



Escape rooms technology as a way of teaching mathematics to secondary school students

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Abstract

The aim of this study is to determine whether Escape Rooms can be used as an active methodological approach for the purpose of teaching mathematics. The research adapted a quantitative approach via an experimental design. Two different study groups were established, the first of which comprised the control group who were taught using conventional training methods, and the second consisted of the experimental group, who were taught using a novel approach incorporating an Escape Room activity. The participants included 80 students who were all attending secondary school within the Kingdom of Saudi Arabia. The findings revealed how the activity involving the Escape Room led to a significant enhancement in the student's motivation, achievement and autonomy. The conclusion can be drawn that using an Escape Room in mathematics teaching can enhance learning achievement, anxiety, motivation and autonomy, with students' negative attitudes regarding mathematics learning considered as an important variable, particularly with respect to autonomy and motivation. Hence, Escape Rooms can potentially be more effective than conventional methods for teaching mathematics.

Keywords Educational innovation · Escape room · Gamification · Teaching method · Mathematics · Secondary school

1 Introduction

In the modern world, technology impacts all aspects of students' lives, which provides many opportunities for stimulation. Consequently, the field of education must confront the reality that students now spend large parts of their daily lives within the digital society (Nikolopoulou et al., 2019). Resultantly, greater focus is being paid to

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understanding the learning and teaching processes of educators and students in addition to the adoption and implementation of active methodologies and novel strategies in order to make students more engaged and motivated, as well as to develop the field of education in general (Rossi et al., 2021). Research recently conducted in the mathematics field on the application of active and gamified approaches demonstrates the benefits this can provide for both students and teachers when implemented in the learning environment (López-Belmonte et al., 2019; Moreno-Guerrero et al., 2020). In recent years, the concept of the Escape Room has gradually been included in classrooms around the world, from primary levels through to professional development (Fotaris & Mastoras, 2019; Veldkamp et al., 2020). “Escape rooms are live-action team-based games where players discover clues, solve puzzles, and accomplish a specific goal (usually escaping from a room) in a limited amount of time” (Nicholson, 2015, p. 1).

Alongside the widespread interest in the entertainment sector, Escape Rooms (ERs) are becoming increasingly popular as learning settings in educational programmes across the educational spectrum (Sanchez & Plumettaz-Sieber, 2019). Motivated teachers were the first to implement educational ERs within their own classes. They disseminate materials via platforms like Breakout EDU, the membership of which totals around 40,000 (Breakout, 2018; Sanchez & Plumettaz-Sieber, 2019). Such advancements depend on teachers who adopt this approach at an early stage incorporating the concept of recreational ER. The development of such rooms by teachers is undertaken on the basis of ER video games as well as their personal experience of recreational ETs (e.g., Franco & DeLuca, 2019). This phenomenon by which ERs have progressed from basic classrooms within the education sector is distinctive and expanding. Hence, it is necessary to examine how they are used, as well as establish guidelines for the development and implementation of educational ERs (Jenkin & Fairfurst, 2019).

1.1 Importance of the study and research questions

It is important and interesting to note that a number of studies have demonstrated that students are largely positive or neutral regarding mathematics when starting school, but their attitudes become negative as they progress. Transitioning from primary school to high school is an ongoing issue due to the abstract nature of mathematics in higher levels of education (Corriveau & Bednarz, 2017; Clark & Lovric, 2008; Mohamed & Waheed, 2011; Thomas, 2008), and Schoenfeld (1994) stated, “the current mathematics education is based on a false mastery model” (p. 54). Nevertheless, it remains unclear at what point this transition happens and what are the causal factors. Singh et al. (2002) described the range of complex factors that impact success in the field of mathematics, stating that it is a product of different variables associated with the learners, parents and school, placing specific emphasis on the function of the teacher providing motivation. It is believed that teachers can convey positive attitudes towards mathematics if they select suitable and novel teaching approaches as well as enhancing the students’ intrinsic motivation. Teachers must ensure that they remain knowledgeable and proficient in the modern world, particularly due to

technological advancements; they should keep to date with students' preferences and develop their lessons accordingly.

Today, education is undergoing a significant methodological change (Kolster, 2021), which has largely been caused by a number of different factors. Technological advancements have led to considerable changes in the way in which educational agents and those with didactic content interact (An & Oliver, 2021). In this regard, the interests of students differ from their counterparts from the past (Galán et al., 2021). Consequently, this has resulted in the development of innovative methods of teaching and models for transmitting information and generating knowledge (Menguál-Andrés et al., 2020), which can particularly be observed in gamification (Putz et al., 2020). This transformation has enabled students to become active participants in the process of teaching and learning (Roig-Vila et al., 2021). Nevertheless, during this period of change, the impact of the Covid-19 pandemic is a factor that has also modified the conventional education principles. (García-Peñalvo & Corell, 2020). The global health crisis has triggered a revolution in educational systems by altering education environments. Moreover, teachers have been required to change from classical in-person teaching within physical classrooms to teaching within virtual environments (Iivari et al., 2020).

It is highly necessary for such requirements to be met through the adoption of innovative approaches and incorporation of new technologies in the educational field (Gudmundsdottir et al., 2020). Furthermore, it is of critical importance that students have active involvement in educational processes (Rossi et al., 2021). Thus, the aim of this study was to determine the extent to which Escape Rooms are effective when used as an active methodological approach in mathematics learning. Thus, in combination, the aim of such actions is to develop an advantageous process for student development in the growing digital world (Parra-González et al., 2020). The research has been motivated to embrace this active methodology by finding answers to the research questions listed below:

- Does the use of educational Escape Rooms influence students' learning achievement in mathematics?
- Does the use of educational Escape Rooms change students' mathematics learning anxiety?
- Does the type of Escape Rooms educational environment affect students' motivation to learn mathematics?
- Does the type of Escape Rooms educational environment influence autonomy?

1.2 Research limits

Objective limits This research was applied to certain topics in the second term exponential and logarithmic relations and functions (exponential functions, solving exponential equations and inequalities, logarithms and logarithmic functions, and properties of logarithms) on mathematics course- 5 for secondary stage - Courses System - Natural Sciences Track, Edition 2021.

Time limits The research was conducted in the first semester of the academic year 2022.

Place limits This research was conducted in one secondary school in Al- Dhahran city.

Population limits The sample comprised 40 male students in the third grade of secondary stage (control sample) and 40 male students in the third grade of secondary stage (experimental sample). However, the study. could have included female students if there were no restrictions of time.

