



## Research article

## Exit for success. Gamifying science and technology for university students using escape-room. A preliminary approach

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## ARTICLE INFO

## Keywords:

Education  
Gamification  
Higher education  
Escape room  
Academic motivation  
STEM Education  
Science education  
Engineering Education

## ABSTRACT

There is a growing tendency to incorporate gamification activities with the aim of improving student's motivation in science, technology, engineering and mathematics (STEM) courses. One of the strategies to apply gamification in the classroom is the use of the escape room. In this work different experiences of escape room in the context of formal university education are analysed. The analysis of students' opinions shows that such activities are well received regardless of background (engineering or education) or gender. The emotions that arise from the experience are mostly positive and the students state that they have developed both specific and transversal competencies. Finally, practical considerations are proposed based on the lessons learned from the developed experiences.

## 1. Introduction

There is a growing interest in improving the success and performance rates in science, technology, engineering and mathematics courses (STEM) at the university level (Bybee, 2013). These courses often have a problem of low student motivation (Borrego et al., 2017; Ross and Bell, 2019). In order to improve the motivation, creating a positive emotional environment has been proposed in order to make the teaching-learning process more attractive (Mellado et al., 2014).

Some possible techniques for creating this positive emotional environment and for improving the motivation are gamification (Sánchez-Martín et al., 2017c; Zamora-Polo et al., 2019a) and Game Based Learning (Papastergiou, 2009). Gamification is defined as the use of game elements and game-design techniques in non-game contexts (Deterding et al., 2011), to engage people and solve problems (De-Marcos et al., 2014; Warmelink et al., 2020; Zamora-Polo et al., 2019a). The design of games for educational purposes is called Game Based Learning (GBL) (Ebner and Holzinger, 2007; Papastergiou, 2009).

Although gamification is not restricted to the educational field, in fact gamification techniques were born in economic, financial and marketing

areas (Deterding et al., 2011; Sánchez-Martín et al., 2017c). Nowadays, their use in education is a tendency (Menon and Romero, 2020; Rodrigues et al., 2019).

The use of gamification, as well as increasing the students' motivation (Deterding, 2012; Fotaris and Mastoras, 2019; Hamari et al., 2016), allows students to develop interesting skills (Menon and Romero, 2020). To this end, they need to develop both specific competencies (directly related to their profession) and transversal competencies, which, apart from being used in the professional world, can be used in the exercise of a critical and committed citizenship (Sánchez-Martín et al., 2017d; Zamora-Polo et al., 2019b; Zamora-Polo et al., 2019d). Market and employers highly value these latter competencies (Zamora-Polo et al., 2019c; Zamora-Polo et al., 2016).

Many of the works published in the scientific bibliography on gamification are related to technological aspects (Fotaris and Mastoras, 2019; Kayımbaşoğlu et al., 2016; Rodrigues et al., 2019). However, game is more than technology (Deterding et al., 2011). In fact, traditional games such as table top, card or board games are currently used in gamification contexts (Clarke et al., 2016).

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In order to optimize the educational outcomes of the games; [Garris et al. \(2002\)](#) proposed the “Input-Process-Game model” (cited by [Menon and Romero, 2020](#)). In this model, instructional content and game characteristics are used as input variables. The process considers the game cycle and outputs the learning outcomes.

In this paper, the use of the gamification<sup>1</sup> technique known as escape room, is analysed in university context. The escape room consists on a recreational activity in which a group of people is confined to one or more rooms from which they have to escape in a certain time. To do this, they must solve a series of puzzles, quizzes and challenges in order to obtain a mechanism to escape the room ([Zhang et al., 2017](#)). Escape rooms are in their infancy ([Warmelink et al., 2017](#); [Zhang et al., 2017](#)), so studies related with the topic are not very common and the analysis of these experiences under a pedagogical, didactical point of view are scarce.

According [Nicholson \(2015\)](#) escape rooms could be defined as:

“Live-action team-based games where players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal (usually escaping from the room) in a limited amount of time.”

The first documented reference to an escape room came from Japan in 2007 ([SCRAP, 2007](#)) and spread rapidly to other parts of the world in 2012–13 first in Asia and, then in Europe, Australia and North America ([Nicholson, 2015](#)).

Although the escape rooms were created for recreational purposes, they can be used for educational purposes by developing skills such as teamwork, lateral and critical thinking, communication, working under pressure, etc ([Nicholson, 2015](#); [Pan et al., 2017](#); [Shakeri et al., 2017](#)).

[Nicholson \(2015\)](#) laid the foundations for the systematic escape room study. Other authors have focused their research on how escape rooms participants search information ([Choi et al., 2017](#)), how the escape room design affects teamwork and collaboration in both the purely physical escape room ([Pan et al., 2017](#)) and escape room that combine the physical and virtual world (mixed reality) ([Warmelink et al., 2017](#)), the application to the elderly sector ([Zhang et al., 2017](#)), tourism ([Kolar, 2017](#)) or crowdsourcing.

Regarding how to integrate escape rooms into a formal educational context, there are just a bunch of he references. An interesting review has been recently published ([Fotaris and Mastoras, 2019](#)). [Vörös and Sárközi \(2017\)](#) used escape room in order to teach Fluid Mechanics. With pre-university students, [Bassford et al. \(2016\)](#) created a scenario-based learning experience in order to engage young people in *STEM* courses by investigating a traffic accident and [Batzogiannis et al. \(2018\)](#) use the co-creation of escape rooms for improving Greek students' motivation. Most of the experiences in the field of education are developed in the context of higher education ([Fotaris and Mastoras, 2019](#)). In this area, [Borrego et al. \(2017\)](#) successfully implemented an escape room activity in a course entitled Information and Security and Computer Networks of the degree in computer science at a Spanish university; [Lopez-Pernas et al. \(2019\)](#) applied the escape room activity in a programming course, [Friedrich et al. \(2019\)](#) design an interprofessional escape room. Additionally, [Eukel et al. \(2017\)](#) designed an escape room addressing the issue of diabetes in the Pharmacy degree, [López \(2018, 2019\)](#) used escape room for teaching English at university context. Finally, [Clarke et al. \(2016\)](#) carried out a pilot experience with university teachers. Other successful escape room experiences have been related to medical studies ([Kinio et al., 2019](#)) and nursing education ([Morrell and Ball, 2020](#)).

