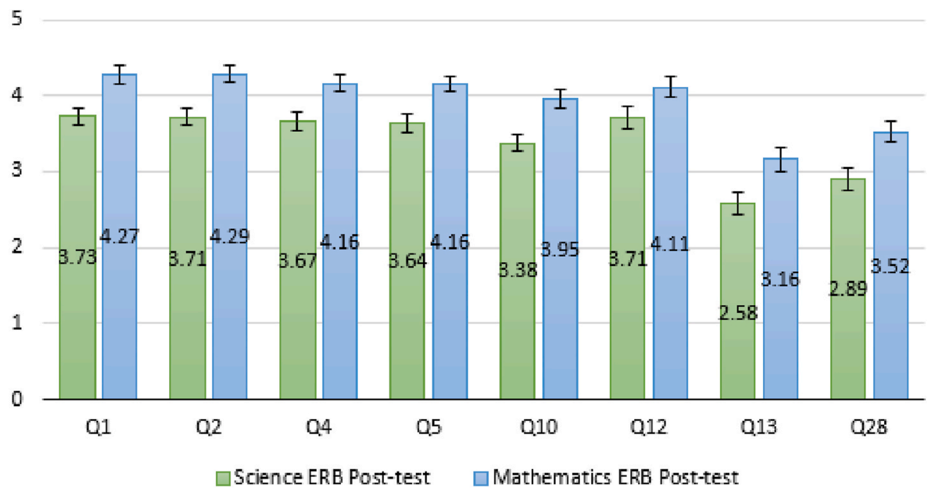

Fig. 4. Performance reached by the Pre-Service Teachers (PSTs) in the theoretical content test before and after the implementation of two ERBs.

difference of 1.35 in the mathematics theoretical content test. Therefore, although the performance in mathematics was higher than in science, there were significant differences and increase in the performance for the theoretical science contents.

3.4. Correlation between variables

To determine the correlation between variables of both subjects, Spearman correlation coefficient was applied. Spearman correlation coefficient fluctuates between -1 and $+1$, indicating negative, neutral ("0"), or positive associations respectively [56].

For a simpler correlation study, the variables "positive emotions" (mean of the 7 positive emotions), "negative emotions" (mean of the 7 negative emotions), "Self-efficacy – attitudes (SE-ATT)" (mean of the 28 items related to self-efficacy and attitudes), and "performance" (mean of grades obtain in theoretical contents test) had been created. For this purpose, data from both interventions (Science ERB and Mathematics ERB) have been selected.

According to this analysis, each positive emotion was positively correlated with the variable "positive emotions" and each negative emotion was positively correlated with the variable "negative emotions". The variable "positive emotions" was correlated positively with the variable "SE-ATT" (Rho = 0.482). Likewise, the variable "negative emotions" was correlated negatively with "SE-ATT" (Rho = −0.298). “Performance” was also correlated with the variables “positive emotions”, “negative emotions”, and “SE-ATT”. Table 3 summarizes the results obtained in the correlation study.

It is also interesting to analyze which items of emotions, self-efficacy, and attitudes most influence in the PSTs’ performance. In this case, it had been observed that the emotions that most positively influence in the PSTs’ performance were satisfaction, confidence, and pride. Likewise, the variables that most negatively influence in the PSTs’ performance were uncertainty, boredom, and fear. In addition, the items relating to PSTs’ self-efficacy and attitudes that most positively influence in the performance were Q1 “I understand scientific-mathematic concepts well enough to teach science-mathematics at lower educational levels”, and Q12 “I am comfortable in science-mathematics class” (Table 4).

In the Science ERB, the emotion "nervousness", despite being considered negative, was positively correlated with some positive emotions such as joy, satisfaction, hope and pride (some of these were closely related to high PSTs’ performance in the theoretical content test). Nervousness was also correlated negatively with boredom, although this correlation was not statistically significant (see Table 5). Moreover, according to the results of the correlation analysis, nervousness did not negatively influence PSTs’ performance but had a correlation very close to 0 and could be considered neutral (Rho = −0.008).