2 Theoretical framework

2.1 Gamification as innovation

The concept of gamification comprises a particular active methodology that has been increasingly developed by students and teachers around the world (González, & Carrillo, 2016). Gamification complements and expands on the basic principles of active methodologies as well as game mechanics, and its usage has the potential to improve the learning experience, engagement and performance (Bai et al., 2020; Cechetti et al., 2019). Specifically, gamification refers to “the use of game design elements in non-game contexts” (Deterding et al., 2011, p. 9). Furthermore, the popularity of using Escape Rooms in educational environments is increasing due to the fact that they conform with the fundamentals and ideas of gamification, play theory and active methodologies. When involved in an Escape Rooms activity, participants are confined within a given virtual or physical area and must work on their own or in collaboration with others to self-manage their knowledge and identify hints that can aid them in solving puzzles, riddles, conundrums or overcome general obstacles within a specified time period (Nicholson, 2018; Pitoyo et al., 2020). It is important to note that it is possible to use Escape Rooms and gamification in virtual or physical settings. Moreover, as there is some overlap in their objectives and characteristics, it is possible to use them together to produce improved educational results.

Because gamification comprises an innovative means of enhancing the engagement of learners, it is becoming increasingly popular as an educational tool due to the positive impacts it has on learning in general, which requires students to be suitably engaged and motivated throughout the process (Hamari et al., 2014; Majuri et al., 2018). Through the application of game mechanics and aspects of game design in educational settings, students gain a greater sense of enjoyment from the learning experience in general and are intrigued to learn further (Anastasiadis et al., 2018), they become increasingly engaged and involved, (Bouchrika et al., 2019) and at the same time, an improvement in their level academic performance and learning outcomes is observed (Barna & Fodor, 2017; Yildirim, 2017). Additionally, gamification can potentially induce a positive transformation in learners’ psychology and behaviours (Kim et al., 2017) and can influence the intrinsic and extrinsic motiva-

tions of learners (Dicheva et al., 2015; Roy et al., 2018), which is critical due to its direct connection with educational achievement (Wigfield et al., 2019). Studies recently conducted in the mathematics domain on the utilisation of gamified and active approaches indicate that students and teachers who have implemented such methodologies gain significant benefits from the abovementioned aspects and others, therefore, mathematics education requires changes in the processes of both teaching and learning (Moreno-Guerrero et al., 2020; López-Belmonte et al., 2019).

2.2 Using the scape room as a gamification tool

There are multiple ways in which gamification can be implemented, one of which is the Escape Room (Lopez-Belmonte et al., 2020). ERs can include a variety of different scenarios, as demonstrated by the fact that 175 recreational ERs are included in Nicholson's inventory (2015). It is necessary for participants to transfer elements of the real world into the game environment, which may include the scene of a crime or a historic submarine. Thus, it is critical that participants become immersed when playing the game. Immersion denotes the process by which a player is enticed into a narrative or specific problem (Douglas & Hargadon, 2001). For games in education, it is employed for increasing learner engagement, overcoming problems and completing the activity (Annetta, 2010). It is recommended that the context of the game (period of time and locations), the players, characters, the tasks, the instruments, and the materials used are consistent to avoid cognitive dissonance (Nicholson, 2016). In studies on the topic of ER, tasks are referred to as puzzles and a basic game loop is used involving a challenge, solution then reward (e.g., a lock code, or clues for the subsequent puzzle). It is possible to group puzzles into different categories: (a) cognitive puzzles in which the thinking abilities and logic of users must be used; (b) physical puzzles in which artefacts must be manipulated to overcome an obstacle, like navigating around a laser maze; and (c) meta-puzzles, the game's ultimate puzzle where the players must deduce the final solution or code from the outcomes of the preceding activities (Wiemker et al., 2015). The most frequently used type of puzzle in ERs is the cognitive variety (Nicholson, 2015).

Nicholson (2015) determined that puzzles can be organized in one of four different ways, as shown in Fig. 1. When the structure of the puzzle is open, players have the opportunity to simultaneously attempt to solve various puzzles. Before completing the ultimate puzzle, it is necessary for all others to be solved. In a sequential structure, puzzles are presented in sequence; when one puzzle is solved, the subsequent puzzle becomes available, until the players reach the meta-puzzle. In the path-based structure, various puzzle paths are available. When the simple structures are combined, an intricate, hybrid structure is formed, which could consist of a pyramid, among others. For the puzzles to be solved, players must be able to search, observe, memorise, reason, read, recognise patterns and apply their mathematical skills (Wiemker et al., 2015). Subsequent to playing the game, the players are questioned by the gamemaster on the procedure and their achievements (Nicholson, 2015; Wiemker et al., 2015). The skills needed as well as the reflection on player accomplishments indicate the potential for ERs to be utilised in the educational context.

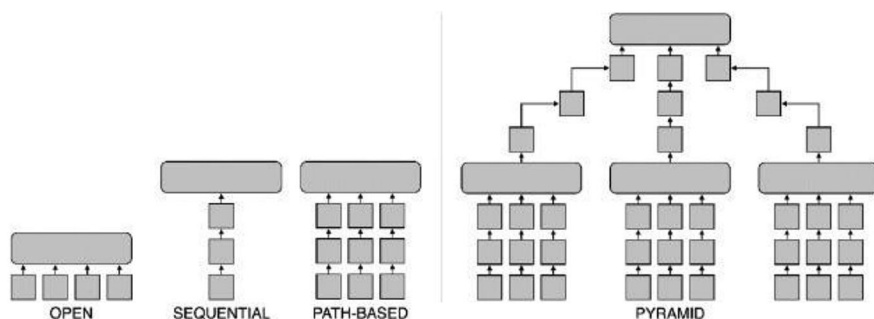


Fig. 1 Puzzle structures in escape rooms: (a) basic structures: open, sequential and path-based; (b) a complex, hybrid structure, such as a pyramid. Squares are puzzles and rectangles are meta-puzzles. (adapted from Nicholson, 2015)

2.3 Escape room in mathematics

In the mathematics field, various studies and training programmes have resulted in an increase in students' academic achievement through the utilisation of Escape Rooms. In spite of the normal difficulties, insufficient attention to directions, as can be observed in conventional teaching, is actually advantageous when applied in the context of mathematics, as it makes students more competitive to learn, motivated and interested (Lim & Jakop, 2019). Additionally, the application of tasks associated with the Escape Room in the mathematics field enhances student autonomy while also facilitating learning, enhancing team collaboration as well students' problem-solving abilities in terms of conflicts or problems designed by the teacher (Arnal et al., 2019). These factors promote collaboration among learners in addition to their autonomy, which enables them to confront learning confidently in the future (Ben-Zvi & Sfard, 2007; Garcia & Pintrich, 1991; Sakui, 2002; Segura-Robles & Parra-González, 2019; Takagi, 2003; Ushioda, 2003, 2006; Yackel & Cobb, 1996).