<sup>1</sup> There are differences between the concept of gamification and game-based learning. The experience developed here combines both methodologies. On the one hand, a game has been created (escape room) for the development of a series of competences, on the other hand, this game is within a regulated course (a non-game context). We consider that the term gamification is more inclusive than game-based learning.

An important issue in escape rooms design is the choice of the theme and narrative ([Nicholson, 2015](#)). In the bibliography several themes were described ([López, 2019](#); [Nicholson, 2015](#); [Pan et al., 2017](#); [Shakeri et al., 2017](#)): modern era, a place in the time, horror, fantasy, a place related to Science such as a laboratory, the murder of a doctor and so on. Once the theme is selected, the puzzles and quizzes should be designed. There are a variety of puzzles that can be incorporated into an escape room ([Nicholson, 2015](#); [Shakeri et al., 2017](#)). Selection will depend on the objectives previously selected and the experience of the designer. Finally, equipment should be designed and implemented. It is necessary to select the space where it will be developed, the implementation of the puzzles, the use or not of actors, etc ([Clarke et al., 2016](#)). Although it is more than evident that the live-in experience is the most strong way for profiting the Escape room tool, this is not always possible because it requires a large number of resources (physical space, working in small groups, and materials such as puzzles and other attrezzo materials). Because of that, perhaps a good way of working with this educative tool may be the virtualization of the experience through computer-aid applications. Some relevant works have already been published ([Mystakidis et al., 2019](#)) and surely there will be more promptly.

Escape room activities seem to be a promising tool for education and educators and some scientific publications can be found up to now ([Pan et al., 2017](#)). The emotions experienced by students in this type of activities can be positive for example: joy, gratitude, interest, favoring the process of teaching learning; or negative emotions such as fear, anxiety, competitiveness, etc., the latter emotions can harm the process of teaching learning. In this way, it is essential to know what kind of emotions students' experience ([Jeong et al., 2018](#)).

The fact that the emotional performance is important for the cognitive yield is not new and it has been referred previously ([Sánchez-Martín et al., 2018](#)). Both variables are clear and directly in relationship, as [Mel-lado et al. \(2014\)](#) already pointed out: the higher the emotional performance is, the better academic marks are obtained. And it is also relevant to point out that one of the best ways of improving the student's motivation for science and technology domains is the application of ludic, recreational activities, as [Martínez-Borreguero et al. \(2018\)](#) reported. These authors described better acquisition of difficult scientific concepts when they were taught through recreational experiences.

Particularly, the use of gamification and game-based learning as a teaching method was identified as a successful practice for improving the motivation and the emotional yield of the students ([Sánchez-Martín et al., 2018](#)), ahead from other teaching methods (orally-based exposition or audiovisual-supported explanation). The impact of gamification in the motivation and, consequently, in the academic performance of the students, has been thoroughly studied ([Buckley and Doyle, 2016](#)). It is clearly stated out that gamification is one of the most interesting educative techniques for enhancing the emotional experience of learning ([Mullins and Sabherwal, 2018](#)).

On the other hand, previous studies have pointed out that there are gender differences in the student's opinion about the use of the gamification in education ([Clarke et al., 2016](#); [Lopez-Pernas et al., 2019](#)); nevertheless, these differences were not found in the use of escape room ([Clarke et al., 2016](#); [Lopez-Pernas et al., 2019](#); [Nicholson, 2015](#)). Finally, it is important to know what competencies the students believe they have developed. Clearly, knowing this in a reliable way is very difficult, but this must be the horizon of an efficient way of evaluating the quality of the education process. This work aims to address these issues.

### 1.1. Research objectives

The main goals of the current work can be exposed in the following terms:

- (1) To describe and report the use of escape room in formal education, in the university context, as a tool for improving the acceptance of courses that are perceived as difficult ones by university students.

- (2) To analyze the students' opinion and emotional performance, identifying significant differences between Engineering and Education students, and between male and female students.

## 2. Methodology

The whole study an exploratory piece of research in which we have use the survey as quantitative data collection method and statistical parametric and non-parametric studies for data analysis. The focus of the data collection and process is to inquiry about the general perception of the escape room activity, in terms of emotional, attitudinal and cognitive performance; and to find out differences between engineering students and pre-service teachers, as well as to explore if there exists any gender significant difference.

Since this piece of research involves the data collection from individuals, all procedures performed were in accordance with the ethical standards with the 1964 Helsinki declaration. Informed consent was obtained from all individuals and the study was validated by the corresponding ethical committee (Comisión de Bioética y Bioseguridad, Universidad de Extremadura<sup>2</sup>).

### 2.1. Sample description

This piece of research was carried out involving students from Faculty of Education (69) and from School of Industrial Engineering (55). Sixty-seven people identified themselves as male students and 57 identified as female students. The average age was 22.4 years old, finding students from 19 to 33 years old. The students came from four different courses: Didactics of Matter and Energy (21), Environmental knowledge in Primary Education (38), Educative Intervention at Science Classes (10), and Continuum Mechanics (55). All of them were undergraduate students that belonged to a class group, no previous selection for the participation in the activity was performed. Only the last group belongs to the School of Industrial Engineering.

