Bringing an Educational Escape Room into the Mathematics Classroom

Lene Hayden Taraldsen
Western Norway University of Applied Sciences

Received: July 2024 ǁ Accepted: February 2025

Recently, there has been an increased emphasis on the use of educational escape rooms (EERs) in educational research. In this article, four pre-service teachers (PSTs) plan an EER for implementation with 9th grade students in their teaching practice period. The aim of the research is to explore the priorities that the PSTs set at the planning and implementation stages regarding both content and form. Qualitative data were collected through observation and focus group interviews, which were analysed in four phases inspired by constant comparative analysis. The results are discussed in relation to theories and research on teacher content knowledge, problem-solving in mathematics, and EER in the mathematics classroom. It appears that planning and implementing an EER for use in mathematics teaching is a complex, challenging task, requiring knowledge-based attention to both content and form, as well as the need for a clear motivation for bringing an EER into the mathematics classroom. Regardless of how an EER is planned and implemented, an implication of the results in the article is that the underlying rationale of the teacher's priorities for the students' learning outcomes must be evident, and these priorities must match the expected features of an EER.

Keywords: • escape room • teacher content knowledge • problem-solving • teacher education

Introduction

According to the literature, an escape room is defined as a live-action team-based game in which the players discover clues, solve puzzles, and accomplish tasks to complete a mission in a limited amount of time (Nicholson, 2015). When a teacher brings an escape room into a classroom context, it can be referred to as an educational escape room (EER) (Veldkamp et al., 2020b). Although the structure of EERs may differ, the game typically consists of an introduction phase, an escape phase, and a debriefing phase (Sanchez & Plumettaz-Sieber, 2019; Wiemker et al., 2015). The game-master (in school settings often a role filled by the teacher) introduces the story to the players (students) and provides information about the game's purpose and the rules that need to be followed. During the escape phase, the game-master monitors the game and may provide players with hints to ensure progress. In the final debriefing, strategies and solutions are discussed. Studies have shown that this debriefing phase is particularly relevant to achieving learning objectives (Botturi & Babazadeh, 2020; Sanchez & Plumettaz-Sieber, 2019; Veldkamp et al., 2022).

Problem-solving is a key element in mathematics, and competence in mathematical problem-solving relies on the application of mathematical knowledge and skills (Schoenfeld, 1993) and heuristic strategies (Polya, 1990). Mathematics education research also emphasises that problem-solving may be a social activity (Liljedahl & Cai, 2021). In mathematics teaching, EERs are being used to emphasise the application of both specific mathematical competences, such as geometry and algebra (Andrews & Bagdasar, 2023; Jiménez et al., 2020), and of soft skills related to problem-solving, such as communication, creativity and cooperation (Charlo, 2020; Peleg et al., 2019; Zhang et al., 2019). Such priorities in mathematics teaching reflect the worldwide acknowledgement of the need to educate future generations in addressing and dealing with complex problems (European Commission, 2018; OECD, 2019).

Studies to date provide knowledge on how EERs can be applied in mathematics teaching (Andrews & Bagdasar, 2023; Charlo, 2020; Fuentes-Cabrera et al., 2020), and about the motivation behind the choice to use them (Taraldsen, in press). Less is known, however, about the priorities teachers set when planning for such use, and about the implementation in the classroom once the decision to bring the EER into the mathematics classroom has been made. The overarching rationale for this article is to contribute to establishing a body of knowledge about "if, how, why and when" EERs are used as a didactic tool (Taraldsen et al., 2020) by focusing on the operationalisation of an EER in mathematics teaching. This is achieved by studying one detailed case of how the use of an EER was planned and implemented in a mathematics classroom in a lower secondary school in Norway. The teacher perspective is at the centre of attention in this case, given that it is the teacher who brings the EER into the classroom. Applying an EER may be a decision that is made outside of the classroom, but once it is made, the teacher—through the authority, trust, and responsibility that come with the position as teacher—is left with the task of operationalising the EER in the classroom with the specific learning objectives in hand. In general, this process lays stress on the teacher's knowledge, both subject matter knowledge and pedagogical content knowledge (Ball et al., 2008; Shulman, 1986).

Nielsen and Bostic (2020) call for pre-service teachers' (PSTs') experiences with problem-solving in their education. The present case involves four Norwegian PSTs, participating in a mathematics course where the emphasis is on problem-solving. One element in this course is the introduction of an EER as a possible didactic tool: one that relies on the PSTs' active and passive experiences with EERs throughout the course. In the course, a general introduction to EERs is given and PSTs experience both an EER related to a break-out box (Veldkamp et al., 2020a) and a fully developed EER with emphasis on school mathematics. Once PSTs are familiarised with the use of an EER as a possible didactic tool, they switch roles from participant to director (i.e., from PST to teacher). This is because one of the mandatory learning activities for the PSTs in the course is to plan an EER and implement it with students during a school practice period. Given that someone (i.e., the course lecturer) made the decision to use an EER in the mathematics classroom, rules out the discussion about "if, why and when", and opens for the PSTs' concentration to be on the "how". PSTs are not affected by prevailing conventions at a workplace (e.g., school), apart from the beliefs about mathematics teaching they bring into their teacher education, which is based on their own previous experience as students (Van Zoest et al., 1994). Hence, when given a mandatory learning activity, the PSTs can devote themselves entirely to the tasks of planning and implementing the EER because they do not have the teacher's need for a long-term perspective or need to attend to the often hectic state of the school's daily life. Thus, the PSTs are on this occasion an ideal source of data. Their attention to bringing the EER into the mathematics classroom is narrowed down to their own priorities within the framework provided by the mandatory learning activity, and discussion with their teaching practice mentor (the teacher of the class where they will have their upcoming practice period) about the curriculum the students are familiar with or to which they are about to be introduced.