2.4 Enhancing positive attitude towards mathematics through escape room

Studies on learners' attitudes regarding mathematics can be traced back to the 1970s, and multiple findings have indicated the significant impacts of affective factors (emotions, beliefs, attitudes) on mathematics achievement levels. Tapia (1996) claimed that a primary aspect of attitude is motivation, whereas attitudes are correlated with the process by which learners are motivated, namely their willingness to engage in mathematics learning. Additionally, Ma (1997) revealed that positive attitudes and mathematics achievement are proportionally correlated.

From the multiple ways in which teachers impact the formation of beliefs and attitudes regarding mathematics, and ultimately achievement levels, according to Singh et al. (2002) the factors that have the biggest impact include the teachers' own beliefs and attitudes regarding mathematics, as well as their knowledge, teaching approach and social abilities, class management, creation of the class environment, cognitive modelling, expectations, style and individual attributes. It is believed the selection of

suitable and novel teaching approaches and increasing students' intrinsic motivation can enable them to view mathematics positively. It is important for teachers to keep abreast of the modern world and technological advancements; they should remain cognisant of students' preferences and develop their lessons accordingly.

It is widely acknowledged that the field of education is currently undergoing a rapid transformation in terms of methodological approaches and innovative methods of transferring knowledge (Pataki, 2016). This is connected with the development of novel educational instruments as well as the usage and inclusion of various factors within the educational field. In this regard, active methodologies comprise an aspect of this group of teaching methods that are aimed at enhancing the quality of education and enabling students to achieve their goals in more suitable ways, as they are the key actors in the process of achieving goals (Parra-González et al., 2020).

However, novel strategies and training approaches are impractical if they have no association with students (Marín-Díaz, 2015) or are not linked with the socio-educational conditions in the real world (López Noguero, 2008). Hence, it is necessary to transform teaching methodologies. Teachers must function according to the theory that students can design their own learning processes without generating detrimental experiences as a result of poorly designed or planned strategies (Burke, 2014).

This can all be achieved by teachers innovating their actions to enhance the accomplishment of learning goals. Resultantly, it is critical that an effective class environment is formed for the development of such methodologies (Pérez-López & Rivera García, 2017).

As claimed by researchers, there has been a significant increase in the application of Escape Rooms as learning environments (Shute & Ke, 2012), with positive outcomes reported (Hursen & Bas, 2019). Hence, the notion of activation is considered to be where the learner participates in the process of learning by acquiring new knowledge on their own (Santos et al., 2019).

With regard to the lack of a negative impact, it is grounded on the reflection or view of negative emotions exhibited by students, including a sense of annoyance, hostility, or frustration when performing tasks or completing tests designed by the teacher (Segura-Robles & Parra-González 2019).

For sufficient activation levels to be fostered, the recommendation is that training dynamics grounded on gaming are used (Wang, 2015) with the aim of establishing a playful atmosphere in which students have the perception that they are involved, think they are primary actors and are engaged in the activities to be completed (Pérez-Manzano & Almela-Baeza, 2018). Additionally, to promote the absence of any negative effects in the process of learning and teaching, specialists suggest that games be used. The use of Escape Rooms or virtual media via video games or digital applications allows students to complete instructional activities on a repeated basis without being concerned about making mistakes (Contreras Espinosa, 2016; Lee & Hammer, 2011).

In this regard, using active methodologies is a potential means of transmitting and assimilating the didactic contents involving the participation of learners, thus facilitating student activation in their personal learning work. Nowadays, students take responsibility for constructing their own knowledge through this kind of methodology (Khalil & Elkhider, 2016; Pumilia-Gnarini, 2013); resultantly, this causes them

to be less anxious and stressed, as they have the opportunity to work at their own speed, in an autonomous and individual way, based on their individual and cognitive attributes. This entire process is complemented by collaboration with peers in the class. Ultimately, students can achieve the goals set by the teacher in an active way without becoming frustrated (Parra-González et al., 2020).

3 Literature review

Veldkamp et al. (2021), this descriptive study aimed at inquiring about 50 teachers' and 27 students' experiences and perceptions when using an Escape Rooms as a teaching and learning environment in science secondary education, regarding: user experiences, the usability of Escape Rooms in terms of learning goals and learning outcomes. The results showed that the Escape Rooms as a learning environment seemed to appeal to teachers of different ages, gender and teaching experiences. In addition, students described being more active, mutual interdependent and thinking more thoroughly or critically than in a regular lesson.

Another study, conducted by Dimova et al. (2020), presented the process of creating and implementing a large-scale experiment that involves 881 students from 12 different primary schools using the Escape Rooms style educational game in the classroom, to provide an engaging activity for the students. The findings of this study provided evidence that educational Escape Rooms constitute a compelling way to increase student engagement. The most important finding during the activities in all participating schools was that students who had good teamwork, proper distribution of tasks and coordination among team members achieved the best results.

LÓPEZ-PERNAS et al. (2019), in their study on the use of an educational Escape Room in a programming course at a higher education institution. The researchers used survey which was completed by a 84 students, who volunteered to do so at the end of the activity. This sample represents 67.7% of the 124 students who attended the educational Escape Rooms. They founded that appropriate use of educational Escape Rooms can have significant positive impacts on student engagement and learning in programming courses. These results also suggest that students prefer these activities over traditional computer laboratory sessions.

In the study of Hermanns et al. (2017), a qualitative descriptive approach was adopted to explore the application of the Escape Room methodology in the field of Medicine. The findings indicated that students were highly involved in learning tasks, developing communication abilities and solving problems in the process of learning the contents of the curricula and their subsequent application. The researchers suggested that such an approach could be adopted in fields that typically necessitate learners to read and memorise large volumes of information, making students more self-confident and enhancing their academic achievement.