Both groups of individuals can be identified as "low motivated students" because of different but complementary reasons. In the case of engineering students, the origin for this low motivation is placed in the difficulty they perceive in the subject, which is felt as a very hard one. These courses have a lower success rate than other courses in the degree. However, they do not present a lack of motivation for science and technology issues, as pre-service teachers do. In that case, the psychological profile of these students involved a "science-subject fear" and the perception of science issues as non-useful out-of-scope subject for a primary teacher. This is thoroughly presented elsewhere (Zamora-Polo, Corrales-Serrano et al., 2019a).

The data collection method was the survey. In it, those questions that could be answered by assigning a level of agreement were used to describe how these two main groups in the sample reacted to the escape room and their beliefs and feelings on science and technology issues once this activity was over.

### 2.2. Escape rooms description

Escape rooms were implemented in courses with low student motivation. For example, Continuum Mechanics is a course in mechanical engineering degree. It is studied in the 5th semester (over 8). Traditionally, this course has a low pass rate and students often find it difficult. The main objectives of the escape room activity were:

- To increase the students' motivation and to promote a positive experience, and;
- To review the knowledge acquired during laboratory and computer practice.

In order to achieve these objectives, escape room activity in engineering course consisted on four problems, related to the previously developed laboratory classes. The statement of each of these problems was contextualized in the popular television show Game of Thrones. Other authors have previously used this narrative in their educational work, for example in the teaching of "International Relations" (Young et al., 2018). Figure 1 shows an example of one of the problems proposed to students.

In the engineering group, students had to test the solution of the problems' activity in Moodle course. Once the problem was solved, the students received a hint to find the next problem. In the last problem, the students received a key that opened a box containing the key to leave the lab.

The experience was carried out during the seminar-laboratory timetable of the course. It was scheduled for a maximum of 90 min. However, students required between 60-80 min. It was developed in groups of 15 students. All groups were able to obtain the key to the laboratory.

Regarding education students, the courses involved are Knowledge of Natural Environment in Primary Education and Didactics of Matter and Energy (2<sup>nd</sup> Year, Pre-service Primary Teacher Degree). They are both traditionally perceived by the students as difficult ones and for this reason students have a low motivation. The specific characteristics of this population usually make them think on Science and Technology as non-useful tasks. In addition, Science and Technology usually involve Mathematics, which adds rejection feelings (Sánchez-Martín et al., 2018; Zamora-Polo et al., 2019a).

Therefore, the main aim was to improve the students' motivation making science and technology contents easier to approach and getting them involved in a recreational environment where solving basic science problems should be a fun task to work on. For this end, students were locked in a lab and were encouraged to open a box which was hung from the cellar. The box could be moved downwards only by unlocking several safety padlocks whose combinations are the solutions of some scientific problems and other kinds of puzzles. Scientific problems were contextualised in general Primary Education Syllabus, such as the one showed in Figure 2. In it, basic trigonometrical contents (Pythagoras and Thales theorems) and volumetric calculus (non-regular prism volume) were involved. Other puzzles that should give an escapist atmosphere were also proposed, such as the decodification of a Caesar-encrypted message or even the use of the Periodic Table of Elements for unlocking an alphabetic lock.

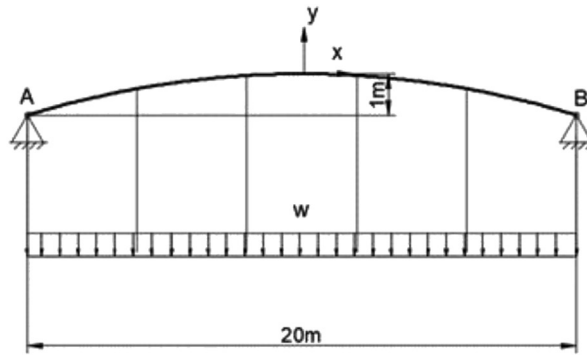
The escape room within pre-service teachers' activity was carried out in a similar way, with a final duration of maximum 60 min. Groups were arranged in 7-9 students. The escape room design allowed the students to compete amongst them, even though they belonged to different teams, because time was important for the final classification.

### 2.3. Data collection

There are several strategies in order to assess the experience for example recording the experience (Choi et al., 2017), direct observation (Pan et al., 2017), questionnaires (Eukel et al., 2017; Lopez-Pernas et al., 2019; Pan et al., 2017; Shakeri et al., 2017; Warmelink et al., 2017) and discussion group (Pan et al., 2017).

The entire work is made on the basis of a merged methodology: both quantitative and qualitative data collection. However, some previous studies already pointed out the importance of quantitative methodology even in the case of emotional performance record (Sánchez-Martín et al., 2018). Since this is a preliminary approach, the hybrid methodology was preferred in order to identify probable tendencies.

<sup>2</sup> All information about the bioethics and ethics in research activity at University of Extremadura can be retrieved from <http://investigalia.unex.es/#!/page36.do?acondd12=es&rcond3.att2=197&kcond92.att3=229> [Accessed on 06/22/2020].



To move the troops commanded by John Snow, who must fight the King of the Night; a parabolic bridge must be built. Knowing that the force per unit area that the bridge platform must support is  $10 \text{ kN/m}^2$ . It is asked to determine the horizontal reaction at the A support in kN, knowing that the width of the platform is 5 meters.

Figure 1. A problem of Continuum Mechanics escape room.  
Source: Own elaboration.



### Shadows and volumes

A building with a perfect external cubic shape is placed in the middle of a square. Walls are 35 cm width, and it can be considered completely hollow and without floor. When the sun is  $45^\circ$  over the horizon, this building's shadows is 4382,63 mm length.

How many liters of air are inside?

Figure 2. An example of basic scientific problems for pre-service teachers. Image credit: José Luis Cernadas Iglesias by PxHere.com [CC BY 4.0].