Focusing on "how" in the PSTs' planning and implementation implies accepting the rationale for EER as a mandatory learning activity, and for individual PSTs it relies on both their curiosity about how an EER may be used in the mathematics classroom, and on their motivation for carrying out the activity. At the operational level it implies focus on their priorities in the planning and implementation of the mandatory learning activity. This represents an opportunity to gain new insight into the PSTs' priorities regarding both content and form, and the foundation for these priorities. Based on such considerations, the following research question is addressed in this article, with the aim of elucidating priorities that influence the operationalisation of an EER in the mathematics classroom:

> *What priorities are set by PSTs when planning and implementing an educational escape room in mathematics teaching?*

Theoretical Background

Teacher Content Knowledge

Shulman (1986) addressed the issue of teachers' content knowledge and identified different kinds of intertwined knowledge. He emphasised that it is not sufficient for teachers simply to master the content (i.e., subject matter knowledge). It is also imperative that they facilitate the desired content so that students can learn in a way that makes it comprehensible (i.e., pedagogical content knowledge); moreover, teachers should aim to relate their approach to teaching to topics and issues encountered by students in other subjects (i.e., curricular knowledge). This means that learning objectives are influenced by subject matter content, teachers' beliefs about what to learn and how to learn it, and by their attention to students' near (in school) and distant (societal) surroundings. Influenced by Shulman's work, Ball et al. (2008) developed a practice-based theory that identified domains of mathematical knowledge for teaching in which the teacher should pay attention to knowledge of both content and form when planning and implementing the learning of mathematics. Such attention will then be of importance when planning and implementing an EER.

Problem-solving in Mathematics

Based on the theory of mathematical problem-solving proposed by Polya (1990) in the 1940s, a problem is identified when one faces a challenge, and experiences a need or desire to solve it, but do not have an immediate approach or method for this purpose at hand. According to Polya (1990), problem-solving is the process of analysing the problem, developing a plan, executing the plan, and validating the outcome. In mathematical problem-solving, the first of these four stages requires the problem-solver to acknowledge that there is a problem to solve and then apply one or more heuristic strategies to analyse the problem, with the subsequent goal of developing and executing a plan that will produce a viable solution to the problem. With reference to Polya's (1990) proposed heuristic strategies, Liljedahl et al. (2016) identified some recognisable characteristics of the high-quality problem-solver as being able to: reduce the problem to its essential nature by visualisation and structuring; think backwards from a desired outcome; see the problem from various angles, and thereby recognise internal relations; change the approach adopted; and transfer well-known approaches and procedures from one problem to another.

Bringing problem-solving into the mathematics classroom requires the mathematics teacher to emphasise both mathematical content (what mathematical objectives to plan for) and pave the way for students to develop into high-quality problem-solvers (how to work with problems in mathematics). These two goals make demands on the teacher's mathematical content knowledge, knowledge of the students' experience with problem-solving, and knowledge of how to develop the characteristics of good problem-solvers. In other words, the teacher needs to be mathematically skilled and be able to improvise while the students work on a problem based on developments taking place in the mathematics problem-solving classroom.

Smith and Stein (2018) present five practices for orchestrating productive mathematics discussions with an aim of mitigating the need for teacher improvisation while promoting reasoning and problem-solving: *anticipating*, *monitoring*, *selecting*, *sequencing,* and *connecting.* In addition, they argue for a "Practice 0" consisting of *goal setting*, since this must occur in any case before the teacher can orchestrate a productive discussion. This argument adds to the requirement of a planning phase. Attention needs to be given to goalsetting to anticipate possible strategic approaches and attempts to solve the problem, monitoring students to determine how action may be carried out, organising the selection and sequencing of students' approaches and attempts for plenary sharing, and finally, and linking the shared attempts to the mathematical learning objective(s) for the lesson. Then, the latter four of the practices proposed by Smith and Stein (2018) are put into action. Hence, the teacher's reliance on subject matter knowledge in mathematics, pedagogical content knowledge and curricular knowledge are present both before and during the planned mathematical problem-solving lesson. This strategy for diminishing the necessity of the teacher's content knowledge virtuosity and improvisation is recognised with respect within mathematics education (e.g., Kaplinsky, 2019; King, 2019). The five-practice structure of Smith and Stein (2018) relies on acknowledging socio-cultural principles such as participation in a learning environment, communication with others, and students' co-responsibility for linking of content and form. This also implies, in a Deweyan sense, acknowledging that learning is something more than merely acquiring knowledge, because students are assumed to learn by participation; that is, through engaging in (i.e., reflection on) shared active experiences (e.g., Dewey, 1916, 1938).

EER in the Mathematics Classroom

A number of studies have reported on bringing the EER into the mathematics classroom (e.g., Arnal-Palacián et al., 2019; Fuentes-Cabrera et al., 2020; Jiménez et al., 2020). Clarke et al. (2017) presented a theoretical framework for creating EERs that was inspired by game-based learning, and is comprised of six areas: *participants*, *objectives*, *theme*, *puzzles*, *equipment,* and *evaluation*. All these areas are part of the teacher's planning, and although some of them are quite fixed in a school setting (e.g., the number of students, down-to-earth complexity regarding equipment, and matters relating to the curriculum), other aspects are left for the teacher and, if desired, the students to decide (e.g., learning objectives, the escape room theme, puzzles to be used, and evaluation). Clarke et al. (2017) stressed that their framework is a proposed development tool that needs to be modified based on conducting specific case studies that focus on the planning, facilitation, execution and evaluation of EERs, for example, in a mathematics classroom setting in a Norwegian lower secondary school.

Clarke et al. (2017) argued that EERs allow students to apply a variety of problem-solving approaches to develop their abilities in learning processes and to experience the impact they may have in problem-solving processes through the human tendency to learn by playing. Bertoni and Maffia (2022) added to the focus on problem-solving abilities and soft-skills development by reflecting on the opportunity that EERs provide to enhance students' development of creative skills. In this way, they echo the attention given by Polya (1990) and Liljedahl et al. (2016) to problem-solver strategies and characteristics. They conject that puzzles in EER may provide contexts where the mathematics that needs to be used is not already explicated to the contestants. In sum, when planning and implementing an EER in mathematics teaching, the teacher has to attend to priorities regarding both content and form, or as argued by Ball et al. (2008), rely on knowledge about mathematical content, teaching and students as Smith and Stein (2018) suggested.