Borrego et al. (2017) in their study, presented a teaching experience consisting of a Room Escape activity developed at the Engineering School at Universitat Autònoma de Barcelona. The aim of this activity was to increase the student motivation for two subjects of the second year of the Degree in Computer Engineering: Computer Networks and Information and Security. The results of the study were highly posi-

tive, indicating that they became more motivated and their learning performance improved. Students have actively participated in the Room Escape access challenges proposed in both subjects, increasing their motivation and willingness to learn.

Macías (2017) performed research in English with students attending high school involving an Escape Room. The findings revealed the benefits such an approach could provide in education, as it represents an effective means of stimulating students' engagement in curricular tasks. Nicholson (2016) reported the outcomes of a survey administered by parties who deliver Escape Room experiences across the globe, detailing the existing situation of this phenomenon in areas other than Education.

The factor that differentiates this study is that it focuses on the extent to which using educational Escape Rooms for teaching mathematics is effective, in comparison to the conventional approaches involving presentations and lectures given by teachers in which novel tools and resources are disregarded. To the best of the researcher's knowledge, no previous study has been conducted on the effectiveness of using educational Escape Rooms for teaching mathematics in the context of the Kingdom of Saudi Arabia.

3.1 Aspects drawn from the literature reviews

- Based on the pedagogical literature, review of the literature and scientific methodology, the theoretical framework utilised in this study is formed.
 - The research methodology and tools suitable for this research are identified.
 - The statistical techniques used are reviewed and adopted for this research as appropriate.

4 Materials and methods

4.1 Research design and data analysis

The study involved an experimental design comprised of descriptive and correlational analysis according to the quantitative perspective in line with field experts (Hernández-Sampieri, 2014; Rodriguez, 2011). For the analysis, two distinct groups were formed to which the students were assigned. The first of these groups, designated as the control group, were instructed with the conventional teaching approach. Conversely, the second group were the experimental group, and an Educational Escape Room was used as the methodological approach by this group for the practice of mathematics content. The independent variable comprised the methodology used, whereas different factors and the extent to which these methodologies were effective were chosen as dependent variables for the purpose of evaluation. Participants were selected via stratified sampling, where the whole population is divided into separate sub-groups by the researcher. Subsequently, the final subjects are chosen from the various strata in a proportional manner on a random basis. As the course, subject area, content and teachers were the same in both groups, it was ensured that no significant differences existed between them before the experiment started. Data were statistically analysed using Statistical Package for the Social Sciences (SPSS).

When conducting the analysis, descriptive statistics mean (M) and standard deviation (SD) were employed. The biserial correlation (r) developed by Cohen was used for measuring the effect size Cohen (2013). Additionally, for the purposes of the present study, $p < 0.05$ was determined to indicate that a difference was statistically significant. The value of the effect size of Pearson r correlation ranges from -1 (correlation is perfectly negative) to +1 (correlation is perfectly positive). In this situation, subsequent to the determination that the data are not normally distributed, it is necessary to use non-parametric statistics. In particular, in order to make a comparison between two groups that are not normally distributed, the Mann-Whitney U test is employed (Sheskin, 2020).

For the purposes of the current study, when designing the Escape Room experience, the factors listed below were taken into account by the researcher:

- Student type: It is essential to understand the kind of students included in the group, such that all puzzles can be designed accordingly;
- Time: It influences the type of project that will be implemented;
- Difficulty: The level of complexity should be chosen or established in line with the kind of students within the group. As part of the experience in this study, the groups were arranged homogeneously, where some puzzles were simple and others slightly more challenging, which ensured that they remained interested, but the difficulty was not so high that the puzzles could not be solved.
- Learning aims: The project was aimed at practicing mathematics, which the teachers believe is very challenging to remain interested in.
- Theme and space: An important aspect of the class was recreation. In this class, a castle was recreated.
- Enigmas: They represent the fundamental aspect of the Escape Room and were connected with mathematics from a game perspective.
- Materials and technology: They were selected on the basis of those materials that could be utilised within class. As students were not permitted to take their mobile phones to school, they were excluded from the experience.
- Evaluation: A control list was applied to various items for the purpose of assessing the distinct learning objects and required competences.
- Trial: A trial was implemented prior to organising the experience within the class to ensure that the order of the elements was correct.

The different elements were combined into a single story to ensure the students were engaged. The theme of the story narrated by the teacher was focused on action and suspense to promote student motivation. The aim of doing this was to immerse the students in the formative task in an active manner.

4.2 Participants

A total of 80 students attending secondary school participated in the experiment. Studies on relevant impact have recently concluded that the size of the sample in such investigation does not influence their effectiveness (Yılmaz & Soyer, 2018). The sample was randomly selected from secondary school students, three of the teachers in this school identified the necessity to conduct such research based on their work with these students.

Table 1 Study groups by the negative and positive attitudes of students towards mathematics

Groups	Positive attitudes n (%)	Negative attitudes n (%)	Total n (%)
Experimental group	21 (52.5)	19 (47.5)	40 (50)
Control group	17 (42.5)	23 (57.5)	40 (50)
Subtotal	38 (47.5)	42 (52.5)	80 (100)

The participants were intentionally chosen from those in the third grade of secondary school ($n = 80$; Mage = 18 years; $SD = 1.62$). Table 1 presents the configuration of both the experimental and control groups.

4.3 Instrument

Data were collected through the administration of an ad hoc questionnaire. The aforementioned instrument was designed according to tools that had previously been validated in the academic literature (Brady & Andersen, 2019; Martin-Rodríguez, 2016). A total of 42 items were included in the questionnaire, which were separated into 20 distinct dimensions. Each item was answered according to a five possible answers, Strongly Disagree (S D), Disagree (D), Neither agree nor disagree (N), Agree (A), and Strongly Agree (S A).

It is an important to mention that it is possible to verify the questionnaire's external validity by considering the opinions of academics regarding its framework and content (Bryman, 2008; Cohen et al., 2007; Cowl, 1996; Gay & Airasian, 2003; Gass & Mackey, 2007). In order to attain this objective, fifteen members of an academic curriculum and instruction department at Saudi Arabian universities were consulted for discussion of the questions asked in the questionnaire.