In this experience, an on-line questionnaire was proposed for data collecting. It was applied after the escape room activity was carried out. This technique was used previously by Lopez-Pernas et al. (2019), they used an online questionnaire to evaluate a escape room activity. In the questionnaire design, firstly bibliographic search and a panel of experts were carried out. Subsequently, in a second step, the proposed questionnaire was validated by a panel of independent experts. This questionnaire is presented in Table 1. Students were asked to fill it anonymously; in this way, students could freely express their opinions, the survey was conducted using the Google Drive, thus ensuring anonymity (Ortega-Sánchez and Gómez-Trigueros, 2019).

As can be seen, there are three kinds of variables:

- (1) Categorical variables, those that can be answered with a qualitative response that can be chosen amongst a limited number of options: Yes/No, Male/Female, etc. These questions were 1, 6, 7, 8 and 11.
- (2) Numerical variables, those that can be answered by assigning a value in a Likert scale. Comments are included only at 0 and 10 level in order to show the scale's direction. These questions were 2, 3 and 4.
- (3) Open text response, the students were able to write down freely what they felt or thought, without any preliminary options. These questions were 5 and 10 and were studied according to a content analysis.



**Table 1.** Data collection questionnaire.

Question number	Question text	Variable type	Options
1	Gender	Categorical	Man Woman I prefer not to say
2	How interested you are in Science/Technology?	Numerical	1 – It is none of my interests 10 – It is really interesting for me
3	How important is this course for your professional future?	Numerical	1- Absolutely negligible 10- It is one of the most important courses
4	Did you like the escape room activity?	Numerical	1 - It was horrible! 10 - It was great!
5	What emotions did the escape room make you feel?	Open text response	
6	Do you think this kind of activities made the course more attractive?	Categorical	Yes/No
7	Would you like this kind of activities were repeated during the course?	Categorical	Yes/No
8	Do you think this kind of activities give scientific or technological knowledge?	Categorical	Yes/No
9	Do you think this kind of activities ALSO give other skills?	Categorical	Yes/No
10	If you answered Yes, please indicate which ones	Open text response	
11	Lastly, would you like this kind of methodologies were a general practice in your degree?	Categorical	Yes/No

#### 2.4. Data process

Statistical Package for Social Science software v. 14 for Windows (IBM, 2015) was used for data processing. Quantitative analyses in the form of descriptive and inferential statistics (parametric when possible, non-parametrical if the normality and homocedasticity hypotheses were not checked) and qualitative analyses in the form of frequency count where carried out, bearing in mind the three kinds of variables that were collected. Data results were presented as follows:

- (1) Firstly, a descriptive data landscape was examined, showing some relevant aspects of the sample: gender distribution, origin of the studies, etc.
- (2) After that, a descriptive analysis of each question was performed. Open text questions were coded by two researchers independently. In case there were differences between the two researchers, the two reached a consensus proposal. In order to categorize the emotions, Bisquerra's definition (Bisquerra, 2009) was taken into account the modification of Borrachero's taxonomy (Borrachero et al., 2019; Borrachero et al., 2014). According to these authors, the final taxonomy we used involved three kinds of emotions: positive (or pleasant ones), negative (or disgusting ones) and neutral (those ones that depend on the subject and on the experience, such as surprise).
- (3) Finally, an inferential analysis was developed considering both quantitative aspects (where  $\chi^2$  was the most significant test) and qualitative ones (where Student's *t*-test and/or Kolmogorov-Smirnov tests were used). This is fully detailed in the next section.

Significance of each test was established at 0.05 level ( $\alpha = 95\%$  of confidence).

As can be seen, data analysis included a preliminary reliability guarantee (since two experts from a social sciences research area were consulted about the accuracy of the questions in the instruments), different experts were also asked for applying the categories involved in the qualitative analysis (different from the other ones) and the statistical data processing was validated under a representative level of significance. In addition, in order to ensure the reliability of the coding process, two independent reviewers coded the students' responses, in cases where there were disagreements, a consensus code was agreed.

### 3. Results and discussions

The success rate of the engineering group was 100%, all students got the key to the lab. In the case of the education group the success rate of

the activity was 60%. These values are higher than the success rate of other commercial escape room (41%) (Nicholson, 2015). Most educational works do not provide information about the success rate of educational escape rooms (Lopez-Pernas et al., 2019). These values could be related with a) duration of escape room, b) size of the groups or c) difficulty of activities. The combination of these parameters is fundamental for the management of the negative emotions that can appear in the activity such as anxiety or boredom (Lopez-Pernas et al., 2019).

In most of the educational escape room experiences published (Fotaris and Mastoras, 2019): the experience last less than 60 min, and the group size was usually between 1 and 5 participants. Future research could investigate the optimal group size and duration of the experience.

The population sample was split into two main groups: those students who belonged to the School of Engineering (namely "Engineering" students, 44.6%) and those who belonged to the Faculty of Education (namely "Education" students, 55.4%). Sociologically, the gender distribution of the entire sample followed a 50/50 pattern (45% female, 54% male). No previous selection of students was applied prior to the development of the activity since the objective was to test the escape room as a educational tool in a preliminary piece of research.

#### 3.1. Description analysis

##### 3.1.1. Quantitative questions description

According to the initial segmentation, Figure 3 shows the descriptive results of Question 2 for both groups.

As Figure 4 clearly depicts, the case of pre-service engineers is different from education students, since this second group presents a wider response distribution. That can be interpreted as a larger variety of sensitivities toward science and technology aspects. While engineering students seem to be accumulated around an average value of almost 9 (of 10) with a low standard deviation (0.88), in the case of pre-service teachers this central value is of 6 and the standard deviation increases (1.9). This is in line with the general description of the education group, made of students with different origins and mainly with a low affinity to science and technology matters, as Jeong et al. (2016).