Method

Qualitative research is used to understand individuals' opinions about social or human phenomena (Creswell, 2014). The present case examines the approach of four PSTs to issues concerning "how" in their work with a mandatory learning activity involving an EER in mathematics teaching. A qualitative approach was applied to explore the priorities that the four PSTs set when planning the EER for implementation with 9th grade students (approximately 15 years old), in a practice period as part of their teacher education. According to Yin (2014), a case study is defined as an empirical investigation that studies something in its real context but is limited by both time and place because the boundary between what is to be studied and the context is unclear. The present case study was conducted within a two-month period during the sixth semester of the PSTs' 5-year teacher education.

Description of the Case

In the beginning of 2021, four PSTs participated in the study; they were part of a group of 44 PSTs taking a 7.5 ECTS (European Credit Transfer and Accumulation System) mathematics education course on problem-solving. One part of the course focused on EER as a didactic tool in mathematics teaching. The four PSTs were given a general introduction to the use of EERs, and a mandatory learning activity was introduced (Figure 1). The four PSTs worked together on campus with the planning of the EER and then implemented it in their practice period. They were assigned to the same practice group at a school and had a teacher at the school as their joint practice mentor.

Mandatory learning activity: Planning and implementing an EER in mathematics teaching

In groups, you are required to plan an EER and implement it during the upcoming practice period.

The aim of this activity is for PSTs to proceed in accordance with the following learning objectives:

- PSTs can critically assess and adapt didactic approaches that encourage students to reflect, be creative, and explore.
- PSTs can contribute to the analysis of, reflection on, and justification of how teachers can influence the learning environment and motivation for mathematics through their didactic choices.

The learning activity comprises the following three steps:

1. Planning of teaching that includes implementation of an EER, which is to be adapted to the age of the students and should contain mathematical content that students are either familiar with or will encounter during the practice period. Development of the EER must take place before the practice period starts. The EER must last at least 60 minutes, and consist of an introduction phase, an escape phase, and a debriefing phase. The EER shall be piloted with fellow PSTs before the practice period (the time schedule for this is published on Canvas).
2. Implementation of the EER during the practice period.
3. Submission of a written report (the criteria for content and structure are published on Canvas). The group of four PSTs submits a joint report.

Figure 1. The mandatory learning activity (author translation).

The mandatory learning activity was divided into two parts (Figure 2). In Part 1, the PSTs planned an EER, in Part 2, they implemented it in the teaching of mathematics during their practice period. In this study, data were collected through both observation and interviews. The author observed the PST group in four planning sessions and in their piloting of the EER with fellow PSTs, after which the first semi-structured group interview was conducted. Later, two sessions were observed to capture the implementation phase of the EER during the PSTs' practice period. Data collection ended with the second group interview about one month after completion of the practice period. Figure 2 shows a timeline of the case with data collection.

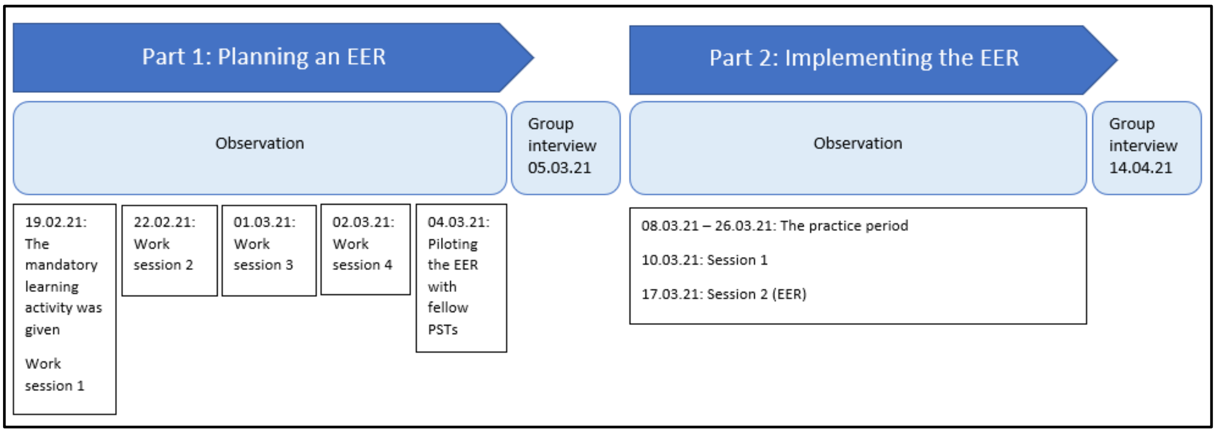

Figure 2. Timeline of the case.

In Part 1, *Planning an EER*, the PSTs started the group work directly after the learning activity had been introduced. No fixed meeting times were set and the PSTs themselves decided when to work on the assignment. In the description of the learning activity (Figure 1), there were some guidelines that the PSTs had to follow. For instance, the EER had to be related to the mathematical content on which the students in the practice period class were working. I observed the group when they worked together, one advantage of which is that information is obtained about participant interaction in the context being studied (Krumsvik, 2019). During the four group work sessions, I completed an observation form where I wrote down my descriptions of what happened and my immediate impressions of PSTs' active and passive experiences (Dewey, 1916, 1938). During the subsequent piloting of the EER with fellow PSTs, I used video observation, where two of the PSTs who had created the EER wore head cameras. The purpose of this was to gain insight of the observing PSTs' focus during the piloting, and to access their attention and conversations while they were observing. Before the practice period, a focus group interview was conducted. The purpose of this interview was to collect data from PSTs' discussion about their experiences in the planning of the EER, and their thoughts about using the EER as a potential didactic tool in mathematics teaching (Brinkmann & Kvale, 2015). I moderated the interview using an interview guide with a semi-structured format.

In Part 2, *Implementing the EER*, the PSTs brought the EER into the mathematics classroom during their teaching practice period. During their planning, they had decided to devote one session (Session 1 in Figure 2) to an introduction to students about the escape room and problem-solving, and then to try out the EER in the subsequent mathematics session (Session 2 in Figure 2). I observed these sessions using video recordings. In both sessions, I used a stationary camera and two of the PSTs wore head cameras. By using head cameras, these PSTs were given a more active role in the collecting of data, and the line between participants and researcher became less visible (Blikstad-Balas & Sørvik, 2015). The use of video in data collection provided a detailed non-interpreted rendering of what took place. After the practice period, another semi-structured focus group interview was conducted. In contrast to the first interview, the focus here shifted to PSTs' actual experiences from implementing the EER in the classroom.