In order to attain the optimal degree of the validity in this research, particular actions were taken prior to the final dissemination of the questionnaire. Such actions may be summarized as follows: submitting the questionnaire to a proof-reader in order to improve clarity; offering it to colleagues at the Department of Mathematics Education, particularly for discussion with mathematics teachers, and submitting it to experts and specialists in this area of research and study. The final step was to submit the questionnaire to a committee comprising referees, in order to assess for every aspect including clarity, language, duplication, and contradiction. The Arabic and the English versions were presented to this body, accompanied by a cover letter. Furthermore, the questionnaire was submitted to a statistician for the purpose of assessment, as well as to receive help in selecting the correct measurement (Cohen et al., 2004; Gay & Airasian, 2000; Oppenheim, 2001).

Validation of the tool was firstly performed qualitatively and then quantitatively. During the initial stage, a Delphi method was implemented for the qualitative validation. In this process, 13 specialists on active methodologies from various higher education institutions contributed. All items were rated by the reviewers according to the extent to which they were transparent and relevant based on a scale of 1 to 6, as suggested in the literature (Hernández-Nieto & Pulido, 2014). The specialists valued the questionnaire highly ($M = 4.93$; $SD = 0.26$; min = 1; max = 6), and the suggestions made were applied. Kappa de Fleiss and W de Kendall were both implemented

Table 2 Summary of the instruments used

#	The instruments
1	Delphi method
2	Kappa de Fleiss and W de Kendall
3	The principal components' method with varimax rotation
4	Bartlett's test of sphericity
5	The Kaiser-Meyer-Olkin Measure of Sampling Adequacy
6	Cronbach's alpha
7	Compound reliability (CR)
8	Average variance extracted (AVE),

to accomplish the indexes of concordance and relevance of observations granted, the outcomes of which were positive ($K = 0.86$; $W = 0.88$). Subsequently, quantitative validation was undertaken through exploratory and confirmatory factor analyses via principal components analysis with varimax rotation. The findings indicated that the factorial structure was suitable for the initial theoretical approach and positive correlations between factors were observed. Tests identified the dependence among the delimited variables (Bartlett's test of sphericity = 2659.21; $p < 0.001$) as well as the sample adequacy (Kaiser–Meyer–Olkin = 0.87).

The data were statistically analysed further to evaluate the extent to which the questionnaire was reliable, with methods including Cronbach's alpha (α), compound reliability (CR) and average variance extracted (AVE) applied, which confirmed that the questionnaire results were internally consistent, see Table 2.

4.4 Procedure

The experiment was conducted in a number of stages. The first stage involved the design and validation of the ad hoc tool. Subsequently, students who would participate in the experiment were selection. Consent was obtained from the families of the students for their participation. In this study, it was ensured that all ethical confidentiality principles were honoured. Therefore, two groups were formed to which students were randomly assigned, where the first constituted the control group and the second was designated as the experimental group.

Data were collected both prior and subsequent to the teaching process, with an interval of two months. A total of 10 sessions were implemented by the teachers, during which the teachers instructed the students on contents using the traditional approach for the control group and the novel method involving the Escape Room for the experimental group. Session duration was approximately 45 min on average. The subjects of the lessons comprised exponential and logarithmic relationships and functions (exponential functions, solving exponential equations and inequalities, logarithms and logarithmic functions, and properties of logarithms). These subjects are very important because the Common Core State Standards (CCSS) wants students to understand the concept of exponential functions and use it to represent real life situations. They expect students to “recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another” (CCSS, 2010, p. 70). They also want students to represent a given situation as a function “construct linear and exponential functions, including arithmetic and geometric

sequences, given a graph, a description of a relationship, or two input-output pairs” and “interpret the parameters in a linear or exponential function in terms of a context” (CCSS, 2010, p. 71).

Two groups of participants were formed, which mirrored the different classes to which they belonged. The learning methodology adopted by the control group was traditional, whereby the teacher was responsible for presenting the contents and completing the exercises on the blackboard. In such teaching processes, the only active participant is the teacher. On the other hand, students are required to concentrate on what the teacher is doing, making them passive participants. This hampers and obstructs interactions among educational agents, thus preventing them from learning and solving problems collaboratively. Students attempted to solve the equations on their own in their personal class notebooks. On the other hand, the learning approach adopted by the experimental group included an Escape Room. This encouraged students to interact with their classmates, work as a team, while also making them more motivated and increasing their involvement in the process of learning and practicing contents.

The process of designing the Escape Room was performed by the teachers of mathematics with the assistance of the researchers, who are specialists in this area. The room contained three computers as well as a tablet, which allowed the students to browse online to help them with solving the codes in order to progress. A total of five enigmas were concealed within the room, which were grounded on mathematics problems that required solving; after solving a given problem, this directed participants to the next one because it had a track leading to the subsequent enigma. The design of the mathematical problems was intended to encourage the students to adopt innovative ways of practicing mathematics. Of the various tasks students were asked to complete as part of the Escape Room, one consisted of the following: A story was told by the narrator to create an ambiance of a ghostly dwelling in which all doors had been mysteriously shut, and a haunting sound had been heard. A ghost's shadow appeared and instructed them that in order to escape from the ghostly dwelling, a number of different problems had to be solved. During every test, the ghost provided the participants with a card containing exercises (Fig. 2) that needed to be solved satisfactorily to ultimately escape from the room. A time limit was set for completing each of the tests, which varied according to the level of difficulty. After this time had finished, the participants were given a clue or puzzle with which they could discover the following test.

The role of the teachers was only to assess or guide the students in the experience, as the latter were required to collaboratively find solutions to the enigmas within their groups. Both groups were assigned a specific colour, and the enigmas were also marked with these colours, meaning that the groups were required to identify the paths of their designated colours. The enigmas were concealed in different areas of the classroom. To facilitate the process of locating the enigmas, it was important for them to focus on the specific information provided in the story. After solving an enigma, students were awarded a badge, which they could subsequently swap for a reward. With these rewards, they had the opportunity to obtain additional points in the attitudinal part of the subject within the participation block or additional hints to discover the enigmas. While this approach was adopted for the experimental group,

$8^{4x+2} = 64$	$5^{x-6} = 125$	$\left(\frac{1}{2}\right)^{4x+1} = 8^{2x+1}$
$3^{5x} = 27^{2x-4}$	$16^{2y-3} = 4^{y+1}$	$\left(\frac{1}{5}\right)^{x-5} = 25^{3x+2}$
$2^{6x} = 32^{x-2}$	$49^x + 5 = 7^{8x-6}$	$216 = \left(\frac{1}{6}\right)^{x+3}$
$81^{a+2} = 3^{3a+1}$	$256^{b+2} = 4^2 - 2b$	$\left(\frac{1}{8}\right)^{3x+4} = \left(\frac{1}{4}\right)^{-2x+4}$
$9^{3c+1} = 27^{3c-1}$	$8^{2y+4} = 16^y + 1$	$\left(\frac{2}{3}\right)^{5x+1} = \left(\frac{27}{8}\right)^{x-4}$

Fig. 2 Example of tasks performed

on the other hand, the control group was given the identical amount of mathematical problems (five), which were written on the class blackboard, and then asked to find solutions. As the problems given were intended to allow them to practice mathematics, particular instructions were not required as previous explanations had already been provided on such problems and all that was required was practice. The final part of the study involved the collection of data.