The perceived relevance of science and technology issues is more similar in both groups, as can be seen from Figure 4. A slight difference in the case of pre-service primary teachers can be observed since the distribution reaches lower levels (5 and 6), but this is not very significant: the first case has an average level of 8.2 (standard deviation of 1.17) and the engineering group has an average level of 8.6 (standard deviation of 1.04). Surprisingly, pre-service teachers assume the

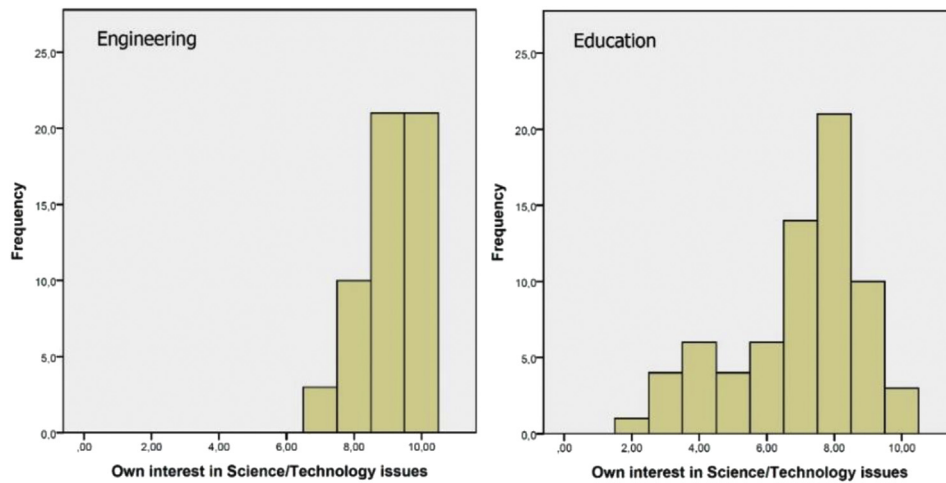


Figure 3. Response to Question 2: How interested are you in science/technology issues?.  
Source: Own elaboration.

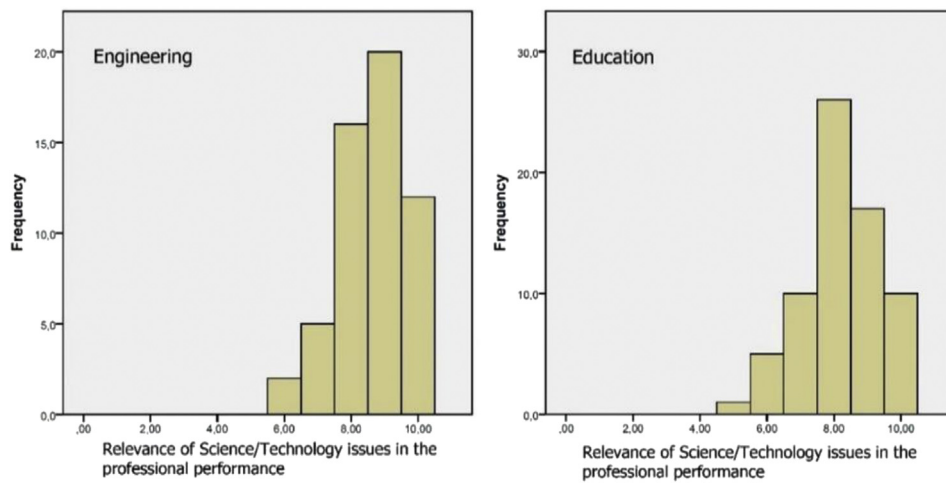


Figure 4. Response to Question 3: How relevant do you think science and technology are for the professional performance of your future job?.  
Source: Own elaboration.

importance of Science and Technology Education and the preminent role these contents have in the primary education syllabus, although they show a clearly lower level of interest in them.

Regarding the student's general feeling towards the activity itself, when asked if they liked it, the behaviour of both samples is very similar, as can be observed in Figure 5. Either engineering and education students

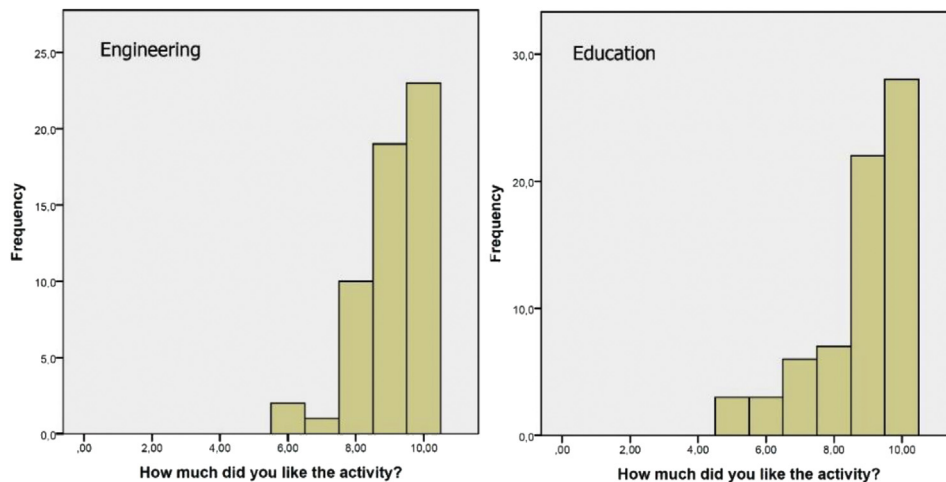


Figure 5. Responses to question 4: Did you like the activity?.  
Source: Own elaboration.

showed a high level of acceptance, since the average level of response was 8.8 in the case of pre-service teachers (standard deviation of 1.4) and 9.0 in the case of engineering students (standard deviation of 1.0). This fact was partially reported by Sánchez-Martín et al. (2018) when they reported the prevalence of emotions such as surprise when students dealt with science issues under hands-on activities or gamification.