Data Analysis and Trustworthiness

To gain insight into the four PSTs' priorities when planning and implementing an EER in mathematics teaching, a phenomenological condensation of impressions produced by data from observation and focus group interviews was inspired by a grounded theory approach, more precisely narrowed down to a constant comparative analysis (Glaser, 1965; Strauss & Corbin, 1998). The analysis was comprised of four phases; the first phase included three steps. In the first step, I wrote memos based on field notes and observations from Part 1 and transcribed data from the first interview (Figure 2). This provided impressions and incidents from the PSTs' planning and prospects for implementation. A similar process was then conducted in the next step with a focus on implementation of the EER (Figure 2). Finally, through an inductive approach, impressions and incidents from the data were compared to identify and interpret priorities set by the PSTs. The four PSTs were assigned alpha-numeric codes (S1–S4) to follow them individually within the group. In a second phase, with the condensation of the PSTs' planning and implementation of the EER following the timeline for the case and the subsequent interpretations, the data were organised according to the themes, *Planning an EER* and *Implementing the EER*.

In constant comparative analysis, there is a continuous flow from one phase to the next, and my experiences from the first two phases were important for the third phase. In this phase, I developed grounds for discussing the priorities made by the PSTs when planning and implementing an EER by relating my interpretations to a theoretical background consisting of teacher content knowledge, problem-solving in mathematics, and EER in the mathematics classroom. These three areas were chosen because of the study's focus on bringing an EER into the mathematics classroom. From the aim of the study and the presented research question the teacher's role emerges as pivotal. As a consequence, theory on teacher content knowledge was emphasised. Furthermore, with the definition of EER in mind

(Nicholson, 2015), problem-solving was recognised as a necessary element in use of an EER. This aligns with previous research on use of EER in mathematics (e.g., Andrews & Bagdasar, 2023). The discussion is in relation to Smith and Stein's (2018) framework, because it emphasises what the teacher may prioritise in various phases when working on problem-solving in mathematics. This aligns with the various phases recognised in a typically EER structure consisting of an introduction phase, an escape phase and a debriefing phase (Sanchez & Plumettaz-Sieber, 2019; Wiemker et al., 2015). In the final phase, conclusions and implications were generated on the key research question to be addressed.

Theoretical sensibility is a core concept within constant comparative analysis and reflects the researcher’s personal qualities (Glaser & Strauss, 1967). From my knowledge and experience related to EERs, I was aware of such potential impact. Therefore, I strived to connect my theoretical sensibility to the data analysis without diminishing the transparency of the data. I needed to understand the PSTs' priorities before it would be possible to explain them and allow my subjective experiences and theoretical development of sensibility to capture an holistic understanding of such priorities when planning and implementing an EER in mathematics teaching.

Planning and Implementing an EER: Escape the Prison Cell

Planning an EER

At the planning stage, the PSTs were challenged to organise their own group processes, to decide what theme to apply, what puzzles and equipment to put into the EER, and what learning objectives to emphasise for the students participating in the EER experience (Clarke et al., 2017). Work Session 1 was initiated by the four PSTs with a discussion about how they should collaborate on the mandatory learning activity in an appropriate manner. The activity required them to work as a group in all three parts (Figure 1), and the PSTs assured each other that they were aware of this. They made deliberate choices about distributing work to be done in the group, which alternated between individual work, pair work, and joint cooperation in Work Sessions 1–4. During these sessions, the four PSTs had unique personal experiences that were then shared verbally with the other three, receiving responses and generating discussion. PSTs' knowledge did not remain tacit but was shared and negotiated until consensus was reached. I observed that the PSTs took on different roles in the group. S1 showed leadership already in Work Session 1, putting forward questions such as "*What theme can we use?*" and "*What should be the centre of attention in the EER?*" He showed initiative and expressed a desire for progress. Later in the planning part, this role was strengthened by his urge to connect the various selected elements in the EER to sustain control of both content and progress in the planning. S1 was the PST who monitored most conversations in the four work sessions and collected everything the group discussed and agreed on, through writing and editing a text file on his computer.

Designing an EER is a complex process (Botturi & Babazadeh, 2020), with decisions to make on both content and form. In Work Session 1, the group primarily focused on the EER form. I observed that the PSTs spent time discussing the theme of the room. There were some disagreements within the group, for instance, when S2 pointed out that the narrative had to be as realistic as possible for the students to find it exciting. This comment was met with hesitation from S3 and S4 because they did not think that the introductory narrative of the escape room would make much difference; rather, they found it imperative to focus on the puzzles to be solved. Various theme suggestions were discussed, and towards the end of Work Session 1, the group decided the theme would be a prison cell, and that the narrative should be about a mathematical genius who previously had been behind bars in the cell. He had been wrongfully convicted, and rumour had it that he was about to escape just before being transferred to another prison. In the first interview, I asked the group about this choice, and they said that they were satisfied with the theme because it added realism to the narrative. Moreover, it would be feasible to carry out this EER activity in the mathematics classroom with 16 students (i.e., with four equal prison cells). After Work Session 1, the PSTs were in contact with their teaching practice mentor, who suggested that they should relate the mathematical content to fractions. The PSTs agreed and said they would each come up with some puzzle suggestions for their next work session.

Work Session 2 appeared somewhat chaotic from an observer's perspective. All four PSTs had individually followed their own line of thought about the puzzles in the EER, and they were keen to show the others their suggestions. The conversation jumped from one suggestion to the next, but "all the pieces in this puzzle" did not seem to fit. Eventually, S1 suggested that it might be a good solution to collect all their thoughts and potential puzzles in a shared document. Accordingly, the group discussion moved towards agreement about five puzzles in which individually hatched puzzle inputs were selected and adapted to fit the overall objectives of the EER. In the first interview, the PSTs were challenged to describe their selection of content, and possible learning outcomes for the students. The PSTs explained that the mathematical objective for the EER was to have students recall their knowledge about fractions, while at the same time wanting them to improve their collaboration. They elaborated on the five puzzles and argued for some of their choices. An example of one of the puzzles is presented in Figure 3.