5 Results

Significant improvements were observed in every dimension subsequent to the application of the Escape Room as a pedagogical instrument (Table 3). In terms of learning, the values for of Learning Achievement were significant ($U = 357,000$; $Z = -2091$; $p = 0.056$) and the effect size was large ($d = 0.541$). Analogous results were found for Learning Anxiety ($U = 92,000$; $Z = -5772$; $p = 0.000$) and the effect size

Table 3 Mann–Whitney U test for control and experimental groups differences

	Group	Ranks	U	Z	p	d *
L Achievement	Control	33.10	357,000	-2091	0.056	0.541
	Experimental	46.90				
L Anxiety	Control	61.77	92,000	-5772	0.000	0.546
	Experimental	18.23				
Motivation	Control	33.90	672,000	2498	0.031	0.671
	Experimental	46.10				
Autonomy	Control	46.10	672,000	2479	0.033	0.674
	Experimental	33.90				

* Cohen's d small < 0.20, Medium < 0.50, large > 0.50

was also large ($d = 0.546$). Significant differences were also observed for both Motivation and Autonomy ($U = 672,000$; $Z = 2498$; $p = 0.031$ and $U = 672,000$; $Z = 2479$; $p = 0.033$).

The effect sizes of $d = 0.671$ and $d = 0.674$ can be interpreted as being large. For each of the dimensions analysed (Achievement: $RC = 46.90$; $RE = 33.10$; Motivation: $Rc = 33.90$; $RE = 46.10$ and Autonomy $Rc = 46.10$; $RE = 33.90$), the values obtained by the experimental group exceeded those of the control group. For Anxiety, different values were detected, as those of the experimental group were lower ($Rc = 61.77$; $RE = 18.23$). According to the findings, the experience implemented had significant effects on each of the dimensions studied.

In the dimensions of Achievement: $RC = 36.06$; $RE = 26.94$; Motivation: $Rc = 25.90$; $RE = 26.94$ and Autonomy $Rc = 37.11$; $RE = 25.85$), the values of the experimental group exceeded those of the control group. However, different values were observed for Anxiety, as the experimental group recorded lower values ($Rc = 44.61$; $RE = 18.31$).

As depicted in Table 4, from a different aspect, we attempt to find whether the variable (being the negative attitudes of 19 students regarding learning mathematics) could have an impact on certain changes that this experience creates. However, in the experimental group, this variable affects only motivation ($U=70,000$; $Z=-2638$; $P=0.026$) and autonomy ($U= 51,500$; $Z= -0.3383$; $P= 0.019$).

The negative attitudes of 19 students towards learning mathematics are the most motivated and show the highest level of anxiety in general. However, such an effect

Table 4 Mann–Whitney U test differences between the experimental and control groups according to the students with negative attitudes regarding mathematics learning

Control						
	Group	Ranks	U	Z	<i>p</i>	d _*
L Achievement	Positive attitudes	17.00	103,000	- 1488	0.193	-
	Negative attitudes	23.00				
L Anxiety		19.00	136,000	-0.099	0.971	-
		21.00				
Motivation		17.00	95,000	-1772	0.111	-
		23.00				
Autonomy		17.00	98,500	-1585	0.137	-
		23.00				
Experimental						
	Group	Ranks	U	Z	<i>p</i>	d _*
L Achievement		21.00	143,500	0.367	0.749	-
		19.00				
L Anxiety		22.00	158,500	0.961	0.370	-
		18.00				
Motivation		17.00	70,000	-2638	0.026	-
		23.00				
Autonomy		15.00	51,500	-0.3383	0.019	-
		25.00				

* Cohen's d small < 0.20, Medium < 0.50, large > 0.50

Table 5 Correlation between dimensions for each group

		Group	L Achievement	L Anxiety	Motivation	Autonomy
Control	L Achievement	<i>r</i>	1	-0.127	0.065	0.313
		<i>p</i>		0.576	0.819	0.125
	L Anxiety	<i>r</i>	- 0.127	1	- 0.180	0.073
		<i>p</i>	0.576		0.401	0.789
	Motivation	<i>r</i>	0.065	- 0.180	1	0.179
		<i>p</i>	0.820	0.403		0.417
	Autonomy	<i>r</i>	0.314	0.075	0.180	1
		<i>p</i>	0.126	0.790	0.409	
Experimental	L Achievement	<i>r</i>	1	0.140	0.382 *	0.422
		<i>p</i>		0.537	0.062	0.042
	L Anxiety	<i>r</i>	0.140	1	0.249	-0.112
		<i>p</i>	0.540		0.232	0.635
	Motivation	<i>r</i>	0.382 *	0.248	1	0.702 **
		<i>p</i>	0.062	0.230		0.000
	Autonomy	<i>r</i>	0.422 *	-0.112	0.703 **	1
		<i>p</i>	0.043	0.634	0.000	

* Significance with values less than 0.05, ** Significance with values less than 0.01

did not manifest in the control group, as differences were not observed in students who harboured negative attitudes regarding mathematics. While these students had the highest levels of motivation and were the most anxious within the control group, significant differences were not identified.

Lastly, it is important to understand the correlations between the various dimensions analysed in terms of the both the control and experimental group (Table 5). For the control group who did not participate in the Escape Room, the distinct dimensions do not appear to be positively or negatively correlated ($p > 0.05$). On the other hand, the correlations in the experimental group are positive and significant. In particular, there is a prominent positive correlation between motivation and achievement ($r = 0.382$, $p < 0.05$), as well as autonomy and achievement ($r = 0.422$, $p < 0.05$), and motivation and autonomy ($r = 0.702$, $p < 0.01$).