4. Discussion

According to the results obtained in the statistical analysis, there are multiples aspects that should be highlighted. Regarding to variables related to PSTs’ affective domain (emotions, self-efficacy, and attitudes towards STEM), there was a general increase in positive emotions, high self-efficacy, and positive attitudes after both ERBs. Furthermore, there were a decrease of the values related to negative emotions, low self-efficacy, and negative attitudes after both ERBs. This results council with several studies that have analyzed the affective domain in PSTs when an active methodology such as ERB tool has been used [27,43,47].

[46] highlighted the importance of promoting positive emotions, especially in STEM disciplines, since the students begin to show disinterest in the sciences at an early age as the result of negative experiences. Here, an effective learning can be achieved during an active methodology such as gamification, since it fosters positive emotional states [48,57].

Emotions such as nervousness, uncertainty or frustration are common in ERB games [40,42] but this is not negative because without them, these types of activities would lose their fun component [43,44].

In this research, the emotions “joy”, “fun”, and “nervousness” had higher values in the Science ERB. The emotion "boredom" had higher values in the Mathematics ERB. Apparently, Science ERB made PSTs had more fun and positive emotions in general, and less boredom towards science or mathematics than during the Mathematics ERB. Here, various studies [58,59] have shown that, traditionally, most of the college students have exhibited negative emotions like anxiety, fear, or tension in anticipation of situations demanding the application of mathematics knowledge. Mathematics has been generally viewed as a challenging subject, and it sometimes produces more negative emotions than other science disciplines [60,61]. Hence, it is recommendable and useful the application of active methodologies such as Escape Room – Breakout in the context of gamification [27,40].

Concerning to the analysis of relations between variables studied, there were some remarkable aspects. Positive emotions, high self-efficacy, and positive attitudes enabled more effective PSTs’ performance. Specifically, satisfaction, confidence, pride, understanding the concepts, and feeling comfortable in class had high influence [48,50,62]. Negative emotions - especially uncertainty, boredom, and fear - obstructed effective learning [63]. Emotions like nervousness or worry have typically been involving negative consequences because they have generally been classified as negative emotions [64,65]. However, according to results obtained in the correlation between variables (Spearman correlation coefficient), it was observed that nervousness is positively correlated with positive emotions like joy, satisfaction, enthusiasm, and pride. Thus, these emotions can occasionally act as positive emotions, activating students and helping them to experience greater intensity in their positive emotions and increase achievement in their performance. This has already been observed in previous studies that have shown the positive correlation of these emotions with other positive emotions and performance [66–68]. The correlation of the nervousness and worry with the improvement of performance is important and their study interesting due to the connection of the affective domain with the cognitive domain [69,70].

Regarding to the values in self-efficacy and attitude towards science-mathematics section, Mathematics ERB had higher rates than Science ERB. Here, there were significant differences in items related to the knowledge of concepts to teach science-mathematics

Table 3
Correlation results (Spearman correlation coefficient) relative to positive and negative emotions, Self-efficacy – attitudes (SE-ATT), and performance. The *p*-value is below the Spearman correlation coefficient value.

Variable	Positive emotions	Negative emotions	SE-ATT	Performance
Positive emotions	1	−.202[a]	.482[a]	.258[a]
		.001	.000	.000
Negative emotions	−.202[a]	1	−.298[a]	−.163[a]
	.001		.000	.009
SE-ATT	.482[a]	−.298[a]	1	.304[a]
	.000	.000		.000
Performance	.258[a]	−.163[a]	.304[a]	1
	.000	.009	.000	

[a] Note: Differences are statistically significant when *p*-value <.05.

Table 4
Correlation results (Spearman correlation coefficient) between some questionnaire items and variable "performance".

Item	Spearman correlation coefficient	Correlation type	*P*-Value
Satisfaction	.279[a]	+	.000
Confidence	.224[a]	+	.000
Pride	.284[a]	+	.000
Uncertainty	−.193[a]	–	.002
Boredom	−.256[a]	–	.000
Fear	−.265[a]	–	.000
Q1	.300[a]	+	.000
Q12	.259[a]	+	.000

[a] Note: Differences are statistically significant when *p*-value <.05.

