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Digital escape rooms in medical education: Lessons learned from design and pilot implementation

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Abstract

Background Innovative learning methods in medical education are steadily growing in interest. Escape room is an educational and social learning setting in which participants, either individually or in small groups, engage in a themed or modular environment to solve a series of problems within a limited time frame. In this context, escape rooms have been used as an experiential, gamified learning approach intended to support developing learners' critical thinking, problem-solving, decision-making, and collaboration skills. This study aims to share the design principles obtained from the pilot implementation results of digital escape rooms prepared for medical students.

Methods The study employed a qualitative design using video recordings, focus group interviews, and a think-aloud protocol, all of which were designed according to the ADDIE (Analyze, Design, Develop, Implement, and Evaluate) model. Pilot implementation was conducted in two rounds. Round 1 included 34 volunteer students (19 Year-IV and 15 Year-V) who completed the escape rooms individually, with screen and room video recordings and post-session semi-structured focus group interviews. Round 2 included four additional students (two Year-IV and two Year-V) who participated in a revised version of the escape rooms using think-aloud protocols. Thematic analysis was primarily based on focus interview data from Round 1, while video recordings and think-aloud data were used for triangulation and identification of design-related issues. Data were analyzed using inductive content analysis to identify recurring themes and inform improvements.

Results Three key themes emerged: (1) Exciting: Students described the games as engaging and motivating, appreciating the opportunity to apply knowledge in a competitive, time-pressured setting; (2) Overwhelming: Some students experienced cognitive overload due to the complexity of the puzzles and the time constraints, which occasionally led to frustration; (3) Needs Improvement: Participants suggested clearer instructions, more accessible hints, and immediate feedback to enhance the learning experience. They also recommended integrating additional mystery elements and refining the scoring system for better clarity and transparency.

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Conclusions Digital escape rooms show promise as effective tools for fostering engagement and motivation in medical education. However, balancing challenge with accessibility, incorporating user-friendly features, and offering targeted feedback are critical to optimizing their implementation. These findings provide a foundation for refining digital escape rooms and exploring their broader application in medical training.

Keywords Escape room, digital escape room, web-based learning, gamification, medical students

Background

Game-based learning enhances cognitive learning outcomes and supports students' motivational and affective processes, such as enjoyment of learning [1]. Compared to traditional teaching methods, game-based learning is described as providing fun and a highly motivated learning environment by presenting content interactively in a competitive context [2]. Game-based learning environments are known to positively affect learning and motivation because they engage students in the learning process, include environments that appeal to multiple senses, and activate players' thinking and meaning-making abilities [3]. Moreover, educational games are highlighted as effective methods in the teaching process due to their ability to increase learners' motivation and provide adaptive features that improve learners' self-regulation skills [4].

Considering that the new generation studying at higher education institutions is entirely "digital natives," integrating active learning processes such as game-based learning into medical education could be effective [1]. Although limited in literature compared to other fields, various studies on game-based learning in medical education are available [2, 5]. Especially in extraordinary situations such as pandemics or earthquakes, the disruption of traditional classroom teaching has led to the rapid adaptation of digital teaching tools worldwide, emphasizing the importance of optimal and continuous use of digital environments such as augmented reality, artificial intelligence, game-based learning environments, and simulation tools in medical education to ensure uninterrupted learning [6]. Furthermore, it is believed that teaching in interactive, multi-environmental settings can help overcome the challenges of teaching within the limited timeframe of medical education curricula, and that game-based learning, due to its problem-based learning context, could be beneficial in medical education [7]. In this context, "escape rooms" [8], which can be defined as a social learning activity where learners enter a web-based environment designed around a theme or scenario and focus on solving various problems under time pressure, stand out as an innovative practice that incorporates problem-based and game-based learning. Similarly, escape rooms are action-adventure games where individuals discover clues, solve puzzles, and complete tasks in one or more rooms to reach a specific goal (usually escaping the room) within a limited time [9].

Escape rooms provide an enjoyable learning environment with minimal resource requirements by integrating traditional lecture-based teaching with clinical teaching in medical education. Especially in extraordinary situations such as pandemics that require a break in education, escape rooms are considered a valuable tool for providing quality medical education to small groups [10]. Escape rooms are seen as an innovative tool for improving issues such as patient safety and provider performance in medical education, as they provide opportunities for teams to practice managing and adapting to unexpected situations through problem-based, interactive, and immersive activities [11].