Table 2 shows the frequency for the “Yes” option in questions 6–9 and 11. These questions were mainly answered in the same way for both groups: Students answered “Yes” when asked if these kinds of activities made the course more attractive (100% engineering and 99% education); most students (100% education and 98% engineering) thought these activities and other similar ones should be repeated along the entire grade and almost all of them also thought they have learned not only scientific knowledge (88% education and 96% engineering).

3.1.2. Qualitative questions description

Emotions were also analysed because of their intimate relationship with motivation, especially internal motivation (Zamora-Polo et al., 2019a). For the analysis of emotions (question 5), they were classified into relevant categories and their graphical representation was used for comparing both groups (Education and Engineering). This can be appreciated in a cloud tag for each group, as Figure 6 depicts.

At a first glance, it is quite interesting to see that the general orientation of the emotions in Education and Engineering group is not as similar as it could be expected. It seems that in pre-service teachers, this activity produced positive emotions in the sense described by Borrachero et al. (2019) towards Science in the students, such as curiosity or intrigue. These feelings are not constricted to motivational reasons exclusively and they are interesting for the teacher and for the educational process because they make it more pleasant and amusing, which are important aspects in the science teaching. In the case of Engineering group, motivational aspects are taken into account because they expressed that they faced the mechanic problems under a competitiveness focus, such a contest. This is relevant from the point of view of the promotion of science intrinsic values (curiosity is one of them, as Gianotti reported in Gianotti, 2015) and this prevalence inside the first group rather than in the second one could confirm the fact that the science and technology vision among pre-service teachers is being conformed during the educational process, whereas in the Engineering group this vision is already developed. This should be the reason why in this second group the most repeated emotions have to do with the general motivation toward the study activity.

This is in agreement with classical studies that already reported the influence of science teaching in the vision of the science itself, and in the fact that science should be transmitted not as a finished corpus, but as an intellectual construct in evolution (Mellado et al., 2006). This is a relevant aspect in the current paper because suggests the preeminent role of this kind of activities in building up the students’ capacities related to science and, consequently, their ability to transmit them afterwards. Specific scientific thinking abilities are encouraged as Figure 6 presents, and this is absolutely relevant for science and technology teaching and learning since teachers of such issues are committed not only to knowledge transfer, but also to enlighten visions of science and technology and affective images of such human constructs (Jiménez and Carracedo, 1993).

Table 2. Frequency for “Yes” option in questions 6–9 and 11.

Question	Education	Engineering
6	99%	100%
7	99%	98%
8	96%	96%
9	88%	96%
11	100%	98%

If one analyses the nature of the emotions arisen, a count on positive/negative emotions can be made for this end, Bisquerra's Taxonomy (Bisquerra, 2009) modified by Borrachero et al. (2019, 2014) was taken into account (Table 3).

From Table 3 two consequences can be extracted: firstly, Education students (although they were not many more than pre-service engineers) were emotionally more active, that is, they responded with more variety of emotions and with a high number of them. That is why a total of 107 emotional expressions were submitted by this group, versus only 59 in the case of the second group. Secondly, a clear prevalence of positive emotions can be seen in both groups and in both groups equally. This is numerically demonstrated by the fact that 132 positive emotions were consigned versus only 34 negative ones. Previous published works have detected that the main emotions raised in these activities are positive ones. In previous studies, users categorized their experience such as: “Fun”, “Innovative” and “Engaging” (Clarke et al., 2016), “innovative”, “motivating” and “funny” (López, 2019), “very fun”, “really enjoyed the activity”, and “was great to get practical confirmation of knowledge” (Ross and Bell, 2019), “a fun experience” (Lopez-Pernas et al., 2019). These results are in line with a previous work that describes the escape room experience as generally positive (Davis and Lee, 2019).

Gamification activities can have a counterproductive effect (Rapp et al., 2019). From students' responses emotions were mainly positive. However, some negative emotions appeared such as fear, insecurity, etc. These negative emotions are common in the teachings of science and technology (Novak and Wisdom, 2018; Sánchez-Martín et al., 2017c). However, previous studies have shown how student-centered learning activities lead to improve emotional performance (Jeong et al., 2018; Jeong et al., 2019; Novak and Wisdom, 2018; Sánchez-Martín et al., 2018; Suwal and Singh, 2018; Zamora-Polo et al., 2019a).

The escape rooms developed met 7 of the 10 ingredients proposed by Reeves and Leighton-Read (2009) and cited by Deterding et al. (2011): they include three-dimensional contexts, introduce a narrative, include teamwork, organize groups by rankings, the rules are explicit and the activity is conducted under pressure.

Regarding the Other skills question (question 10), most responses reported those competencies that have to do with team working with different names such as: teamwork (59), cooperation (14), team spirit (8), social competence (4) or leadership. Other students highlighted the ability to solve problems (6), to learn to learn (5), to work under pressure and time management (5) and course specific competencies (5) among others. As can be seen, most of these competencies are considered as “soft skills” or “transversal competencies”. They can be used in different contexts (professional and non-professional) and they are highly valued by employers. The development of these “soft skills” is one of the strengths of this methodology and has been previously reported in the literature (Clarke et al., 2016; Fotaris and Mastoras, 2019; Kinio et al., 2019; López, 2019; Nicholson, 2015; Ross and Bell, 2019; Warmelink et al., 2017; Zhang et al., 2017).

3.2. Inferential analysis

In order to reveal several links that probably are difficult to appreciate at a first glance, inferential analysis was carried out as the following sections present.

3.2.1. Quantitative variables

Regarding differences between pre-service engineers and prospective primary teachers, Table 4 summarizes the quantitative analysis for questions 2, 3 and 4.

First, the sample homogeneity must be checked out. As a matter of fact, Levene's test on the response for questions 2 and 4 revealed that homoscedasticity of both populations was not assumed (*p*-value of 0.00 and 0.036 respectively), so Student's *t*-test cannot be applied here. Instead, non-parametric tests, such as comparison of medians or Kruskal-Wallis, can be carried out on these population data.