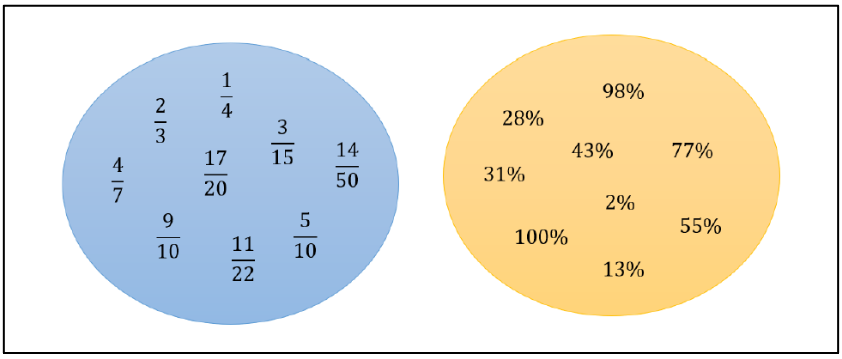

Figure 3. Fractions and percentages: the blue diagram is placed on top of a table and the yellow diagram is attached to the underside of the table.

In the interview, S2 explained the intention behind the puzzle in Figure 3, where students must convert the fractions inside the blue ellipse attached to a tabletop with adhesive tape into percentages, and then collaborate with a fellow student who is looking at the yellow ellipse (attached to the underside of the tabletop) to decide which values matched. In this puzzle, the only correct answer is 28 ($\frac{14}{50} = 0.28 = 28\%$) as it is the only quantity found in both ellipses. The PSTs argued that this puzzle facilitates both repetition of fractions and collaboration through encouraging students to work together by communicating with each other positioned above and below the table. It would be difficult for one person to remember all the quantities while shifting from above to below the table to check. S3 pointed out that this was not a puzzle they invented themselves: "*I feel that many of the puzzles are rip-offs because we have tried out similar puzzles ourselves, but changed the numbers … so we used our experience from the introduction to create our own EER.*" The conversation in the first interview then moved from talking about the puzzles to expressing agreement that the PSTs wanted the students to experience the value of creativity in the EER, and recognition of the need for creativity when making an EER (Bertoni & Maffia, 2022).

In Work Sessions 3 and 4, the five puzzles were planned in detail, and preparations for the pilot were made. The PSTs discussed what physical objects to use to create a prison cell atmosphere that would influence the narrative framing of the EER as well as the unique content of each of the five puzzles. In these two sessions, the PSTs appeared to prioritise both EER content and form to ensure that the students would have a holistic EER experience.

After Work Sessions 1–4, a pilot of the EER was conducted with fellow PSTs from the same teacher education course as contestants. In the first interview with the four PSTs, conducting this pilot was considered important and necessary in their planning of the EER because there were aspects of the game that they had not foreseen. This was related both to the EER developed and to the behaviour of participants in the EER. An example of the former was the deliberate use of physical objects that did not have any connection to the puzzles and were only included to create visual noise or disturbance, such as a newspaper on the floor in the room. An example relating to participants' behaviour was that the group's fellow PSTs did not collaborate as much as they had anticipated. Although the pilot was highly appreciated by the four PSTs, major adjustments to the EER were not made, and only the newspaper and a couple of other physical objects were removed. Towards the end of the first interview, the PSTs broached the topic of their expectations regarding the implementation of the EER with students in the upcoming teaching practice period. They commented that they were looking forward to trying out the game with students as they believed it would be something the students would enjoy; at the same time, they were somewhat anxious about how the game would go. Based on my observations and the first interview, it appeared that in the planning of the EER the PSTs prioritised the introduction and escape phases; planning how to facilitate the debriefing phase was not given explicit priority.

Implementing the EER

Although being well prepared is a prerequisite in teaching (e.g., Smith & Stein, 2018), even if the teacher presents a careful and thorough teaching plan, it is impossible to predict entirely what will capture the students' interest and attention during a session. As noted, (Figure 2) the PSTs decided to devote one session to introduce the escape room and problem-solving to students before the EER was implemented. In Session 1, they first described the EER concept and then facilitated students' individual work with some selected mathematical problem-solving tasks. In the second interview, when asked about Session 1, the four PSTs described the progress in this plenary session and their choice of problem-solving tasks to present for the students. S2 said that the purpose of the selected tasks was to make students aware of the need to have several strategies available: "*If you do not understand a problem-solving task, you have to try another approach to solve it.*" For example, S4 advised the students to sketch the task if it was difficult to understand how to approach it. Another issue raised in the interview was the challenge for a teacher to balance the progress of students by providing supervision and guidance that paved the way for progress, but without reducing the problem to a well-known algorithm. The attention to this issue revealed that the four PSTs experienced the potential difficulty of finding this balance. Observations from Session 1 provided several instances of supervision where the task to solve ended up as a familiar algorithm, as well as several instances where only minor hints from the teacher kept students keen to follow an analytic or experimental self-made strategy. In relation to this case, it is important to stress that the four PSTs did not know the students and their strengths and challenges very well, and that they are still mathematics teachers in training.

Session 2 contained the main event of the mandatory learning activity with the implementation of the planned EER. I observed that S1 held the introduction phase in the hall outside the classroom, where he told the story about the mathematical genius who was ready to escape his prison cell to the 16 students present. He also pointed out some rules before randomly dividing the students into groups of four and leading them into their "prison cells" in the classroom. Figure 4 shows two groups of students working in their prison cells.

Figure 4. Photograph of two groups of students trying to escape their prison cells.