Escape rooms are gaining interest in various fields of healthcare, including dermatology, radiology, emergency medicine, surgical medicine, internal medicine, as well as pharmacy and nursing [11, 12]. Escape rooms can contribute to various aspects of medical education, such as developing learners' clinical decision-making skills [13], reducing students' stress and anxiety by using escape rooms as an alternative assessment tool [14], enhancing the deep understanding of theoretical knowledge during the preclinical period [15], improving technical knowledge in the post-clinical period [16], and teaching patient safety experimentally [17]. In this context, escape rooms can be used as an enjoyable tool to teach both technical and non-technical skills. Additionally, escape rooms facilitate the transition to learner-centered, and team-based methods necessary for applying safe modern healthcare practices [10]. To design such content and structures, it is crucial to use a learner-centered curriculum design approach that takes learners' needs into consideration. This study aims to share the design principles derived from the pilot implementation results of the digital escape rooms developed for medical students.

Methods

The study was conducted as part of a nationally funded research project which adopts one of the widely known instructional design models: ADDIE (Analyze, Design, Develop, Implement, and Evaluate) [18, 19]. This study shares the data from the "Implement" phase of the ADDIE model with readers. The data for this phase were collected through video recordings, focus group interviews, and think-aloud protocols. In this respect, the study adopts basic qualitative research design [20].

Participants

In this study, two escape rooms were prepared for third year medical students (one for the Biological Basis of Diseases and Infectious Diseases committee and one for the Neoplasia-Hematology-Gastroenterology committee) and two escape rooms for fourth year students (Pediatrics and Internal Medicine [Endocrine System]) as part of a pilot implementation.

The participants of the study were fourth- and fifth-year students from Faculty of Medicine of Çanakkale Onsekiz Mart University during the 2024–2025 academic year. Participation in the pilot implementation was voluntary. Fourth- and fifth-year medical students were invited to participate through in-class announcements and email notifications distributed by the faculty administration at the beginning of the academic term. No financial or academic incentives were offered for participation. Data collection was scheduled outside formal examination periods to minimize participation pressure and interference with mandatory coursework. Students who expressed interest contacted the research team directly and provided written informed consent before participation.

Participation in the study was open to all 4th and 5th year students. However, in the first phase of the pilot implementation, 19 fourth year medical students and 15 fifth year students volunteered to participate. In this context, the participants represented approximately 8% of 4th year and 7.6% of 5th year students. The target audience for the prepared escape rooms was third- and fourth-year students. However, during the pilot implementations, the two escape rooms designed for third year students were tested with fourth year students, and the two escape rooms prepared for fourth year medical students were tested with fifth year students. The rationale for this approach was two-fold:

a) Students in senior years are expected to have mastery over the knowledge and skills of the previous years they have already completed. Therefore, the escape rooms designed for 3rd year medical students were tested by 4th year students, and similarly, the rooms designed for 4th year students were tested by 5th year medical students.
b) This approach enabled us to ensure that the students who will be participating in the real implementation in the following year are not exposed to the escape rooms.

Student participation was voluntary, and informed consent forms were obtained from all participants. Therefore, the study sample was determined using a convenience sampling method. Convenience sampling involves selecting participants who are readily accessible for data collection [21, 22]. Following the adjustments to the system based on the data obtained from the first round of the pilot implementation, a second round of pilot testing was conducted. This phase included two fourth year students and two fifth year students.

Data collection tools

In this study, three data collection tools were used: *(1) Video recordings*, *(2) interview form*, and *(3) think-aloud protocol*. The aim was to triangulate the data sources to ensure credibility. The focus group interview data formed the primary dataset for thematic analysis, while video/screen recordings and think-aloud protocols were used to corroborate themes and identify concrete design issues.

Video recordings

Video recordings were used during the first round of the pilot implementation. Each student's computer screen was recorded using a screen capture mode while students were playing the escape room games. Additionally, the entire room was recorded using a professional camera. Informed consent for voluntary participation and video recording was obtained from all students who participated in the pilot implementation.

Interview form

Semi-structured focus group interviews were conducted after the games were completed during the first round of the pilot implementation. In this process, each focus group consisted of 5–7 students and followed a semi-structured interview guide. These interviews were guided by a semi-structured interview form prepared by the researchers. To ensure the validity and reliability of the interview questions, expert opinions were sought. Feedback was obtained from two researchers with experience in qualitative research and one academic expert in educational technology. Each interview question in the data collection tool was evaluated through an expert opinion form with sections labeled "Appropriate," "Partially Appropriate," "Not Appropriate," and "Suggestions, if any." The consistency of the expert evaluations was analyzed using Krippendorff's Alpha inter-rater reliability method, yielding a value of 0.83. This value indicates high inter-rater reliability [23]. Based on this result, the expert feedback was reviewed, suggested revisions were implemented, and the final version of the interview form was prepared.

Think-aloud protocol

The think-aloud protocol was employed during the second round of the pilot implementation to collect data. Necessary adjustments were made to the escape rooms based on data from the first round. Subsequently, the second round involved two Year-IV students and two Year-V

students. In the think-aloud protocol, students were asked to verbalize their thought process while playing the game, explaining every action they took and articulating their internal thoughts. During this process, the students' gameplay screens, along with their verbalizations, were recorded. Think-aloud participants were not re-interviewed. A demonstration video for the Think-aloud protocol used in the study is available within Supplementary File 1 and the full video at "https://www.youtube.com/watch?v=rhKZfyJYrV8".