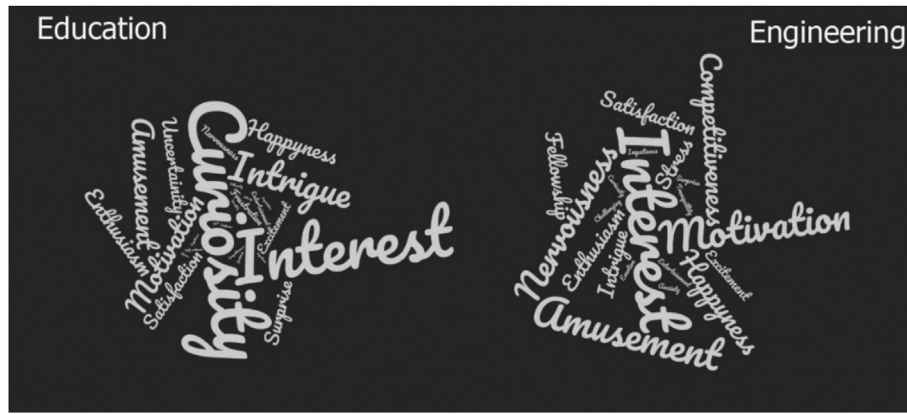


Figure 6. Emotions arisen during the escape room performance. Source: Own elaboration through WordCloud.com.

Table 3. Count of emotional expressions in question 5.

Group	Kind of emotion		TOTAL
	Negative	Positive	
Education	20	87	107
Engineering	14	45	59
TOTAL	34	132	166

On the contrary, question 3 achieved a Levene's non-significant *p*-value (0.652), so for this question Student's *t*-test can reveal if there exists any significant difference between the two groups in terms of the perceived importance of Science and Technology in their professional future.

Bearing this in mind, the comparison of medians test revealed that significant differences can be observed between pre-service engineers and prospective teachers in terms of own interest in science and technology issues (question 2), since *p*-value was equal to 0.00. On the one hand, those students from School of Engineering showed an average interest of 9.09 (of a total of 10 points) in science and technology, whereas pre-service teachers only reached an average score of 6.95 in the same scale for the same question. This is in agreement with the description made by Sánchez-Martín et al. (2018).

The same non-parametric test was made on question 4, where students were asked if they liked the activity itself (the escape room). In this analysis, no statistical differences can be established since *p*-value was equal to 0.965. This means both populations liked the activity similarly

(average score of 8.80 for pre-service teachers and 9.09 for prospective engineers). According to these results, gamification was a good experience for both types of students, in agreement with Sánchez-Martín et al. (2018). The same results are also obtained when Kruskal-Wallis test is applied on both questions (*p*-value of 0.00 for question 2 and 0.556 for question 4).

Regarding question 3, where parametric tests could be applied, Student's *t*-test revealed that non-significant differences can be established between the two populations. That is, the relevance of science or technology as course of study cannot be understood as statistically different amongst pre-service engineers (average score of 8.6/10) and prospective primary teachers (average score of 8.2/10). This is surprising bearing in mind the fact that science study is perceived under negative emotional charge by the students of Education, as it is already reported (Dávila Acedo et al., 2015).

Regarding gender differences, taken as a homogeneous group, the differences related to gender can be studied. The whole sample was then split into two groups and Levene's test was applied on each response. The aim is to inquire whether a significant difference can be identified in the (a) Interest on science/technology; (b) The relevance science/technology seems to have in the professional performance of an engineer or a teacher and (c) How much they like science/technology issues.

Levene's test revealed significance (*p*-value under 0.05) only in the first case, so a Kruskal-Wallis test was made for this specific question. In this case, significance level was achieved so statistically significant differences can be identified between both groups. That means the interest male students expressed on the course (science or technology) was higher

Table 4. Summary of quantitative considerations.

Question number	Compared groups	Main subject	Levene's test p-value	Student's <i>t</i> -test significance/ Conclusion	Non-parametric test applied (if needed)/ significance/Conclusion	Average score of each group
2	Pre-Service Teachers vs. Engineering students	Interest on science/technology	0.001	N/A	Comparison of medians/ 0.001/Significant difference	6.95 vs. 9.09
3		Relevance of science/technology in their professional work	0.652	0.306/No significant difference	N/A	8.2 vs. 8.4
4		Activity like	0.003	N/A	Comparison of medians/ 0.965/No significant difference	8.80 vs. 9.09
2	Male vs. Female	Interest on science/technology	0.008	N/A	Kruskal-Wallis/0.001/ Significant difference	7.09 vs. 8.55
3		Relevance of science/technology in their professional work	0.605	0.306/No significant difference	N/A	8.26 vs. 8.47
4		Activity like	0.473	0.926/No significant difference	N/A	8.92 vs. 8.94



than what female students seem to present (8.55 vs. 7.09 scoring of 10). That is in agreement with already published studies like [Sadler et al. \(2012\)](#), or [Toglia \(2013\)](#), where the male affinity when dealing with science or technology courses was studied.

On the other hand, no significant differences can be applied for the rest of comparisons. That is, although Levene's test reveals that normality and homoscedasticity assumptions can be done on the sample's distribution, no differences can be observed between male and female students in how important they perceive Science/Technology aspects on their professional development and how much they like the analysed escape room activity. These results are consistent with other previously published results ([Clarke et al., 2016](#); [Lopez-Pernas et al., 2019](#); [Nicholson, 2015](#); [Ross and Bell, 2019](#)) that indicate escape rooms are equally interesting for males and females. This fact is a clear difference with other gamification activities such as video games, in which some researchers have already showed a difference of more than 70% of the players were boys ([Ogletree and Drake, 2007](#)).