Table 5
Correlation results (Spearman correlation coefficient) between the emotion "nervousness" with some emotions and PSTs performance.

Item	Spearman correlation coefficient	*P*-Value
Joy	.212[a]	.015
Satisfaction	.187[a]	.032
Enthusiasm	.198[a]	.023
Pride	.200[a]	.022

[a] Note: Differences are statistically significant when *p*-value <.05.

contents, the ability to answer questions, to have fun, and to feel comfortable when solving problems. These aspects are important because the self-efficacy and attitudes towards STEM (science and mathematics) are essential for the students who learn STEM disciplines [71]. Particularly, the concept of self-efficacy and attitudes towards STEM disciplines is especially important in PSTs due to it can act as meaningful predictor for PSTs' future and imminent teaching exercise and practice [72–74]. Fostering positive attitudes towards STEM disciplines is just as important as fostering high self-efficacy [75]. These positive attitudes are important for students to have a positive view of STEM and to have a predisposition and interest in learning these disciplines [15,76].

The interventions compared in the research not only improved the affective domain but also significantly improved the cognitive domain. The PSTs' performance was increased regardless of the implemented ERBs. These results are in line with various research [77, 78], in which it has been stated that the affective domain operates as a fundamental feature of cognition, by design ensuring that emotional outcomes are the central object of perception, thought, and action.

Fostering positive emotions, high self-efficacy and attitudes is essential when teaching STEM courses. The affective domain is closely related to student performance. Hence, the development of strategies, methodologies, and tools (like active learning, gamification, or ERBs compared in this research) that enhance the affective and cognitive domains is crucial. Studying new instruction methodologies is particularly interesting in STEM courses due to their traditional difficulty. This necessity also gains importance when working with PSTs because they will pass on their knowledge to future generations.

5. Conclusions

It is commonly that STEM disciplines are difficult and have generated a sense of rejection, negative emotions, and negative attitudes among students. Here, it is recommendable and useful the application of active methodologies such as Escape Room – Breakout in the context of gamification. These techniques and tools can increase the motivation, positive emotions, high self-efficacy, and positive attitudes towards STEM disciplines. ERB games also can enhance the students' performance.

The research questions proposed were whether there were differences and similarities between the two ERBs designed about the affective and cognitive domains of the PSTs. For this, it has compared the effects of two ERB tools, used as educational tools to teach science and mathematics, on the PSTs' affective and cognitive domain. There were a general increase of PSTs' positive emotions, high self-efficacy, positive attitudes, and better performance after the two interventions. Particularly, Science ERB generated higher values of positive emotions and lower values of negative emotions than Mathematics ERB. However, self-efficacy and positive attitudes were higher after the Mathematics ERB than after the Science ERB. In both the PSTs' performance was significantly increased. According to the variable's correlations, Positive emotions, high self-efficacy, and positive attitudes facilitate more effective PSTs' performance. Negative emotions such as uncertainty, boredom, and fear obstructed effective learning. Due to the positive correlation of the nervousness and joy, satisfaction, enthusiasm, and pride, it can be said that the nervousness occasionally act as positive emotions, activating students and helping them to experience greater intensity in their positive emotions.

Therefore, both didactic tools are appropriate and have multiple benefits when applied to teaching science and mathematics content to PSTs.

6. Limitations and future work

This study focuses on comparing the effects of a Science ERB and a Mathematics ERB on the emotions, self-efficacy, attitudes, and performance of a sample of pre-service teachers. The sample used is from a class of 65 PSTs during one academic year and can be considered a medium sample. Furthermore, the data do not have a normal distribution and cannot be treated with parametric tests because the sample is not large enough. The different challenges in each ERB are also not described in detail due to the length this would take. Nevertheless, the results obtained are interesting as there are many significant differences and correlations between the variables studied.

In future research, various objectives have been proposed to enrich this line of research. It is intended to explain in detail what each ERB consists of and to make a comparative qualitative analysis. We also believe it is necessary to increase the sample using several academic years and to establish a control group to observe the effects of each ERB separately. Statistical analyses of the study variables are also attempted, biased by some descriptive variables such as pre-university background, gender, and age.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at 10.1016/j.heliyon.2023.e12795.

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