6 Discussion

The conducted research has enabled the achievement of the specific overall objective of determining the extent to which using educational Escape Rooms is effective for learning mathematics in comparison to the application of conventional approaches for third grade secondary school students. The study findings have reinforced the findings in the literature regarding the potential benefits of innovative teaching methods and the utilisation of active methodologies for learning and teaching Bai et al., 2020; Cechetti et al., 2019; Rossi et al., 2021). The current study concentrated on the utilisation of the Escape Room as a methodological strategy of gamifying a topic as classical and meticulous as mathematics.

Although gamification is widely accepted and used by teachers, the motivation for conducting this study was the limited research on the utilisation of Escape Rooms

in the field of mathematics. Hence, based on the aim of enhancing the effect of the literature on the given topic, this research was undertaken.

The experience designed by the teachers and researchers was advantageous for motivating the students due to the fact that it created an engaging learning environment, which conforms with previous general findings on gamification (Dicheva et al., 2015; Hamari et al., 2014; Majuri et al., 2018) particularly Escape Rooms (Lim & Jakop, 2019; Arnal et al., 2019; Segura-Robles & Parra-González, 2019). By creating a gamified environment, the student's activation was positively impacted through the design of suitable problems that challenged the students to find solutions on their own or by collaborating with their peers (Veldkamp et al., 2020).

Therefore, this study is grounded on the analysis of past work published on the concept of gamification, with a specific focus on Escape Rooms. The purpose of conducting this research was to analyse the factors which benefit the academic literature on the relevant active methodology. Thus, the major contribution of this research that it presents new findings on a training strategy that has received minimal attention in the field of mathematics.

Research on the application of both gamification and Escape Rooms indicates that they offer significant advantages. Incorporating game mechanics and aspects of game design into educational settings increases students' learning experience in general by increasing their enjoyment (Anastasiadis et al., 2018), making them more engaged and involved (Bouchrika et al., 2019), while at the same time improving their academic success and learning outcomes (Barna & Fodor, 2017; Yildirim, 2017). Furthermore, gamification can potentially induce changes in the psychology and behaviours of learners (Kim et al., 2017), while also influencing their intrinsic and extrinsic motivations (Dicheva et al., 2015; Roy et al., 2018), which is a critical factor due to its direct connection with academic achievement (Wigfield et al., 2019).

Specifically, this study has been described according to the analysis for dimensions, namely learning achievement, learning anxiety, motivation and autonomy. In regard to the answer of the first research question, actually significant improvement was observed in the dimension of learning achievement subsequent to the application of the Escape Room as a pedagogical instrument. For instance, in terms of learning, the values for of Learning Achievement were significant ($U = 357,000$; $Z = -2091$; $p = 0.056$) and the effect size was large ($d = 0.541$) (see Table 3). This conforms with the findings of past studies on the application of this methodology, which showed that the student's achievement in their formative action improved (Barna & Fodor, 2017; Wigfield et al., 2019; Yildirim, 2017).

The researcher think that it is very clear that our current approach in teaching mathematics is not producing the mathematical understanding that we desire, Schoenfeld (1994) stated, "the current mathematics education is based on a false mastery model" (p. 54). Therefore, it is an important to balance the focus between procedural knowledge and conceptual knowledge. According to the results of this study, we can see that in order for conceptual knowledge to be of value it should be taught through Escape Rooms. This type of technology is a great teaching method to introduce and deepen students' understanding in exponential and logarithmic relationships and functions. Exponential function is an abstract topic in mathematics, and

for the acquired knowledge to be permanent students' must value it. To help them value it, we need as educators to let them experience it by using it to Escape Rooms.

The researcher believes that when students moving also to the university to study Bachelor, they will be exposed to exponential functions in Algebra 1 and 2. The Common Core State Standards CCSS wants students to understand the concept of exponential functions and use it to represent real life situations. They expect students to "recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another" (CCSS, 2010, p. 70). They also want students to represent a given situation as a function "construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs" and "interpret the parameters in a linear or exponential function in terms of a context"(CCSS, 2010, p. 71). Exponential functions can be observed a lot in our world; the division of the cell, population growth, half-life, medication in the body, and compound interest. When students are given the chance to explore, discuss, and write exponential equations to represent these situations through Escape Rooms, exponential functions become meaningful and important. This couldn't be achieved if they memorized and applied the rule, and making them passive participants.

In regard to the answer of the second research question, analogous results were found for Learning Anxiety ($U = 92,000$; $Z = -5772$; $p = 0.000$) and the effect size was also large ($d = 0.546$). Actually, different values were detected, as those of the experimental group were lower ($R_c = 61.77$; $RE = 18.23$). The finding indicated that the dimension of learning anxiety significantly improved once the Escape Room was applied as a tool for teaching mathematics, this seem to be consistent with Parra-González et al. (2020), whose found that Escape Room enhanced students' ability to manage their learning anxiety. According to the numbers above we can see that students were more motivated and showed a higher level of learning anxiety, consistent with other works, and this is because of the positive intervention of the Escape Room, which meant they felt less annoyed, hostile, or frustrated while performing the activities or tests proposed by the teacher (Santos et al., 2019), and they perceived themselves as protagonists and were interested in the tasks that needed to be performed (Pérez-Manzano & Almela-Baeza, 2018), they performed instructional tasks repeatedly without fear of error (Contreras Espinosa, 2016; Lee, & Hammer, 2011), and they built on their own knowledge with this type of methodology (Khalil & Elkhider, 2016; Pumilia-Gnarini, 2013). Consequently, this contributed to lower anxiety and stress, since they could perform tasks at their own pace, autonomously, and individually, according to their personal and cognitive peculiarities. All this was supported by collaborative work with other classmates. Finally, students actively and without frustration or negative feelings reached the objectives established by the teacher (Parra-González et al., 2020). Therefore, experts recommend the use of Escape Rooms in learning spaces (Contreras Espinosa, 2016; Hursen & Bas, 2019; Lee, & Hammer, 2011; Shute & Ke, 2012).