### 3.2.2. Qualitative variables

Questions 6–9 and 11 were categorical ones. Basically, they were asking the student to evaluate if these kinds of methodologies are considered as efficient in the teaching-learning process of science and technology issues and if they think these pedagogical approaches should be promoted into the ordinary courses' schedule. Most of the responses (above 88% in all cases) indicated "Yes", so the students' valuation of these teaching methods is more than evident.

These results are consistent with emotional performance of students shown previously. Previous studies have shown that science and technology-related courses often produce negative emotions ([Novak and Wisdom, 2018](#); [Sánchez-Martín et al., 2017c](#)) and that student-centered learning activities lead to positive emotional performance ([Jeong et al., 2018](#); [Jeong et al., 2019](#); [Novak and Wisdom, 2018](#); [Sánchez-Martín et al., 2018](#); [Suwal and Singh, 2018](#); [Zamora-Polo et al., 2019a](#)), increasing positive emotions in students. Student responses seem to indicate that these activities are attractive, and that they consider them useful both for the development of specific skills and for the development of transversal skills.

## 4. Conclusions and further works

A very successful tool for the motivation of university students is the use of gamification in the classroom. Among other gamification activities, the escape rooms have proven to be powerful tools for the development of competencies, mainly transversal or soft skills. However, this methodology is in its infancy ([Ross and Bell, 2019](#)). This work describes and reports the use of escape room in formal education, in the university context, as a successful tool for improving the acceptance of courses that are perceived as difficult ones by university students.

From these analyses, we have found the following conclusions:

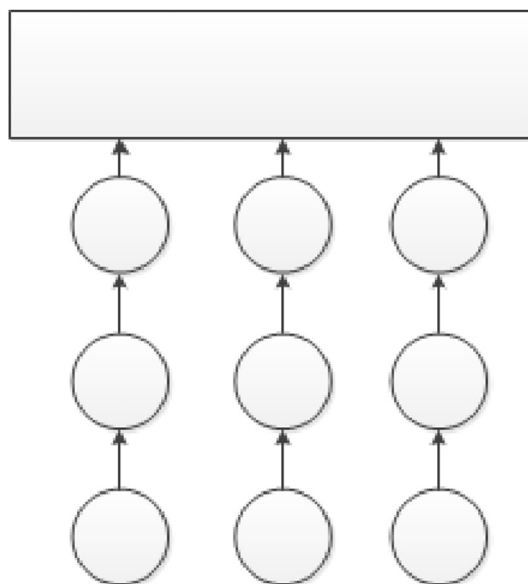
- (1) There do not seem to be any differences between the groups (Engineering and Education) in the opinion about the activity; nevertheless, it was found differences in the interest in science and technology. Engineering students showed a preliminary interest in science and technology issues, while pre-service teacher students presented a lower rate of interest. This is particularly relevant when considering the impact of the following conclusions, where both groups presented similar results.
- (2) The emotions that appear in the students are mostly positive and show that this activity can be used for motivation.
- (3) Students acknowledge having developed both specific (course-related) and transversal skills. The latter are the ones that appear most frequently in their responses and are widely appreciated by employers.
- (4) The use of educative tools such as escape room and other innovative and methods (namely Active Learning Methods) are

widely reported to be an effective way to promote the specific development of scientific and technology content ([Sánchez-Martín et al., 2017a,b](#); [Sánchez-Martín et al., 2017c](#)). The escape room activity suggested in the current work is designed according to the principles of Active Learning Methods. The emotional analysis of the students' experience reveals it is an effective instrument for building up a specific vision of science and technology courses, as human constructs, with thinking styles, supporting all previous approaches. Emotions such as curiosity, knowledge applicability or self-guided learning are clearly linked to scientific values.

Regarding future works, it would be interesting to apply and analyze the experience in other university degrees such as those in health studies or science (mathematics, physics, and so on). The performance in terms of knowledge content acquisition and emotional yield of students throughout the experience should be analysed and evaluated with a view to improving their skills. Previously published experiences include a "debriefing time" following the activity ([Nicholson, 2015](#); [Vörös and Sárközi, 2017](#)). This is a period in which to analyse the experience with users and to obtain lessons learned for everyday life. In the analysed cases, this was done through the online questionnaire; however, it would have been interesting to have socialized the experience. One variable that can be explored in future research is group size. In the case of large groups, path-based design can be chosen ([Nicholson, 2015](#); [Wiemker et al., 2015](#)). In this configuration, several subgroups can work together in the same escape room activity ([Figure 7](#)). Finally, the impact of the activity on the results of the course could be evaluated in the future by using a control group.

Another alternative is use of desktop escape room. In this initiatives a keypad-based lock is used ([Ross, 2019](#); [Ross and Bell, 2019](#)). In this situation a physical room is not necessary, and a low-cost device is used to check the solutions. Previous work has found that students prefer this type of device to other types of web platforms or applications ([Ross, 2019](#)).

Escape room activities such as the one described in the current work should be taken into account in an active-learning process because the collected and analyzed data are promising in terms of enhancing the knowledge content acquisition, emotional performance and therefore, the probably success of the instruction process.



**Figure 7.** Path based configuration of an escape room. Source: own elaboration based on [Nicholson \(2015\)](#).

## Declarations

### Author contribution statement

J. Sanchez-Martin, F. Zamora-Polo: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

M. Corrales-Serrano: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

A. Luque-Sendra: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

### Funding statement

This work was supported by Research Project EDU2016-77007-R (AEI/FEDER, UE) of Ministry of Economy and Competitiveness of Spain, and by Research Project GR18004 of the Regional Government of Extremadura, partially funded by the European Regional Development Fund.

### Competing interest statement

The authors declare no conflict of interest.

### Additional information

No additional information is available for this paper.

### Acknowledgements

Authors thank M. Guerrero-González for her comments and suggestions on the preliminary versions of the manuscript.

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