During the escape phase, the PSTs kept a low profile and hardly communicated with the students. This experience was raised in the second interview; PSTs shared the frustration they felt observing the students becoming confused and frustrated yet retained ownership of the puzzles provided by the EER. S3 noted, "*You feel like stepping into the prison cell to help or give them the solution, because it is right in front of them, and they do not see it … in a way it's frustrating.*" Figure 4 illustrates this apparent dilemma, with one of the PSTs visible on the far left standing outside the delimited area of the prison cell and resembling more a paralysed witness than a supervisor. S2 added to this experience of bewilderment and frustration: "*I thought that the students were going to use hints we offered them more actively, but several students ignored them and continued to fiddle with other things … I found that very strange.*" The students were in the escape phase for 45 minutes and none of the four groups managed to escape the room. In the second interview, when looking back at the outcome, S1 said, "*It looked like they were a bit disappointed. Nobody got out of the room.*"

When the 45 minutes were up, the debriefing phase began. At first, the students were urged to use their cell phones to anonymously share their immediate experiences and opinions by logging into an app that instantly showed the feedback on a smartboard when written and posted by a student. Utterances such as "enjoyable in the beginning", "exciting with something new", "fun to collaborate with others" and "frustrating" came as immediate responses from the students. In the debriefing phase, S2 lingered a little about the feedback, before getting the students to identify the five puzzles they encountered in the escape room. S2 orchestrated the students' verbal input about the puzzles, while S1 wrote the solution of each puzzle on the whiteboard. S2 asked students directly, rather than asking them to raise their hands. She made sure that each group had the opportunity to contribute to the debriefing. For instance, regarding the Figure 3 puzzle, the students said that the purpose of the puzzle was to find out which quantities were equal. S2 then asked them how they had approached solving the puzzle, and it emerged that there were different ways to solve it. In the second interview, S2 stated that although the students found the correct quantity, they did not understand what to do next with it. All five puzzles became part of the debriefing phase, as well as the necessary connections between the answers to the puzzles that were needed to escape the room.

Towards the end of the second interview, the PSTs discussed their impressions of the two implementation sessions, and what they thought the students had gained from those sessions. S3 stated, "*I think they [the students] learned more mathematics in the first session than in the second session*" and S4 nodded in agreement. S1 and S2 pointed out that Session 2 was also about other matters. S2 noted, "*Problem-solving is really about opening your mind to more possibilities … having patience and respect for others' opinions, and ideas about how a puzzle can be solved.*" In relation to the puzzle in Figure 3, she said, "*I think they got a new impression of fractions, percentages and decimal numbers, and how important the relationship between the three is.*" The discussion of impressions about the two implementation sessions revealed that the four PSTs differed in their opinions about what to prioritise when working with problem-solving in school mathematics. However, they unanimously agreed that they had experienced how an EER might offer variety in the mathematics lesson and increase students' motivation to concentrate during problem-solving processes; importantly, this is something that may lead to positive ripple effects in mathematics.

Discussion

As with all attempts to facilitate learning, planning and implementing an EER in mathematics are complex and challenging matters. In this study, four PSTs were tasked with such an assignment as part of a teacher education course. They came to the assignment with their own personal beliefs about what and how to learn in mathematics, as well as their personal knowledge related to mathematics and mathematics teaching (Ball et al., 2008; Shulman, 1986).

In the initial part of the planning of the EER, *Escape the prison cell*, the PSTs focused on the choice of theme, and then on the selection of objectives, puzzles and equipment (Clarke et al., 2017). They prioritised a theme that could feasibly bring a quasi-realistic context into the classroom. This choice is supported by previous research on the use of escape room in education and shows that the realism of the scenario does not seem to limit students' motivation for participation (Taraldsen et al., 2020). The objectives chosen by the PSTs were that they wanted the students' to repeat work with fractions and collaborate through a problem-solving approach. More generally, the PSTs also wanted the students to experience enthusiasm in learning mathematics and the value of being creative. They used the puzzles to emphasise both mathematical relations and collaboration, through joint emphasis on content and form: for instance, in solving the Figure 3 puzzle. In the planning, the PSTs were also concerned with the students' ability to approach a problem from various angles. This approach is recognised as one of the characteristics of the high-quality problem-solver identified by Liljedahl et al. (2016). However, several puzzles turned out to be inspired by puzzles the PSTs had experienced themselves. The reasons for this are manifold, but one obvious reason might be personal experience of a puzzle's elegance and operationalisation of the desired learning objective. The endeavour of both planning and implementing the use of a didactic tool that was new to them, may explain why the PSTs ended up using a variety of content they encountered during their own active and passive experiences (Dewey, 1916, 1938) with EERs in mathematics. Another reason could be the need for mathematical knowledge for teaching (Ball et al., 2008). No matter how eager and persistent the four PSTs were, their limited level of knowledge of mathematics teaching—which on this occasion was manifested through a lack of initiative and ability to revise or replace puzzles based on the pilot—confirms the mathematics teacher's need for content knowledge. The four PSTs may also have been affected by their motivation towards the mandatory learning activity. However, observation of the priorities set regarding initiative, cooperation, and delegation in the group planning sessions, and the reflections made on the planning in the first interview, support the impression of highly motivated PSTs. Collectively, this shows that planning an EER for use in mathematics teaching is a complex process (Botturi & Babazadeh, 2020), and demands knowledge-based attention to both content and form of the EER, and motivation for its use. The latter is important, but the former is crucial. The quality of the EER and the students' learning experience are affected by the teacher's knowledge-based planning, which includes the initiative and ability to make adjustments so that students may achieve the desired learning objectives. This aligns with the importance of planning and anticipating as emphasised by Smith and Stein (2018).

During Session 1 of the implementation of the game, the PSTs prioritised introducing the concept of the EER, where the main ingredient was the students' individual work with mathematical problem-solving tasks. The aim was to familiarise students with the EER experience in the upcoming session. In Session 2, the PSTs followed the guidelines for the mandatory learning activity, which included a three-part structure comprising an introductory phase, an escape phase and a debriefing phase related to the EER. Following Smith and Stein (2018), the monitoring practice was the dominant priority for the PSTs in the escape phase. In this case, and in accordance with their own experiences with EERs, the PSTs decided to monitor the game from outside the prison cell and only provide students with some carefully selected hints given to all four prison cells in the classroom at the same time. Two consequences of this choice were first, that the PSTs felt frustration based on the lack of opportunity to be involved in the students' struggles with the puzzles, and second, that there was little opportunity to observe the students' processes closely. In the debriefing phase, in accordance with the five practices of Smith and Stein (2018), the PSTs maintained their planned priority of participation of all students in the plenary sharing of the various problem-solving strategies applied in the EER. This was achieved by focusing on the strategies used and solutions reached for each of the five puzzles, and then on how the solutions had to be combined to crack the code and escape the room. However, this was only moderately successful because of the lack of monitoring opportunities of students during the escape phase. When the teacher does not register and reflect on observations during the monitoring phase, the orchestration of the plenary mathematical discussion becomes more difficult (Smith & Stein, 2018). The reason for this is the lack of rationale for selecting and sequencing observations according to the objectives of the EER. In turn, this affects the summarising connection of experiences, strategies and solutions because the teacher will have to attend to arbitrary inputs from the students rather than to selected and sequenced observations modified by the teacher. Such conditions require the teacher to rely on content knowledge in a more improvisation-based summary of connections. In this case, the connection practice (Smith & Stein, 2018) was difficult to initiate, and made the foundation for establishing coherence between the use of the EER and the students' active and passive experiences unclear for the students and a bit uneasy for the PSTs in the debriefing phase. However, the influence of knowledge-based initiative and the PSTs' organisation ability in the mathematics classroom (Smith & Stein, 2018) were, as in the planning phase, clearly displayed by their sacrificial and well-intentioned implementation of their planned priority of basing the connection of objectives related to the EER on the students' recent escape room experiences.