Moving to the answer of the third question, significant improvement was observed in the dimension of the motivation subsequent to the application of the Escape Room as a pedagogical instrument ($U = 672,000$; $Z = 2498$; $p = 0.031$). This is consistent with other researchers' findings, such as (Lim & Jakop, 2019), who showed that

Escape Room could help students with increasing their motivation in learning. In this study, of the various tasks students were asked to complete as part of the Escape Room, and it had a significant impact on increasing students' motivation to learn and complete the task, one consisted of the following: During every test, the ghost provided the participants with a card containing exercises (Fig. 1) that needed to be solved satisfactorily to ultimately escape from the room. A time limit was set for completing each of the tests, which varied according to the level of difficulty. After this time had finished, the participants were given a clue or puzzle with which they could discover the following test. It's this ticking clock that really gives the game its thrill, the nerve-jangling excitement as time runs out is very, very real!

The researcher thinks that there's still some debriefing to be done. When time is up, and groups have finished their tasks, it is time for post-discussions about how it all went down. Therefore, the researcher tried to ask the students the following questions: Did you find tasks too simple or too challenging? What did you wish you had done differently? He asked students to answer questions about the process to not only give him feedback but also to help them participate in self-reflection about their own experience. As a result, the researcher found from their tone of voices, enthusiasm, and interaction that the students' motivation towards learning exponential and logarithmic relationships and functions increased significantly. Because games create a safe environment with their own set of rules in which participants are often rewarded for trying different approaches, they are perhaps the best medium for encouraging and increasing motivation.

In regard to the answer of the final research question, significant improvement was also observed for Autonomy ($U = 672,000$; $Z = 2479$; $p = 0.033$). This finding appears consistent with that of (Arnal et al., 2019; Segura-Robles & Parra-González, 2019). We can see that after solving an enigma, students were awarded a badge, which they could subsequently swap for a reward. With these rewards, they had the opportunity to obtain additional points in the attitudinal part of the subject within the participation block or additional hints to discover the enigmas. Developing autonomy in learners has been emphasized as a goal of mathematics education (Ben-Zvi & Sfard, 2007; Yackel & Cobb, 1996). The researcher thinks that for students to have the responsibility and right to influence their mathematics education, they need to take charge of their own learning in mathematics, that is become autonomous, at least partially. Further, if learners are supposed to apply their mathematical knowledge toolkit effectively in order to solve real-life problems after finishing formal education, they should be autonomous learners. Not only to solve their own real-life problems using mathematics, but also to participate as active future citizens of society.

It is interesting to note that the negative attitudes of 19 students towards learning mathematics only influenced the students' motivation and autonomy, which concurs with (Tapia, 1996). The important question that arises from this is, why did only influenced the students' motivation and autonomy? This result supports previous researches which showed that motivation is dependent on learners taking charge of their own learning (Garcia & Pintrich, 1991; Sakui, 2002; Takagi, 2003; Ushioda, 2003, 2006), have revealed that autonomy fosters motivation. It has been found that those students are more motivated and show a higher level of learning anxiety, similar to other works. However, this effect was not observed in the control group, where

there were no differences according to the negative attitudes of students towards learning mathematics. It is important to mention here for international readers what is meant by the negative attitudes of students towards mathematics; in fact, according to the report of their mathematics teacher, 19 students of the experimental group and 23 students of the control group had negative experiences with their previous mathematics teachers when using technology (not through Escape Rooms), as these strategies did not include active methodologies, were not related with students, and were not connected with their socio-educational reality. These students did not know whether it was the poor design or poor planning by their previous mathematics teachers when using technology that caused them to have negative attitudes towards learning mathematics. This is consistent with the findings of (Burke, 2014; López Noguero, 2008; Marín-Díaz, 2015; Pérez-López & Rivera García, 2017; Parra-González et al., 2020).

No correlations were observed with regard to the control group. Conversely, correlations were detected among Achievement-Autonomy, Motivation-Autonomy and Motivation-Achievement in the experimental group. The last of these correlations is particularly prominent, as the increase in their motivation to learn and complete their homework tasks as a result of the achievement obtained is positive. These findings agree with (Parra -González et al., 2020).

7 Conclusions

The findings indicate that using Escape Rooms in the mathematics field enhances achievement, anxiety, motivation and autonomy, where negative attitudes of students regarding mathematics learning represent a variable that should be considered, particularly in terms of autonomy and motivation. Thus, the potential of Escape Rooms exceeds that of conventional approaches in Mathematics, as it enables students to become engaged and interact as part of the teaching-learning process. The researchers suggest conducting further research in the following areas: (1) Conduct similar studies with other school grades to further identify the impact of using Escape Room to teach the mathematics curriculum; (2) conduct further studies to identify the difficulties and obstacles hindering use of the Escape Room in teaching and learning mathematics.

8 Implications and limitations

Different practical and theoretical implications can be drawn from this research. From the theoretical perspective, the current study contributes by resolving the deficiency in the literature with respect to the application of Escape Rooms as a methodological approach in the field of Mathematics. The findings can benefit educators by offering insights such that they can make more informed decisions regarding the implementation of gamification via Escape Rooms in either physical or digital settings.

From a practical perspective, this study concentrates on promoting active methodologies for the implementation of mathematics teaching and learning processes according to the needs of modern society. Furthermore, the development of novel

models that enable content to be taught in engaging and interactive ways is facilitated. Hence, this study inspires educators to become more acquainted with and confident in innovative teaching practices such that they can implement them in their own classrooms.

One of the limitations of this research is that it purely concentrates on the topic of mathematics and other associated subjects taught in the Saudi education system. In addition, the sample of the study was purely comprised of students due to the problems faced with obtaining permission to expand the survey to a wider audience. Moreover, this study focused only on government secondary school in Al- Dhahran city (the east of Saudi Arabia). Consequently, it may not be possible to generalise the results countrywide. We know that the goal of most case studies is not to generalize but rather to provide a rich, contextualized understanding of some aspects of human experience through the intensive study of particular cases. However, the researcher believes that this city was a good place to conduct this study, because it has a big population which is drawn from different parts of the Kingdom of Saudi Arabia. This was seen in these students who participated in this study, who came from the middle of the country, the western part of the KSA, and also from the north-western part of the KSA, and the south-west of the Kingdom. Case studies are often labelled as being too long, difficult to conduct and producing a massive amount of documentation (Yin, 1984). In this case study, the researcher needed this rich information to get an in-depth case study of this school, otherwise it would have been difficult to reach the research objectives which led the researcher to answer his research questions.

9 Recommendations

In view of the findings, the researchers recommend the following:

- 1- The Escape Rooms should be included in mathematics education at various stages of education.
- 2- The programme should be included in mathematics in general, and in teaching exponential and logarithmic relationships and functions in particular.

“Conflict of Interest - None”.

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