Conclusions and Implications

The discussion shows how the teacher's priorities may influence the operationalisation of an EER in the mathematics classroom and underpins the complexity of priorities when planning and implementing an EER. Three reasons for this can be highlighted. First, although teachers may find it useful to bring an EER into mathematics teaching, it is necessary to consider parameters such as the number of students; access to equipment and location; and students' individual needs, characteristics and competence. In the present case, these were not matters for the PSTs to decide. They had to manage the context provided by the mandatory learning activity, and within these specifications, garner motivation to deal with the learning activity in an appropriate manner. Second, the definition of an escape room by Nicholson (2015) and the theoretical framework for creating EERs suggested by Clarke et al. (2017), establish expectations about what an EER ought to comprise regarding both content and form when applying such a didactic tool. In adding emphasis on mathematical content through problem-solving, the game-based perspective must be connected to the development of problem-solving competence. It is conceivable that the four PSTs experienced the activity as a considerable challenge because of the strict expectations of what comprises a mathematics-based EER, and the need for joint motivation for planning and implementing the EER. Third, when planning and implementing a mathematics-based EER, the influence of the teacher's content knowledge is crucial, as emphasised by Ball et al. (2008). In retrospect, based on such expectations, and combined with being learners themselves, it is understandable that the four PSTs experienced the planning and implementation of the EER as something of an ordeal. Nevertheless, the justified priorities of the PSTs regarding both planning and implementation were visible and provided valuable insight into the process of setting such priorities and putting them into action. Therefore, the results from this study both add empirically based knowledge to theoretical frameworks that assist in the investigation of what constitutes productive use of EER in teaching and contribute to the growing body of knowledge regarding use of EERs in the mathematics classroom. From a teacher education point of view, it is not always manageable to address all new didactic tools that become available for mathematics teaching. This challenges mathematics teacher educators on what to give critical and thorough attention in mathematics courses. This study of EER provides an exemplar of integrating mathematics education with practical teaching in a way that offers a relevant teacher experience regarding attention to a new didactic tool.

This study is based on qualitative data from one PST group's experiences with planning and implementing an EER in mathematics as part of their teacher education course on problem-solving. However, irrespective of how an EER is planned and implemented, the underlying rationale of the teacher's priorities for the students' learning outcomes must be evident. Furthermore, such priorities must match the expected features of an EER, such as team-based problem-solving with the aim of completing a mission. This argues for an analytic generalisation value from the four PSTs' commendable effort in the case reported, that ought to be confronted or confirmed through more case studies of similar kind. Further research on the use of EERs in mathematics is required before confirming that their use may be a valuable component in cracking the code to students' motivated application of mathematics in problem-solving situations.

Corresponding author

Lene Hayden Taraldsen
Western Norway University of Applied Sciences
lene.hayden.taraldsen@hvl.no

Ethical approval

The data collection was approved by the *Norwegian Agency for Shared Services in Education and Research* (SiKT) (Ref. no.: 426258), and informed consent was given by all participants for their data to be published.

Funding

Open access funding provided by Western Norway University of Applied Sciences. Western Norway University of Applied Sciences provided research support, including salary and equipment.

Competing interests

The authors declare there are no competing interests.

References

Andrews, J. & Bagdasar, O. (2023). Escape rooms for secondary mathematics education: Design and experiments. *Open Education Studies, 5*(1), Article 20220194. https://doi.org/10.1515/edu-2022-0194

Arnal-Palacián, M., Marcías-García, J. A., & Tosso, I. D. (2019). Escape rooms as a way to teach magnitudes and measure in degrees in education. In E. Bacenetti (Ed.), Proceedings of the international conference*, New Perspectives in Science Education* (EST3640).

Ball, D., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389–407. https://doi.org/10.1177/0022487108324554

Bertoni, A., & Maffia, A. (2022). Promoting creative insubordination using escape games in mathematics. *International Journal of Mathematical Education in Science and Technology, 55*(4), 1054–1064. https://doi.org/10.1080/0020739X.2022.2113468

Blikstad-Balas, M., & Sørvik, G. O. (2015). Researching literacy in context: Using video analysis to explore school literacies. *Literacy, 49*(3), 140–148. https://doi.org/10.1111/lit.12037

Botturi, L., & Babazadeh, M. (2020). Designing educational escape rooms: Validating the Star model. *International Journal of Serious Games, 7*(3), 41–57. http://doi.org/10.17083/ijsg.v7i3.367

Brinkmann, S., & Kvale, S. (2015). *InterViews: Learning the craft of qualitative research interviewing* (3rd ed.). SAGE Publications.

Charlo, J. C. P. (2020). Educational escape rooms as a tool for horizontal mathematization: Learning process evidence. *Education Sciences, 10*(9), 213–229. https://doi.org/10.3390/educsci10090213

Clarke, S., Peel, D. J., Arnab, S., Morini, L., Keegan, H., & Wood, O. (2017). escapeED: A framework for creating educational escape rooms and interactive games for higher/further education. *International Journal of Serious Games, 4*(3), 73–86. http://doi.org/10.17083/ijsg.v4i3.180

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE Publications.

Dewey, J. (1916). Democracy and education. In J. A. Boydston (Ed.), *John Dewey. The middle works, 1899–1922* (Vol. 9, 1916(1980)). Southern Illinois University Press.

Dewey, J. (1938). *Experience and education. Kappa Delta Pi.*

European Commission. (2018). *Council recommendation on key competences for lifelong learning.* http://ec.europa.eu/education/

Fuentes-Cabrera, A., Parra-González, M. E., López-Belmonte, J., & Segura-Robles, A. (2020). Learning mathematics with emerging methodologies: The escape room as a case study. *Mathematics, 8*(9), Article 1586. https://doi.org/10.3390/math8091586

Glaser, B. G. (1965). The constant comparative method of qualitative analysis. *Social Problems, 12*(4), 436–445. https://doi.org/10.2307/798843

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine de Gruyter.

Jiménez, C., Arís, N., Ruiz, A. A. M., & Orcos, L. (2020). Digital escape room, Using Genial.Ly and A Breakout to learn algebra at secondary education level in Spain. *Education Sciences, 10*(10), 271–284. https://doi.org/10.3390/educsci10100271

Kaplinsky, R. (2019). *Open middle math: Problems that unlock student thinking, 6–12.* Stenhouse Publishers.

King, B. (2019). Using teaching through problem solving to transform in-service teachers' thinking about instruction. *Mathematics Teacher Education and Development, 21*(1), 169–189. https://mted.merga.net.au/index.php/mted/article/view/570

Krumsvik, R. J. (2019). *Kvalitativ metode i lærerutdanninga* [Qualitative method in teacher education]. Fagbokforlaget.

Liljedahl, P., & Cai, J. (2021). Empirical research on problem solving and problem posing: A look at the state of the art. *ZDM Mathematics Education, 53*(4), 723–735. https://doi.org/10.1007/S11858-021-01291-W

Liljedahl, P., Santos-Trigo, M., Malaspina, U., & Bruder, R. (2016). *Problem solving in mathematics education. In Problem solving in mathematics education: ICME-13 Topical surveys*. Springer. https://doi.org/10.1007/978-3-319-40730-2_1

Nicholson, S. (2015). *Peeking behind the locked door: A survey of escape room facilities.* http://scottnicholson.com/pubs/erfacwhite.pdf

Nielsen, M., & Bostic, K. D. (2020). Informing programmatic-level conversations on mathematics preservice teachers' problem-solving performance and experiences. *Mathematics Teacher Education and Development, 22*(1), 33–47. https://mted.merga.net.au/index.php/mted/article/view/460

Organisation for Economic Co-operation and Development. (OECD). (2019). *OECD future of education and skills 2023*. https://www.oecd.org/education/2030-project/teaching-and-learning/learning/

Peleg, R., Yayon, M., Katchevich, D., Moria-Shipony, M., & Blonder, R. (2019). A lab-based chemical escape room: Educational, mobile, and fun! *Journal of Chemical Education, 96*(5), 955–960. https://doi.org/10.1021/acs.jchemed.8b00406

Polya, G. (1990). *How to solve it? The classic introduction to mathematical problem-solving*. Penguin.

Sanchez, E., & Plumettaz-Sieber, M. (2019). Teaching and learning with escape games from debriefing to institutionalization of knowledge. In M. Gentile, M. Allegra, & H. Söbke (Eds.), *Proceedings of the Games and Learning Alliance. 7th International Conference on Games and Learning Alliance, GALA 2018* (pp. 242–253). Springer.

Schoenfeld, A. H. (1993). Teaching mathematical thinking and problem solving. In *SÅNN, JA! Rapport fra konferanse om matematikkdidaktikk og kvinner i matematiske fag* [THAT'S RIGHT! Report from conference about mathematics education and women in mathematics subjects], *2*(93), 67–89. Norges forskningsråd [Norwegian Research Council].

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.2307/1175860

Smith, M. S., & Stein, M. K. (2018). *5 practices for orchestrating productive mathematics discussions.* National Council of Teachers of Mathematics.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory.* SAGE Publications.

Taraldsen, L. H. (in press). Introducing teacher education students to escape rooms as a didactic tool in teaching and learning of mathematics. *Mathematics Teaching-Research Journal*. https://mtrj.commons.gc.cuny.edu/

Taraldsen, L. H., Haara, F. O., Lysne, M. S., Jensen, P. R., & Jenssen, E. S. (2020). A review on use of escape rooms in education: Touching the void. *Education Inquiry, 13*(2), 169–184. https://doi.org/10.1080/20004508.2020.1860284

Van Zoest, L. R., Jones, G. A., & Thornton, C. A. (1994). Beliefs about mathematics teaching held by pre-service teachers involved in a first grade mentorship program. *Mathematics Education Research Journal, 6*(1), 37–55. https://doi.org/10.1007/BF03217261

Veldkamp, A., Daemen, J., Teekens, S., Koelewijn, S., Knippels, M-C. P. J., & van Joolingen, W. R. (2020a). Escape boxes: Bringing escape room experience into the classroom. *British Journal of Educational Technology, 51*(4), 1220–1239. https://doi.org/10.1111/bjet.12935

Veldkamp, A., van de Grint, L., Knippels, M.-C. P. J., & van Joolingen, W. R. (2020b). Escape education: A systematic review on escape rooms in education. *Educational Research Review, 31,* Article 100364. https://doi.org/10.1016/j.edurev.2020.100364

Veldkamp, A., Niese, J. R., Heuvelmans, M., Knippels, M-C. P. J., & van Joolingen, W. R. (2022). You escaped! How did you learn during gameplay? *British Journal of Educational Technology, 53*(5), 1430–1458. https://doi.org/10.1111/bjet.13194

Wiemker, M., Elumir, E., & Clare, A. (2015). Escape room games: "Can you transform an unpleasant situation into a pleasant one?" In J. Haag, J. Weißenböck, M. W. Gruber, M. Christian, & F. Freisleben-Teutscher (Eds.), *Game based learning* (pp. 55–68). Fachhochschule St. Pôlten GmbH.

Yin, R. K. (2014). *Case study research: Design and* methods (5th ed.). SAGE Publications.

Zhang, X. C., Diemer, G., Lee, H., Jaffe, R., & Parangana, D. (2019). Finding the 'QR' to patient safety: Applying gamification to incorporate patient safety priorities through a simulated "escape room" experience. *Cureus, 11*(2), Article e4014. https://doi.org/10.7759/cureus.4014