Process

In this study, the following procedural steps of ADDIE model were followed [24]:

Analysis phase

Focus group interviews were conducted with third- and fourth-year students in the 2023–2024 academic year to determine needs analysis. The results of this phase can be reached from the previous study conducted by the researchers [24]. These interviews were conducted face-to-face in a quiet room immediately after completion of the escape room sessions. All interviews were conducted in Turkish by members of the research team trained in qualitative interviewing, none of whom had direct grading or examination responsibilities for the participating students at the time of data collection. To reduce potential power dynamics and social desirability bias, students were explicitly informed that participation or interview responses would not affect academic evaluation and that they were free to withdraw at any time without consequence. Interviews lasted approximately 20–35 min, were audio-recorded with permission, and transcribed verbatim for analysis. These interviews were conducted with all Round 1 participants (n = 34). The focus group interviews analyzed the following issues.

- Problems experienced during the emergency remote teaching process,
- Positive aspects of the emergency remote teaching process,
- Additional resources and materials students discovered and used online during the emergency remote teaching process, and.
- Students' suggestions for escape room designs.

Design phase

Based on the results of the needs analysis, the learning outcomes of the third-year committee courses, and the learning outcomes of the fourth-year pediatrics and internal medicine clerkships, escape room designs were created.

Development phase

The escape room designs were transformed into web-based games that students could play individually on PCs, laptops, and tablets. This phase involved an iterative "design-apply-review-check-revise" cycle between the design team and the technology firm. The development cycle was completed after 20 meetings and made ready for pilot implementation.

Implementation phase

This phase was carried out in two parts: the pilot implementation and the main implementation. In the pilot implementation, two escape rooms designed for the third year were played by 19 fourth year students. Two escape rooms designed for the fourth year were played by 15 fifth year students. Since the target audience for the main implementation during the 2024–2025 academic year would be third year and fourth year students, the pilot implementation was conducted with fourth- and fifth-year students. In the implementation phase, the participants were in the same physical room but completed tasks individually on separate computers.

Data analysis

The data were analyzed using content analysis. Data collection continued until successive focus group interviews yielded no substantively new codes related to usability, puzzle difficulty, hints, feedback, and scoring. At this stage, the coding team agreed that thematic categories had reached stability. According to Mayring [25], there are mainly two types of content analysis: inductive and deductive. This study employed inductive content analysis, in which themes and categories are directly derived from the dataset during analysis. Three researchers (G.K., M.G.K., and Ç.T.) independently coded the transcripts to enhance the credibility of the findings. The researchers came together to cross-check their analyses, reaching consensus on the results, a practice commonly recommended in the literature [26]. To further ensure credibility, participant verification was employed [27]. All Round 1 participants (n = 34) were contacted for participant verification. Responses were received from all participants. No substantive changes to themes or interpretations were required, as respondents confirmed that the findings accurately reflected their experiences. After completing the data analysis and generating the findings, the participant students were contacted again to confirm whether the results accurately represented their experiences. Furthermore, participants' statements were included using verbatim quotations, implementing the direct quotation strategy [28]. In this way, the researchers aimed to strengthen the credibility and dependability of the qualitative findings.

The data from the videos and think-aloud protocols were used to triangulate the data sources. To do this, the videos and the discussions that students had while playing the escape room game were watched and transcribed in full by three researchers. Second, the researchers watched the videos again by focusing on participants' non-verbal behaviors such as gestures, expressions, and actions. In this way, the researchers were also able to gain insights into students' escape room experience, identify issues with the case problems and puzzles, discover the content and design that needs to be improved. For example, participants' reports of initial ambiguity were corroborated by video observations showing prolonged inactivity, visible hesitation, and repeated requests for clarification during the first minutes of gameplay. The video-recording and think-aloud protocol results added great value for theme generation during content analysis. However, although the findings from videos and thinking-aloud protocols were stated in the results section, the quotations were given for the interview data only.

Results

As a result of the analyses of video recordings, think-aloud protocols and focus group interviews conducted during the pilot implementation with fourth- and fifth-year students, three themes were identified: (*1) Exciting, (2) Overwhelming, and (3) Needs Improvement*. The findings related to these themes are as follows:

Theme 1: exciting

The analysis revealed that fourth- and fifth-year students found the escape rooms exciting. The findings related to this excitement are presented in Fig. 1.

Medical students experienced great excitement in applying what they learned through the escape rooms. The escape rooms were structured according to the learning outcomes of the committees and clerkships the students had completed. The students were informed about this structure before starting the games. One of the students who participated in the pilot implementation shared the following view:

> *It was exciting to wait and see where I would apply what I had learned in the puzzle. The game consisted of five stages, and in each stage, I encountered one or sometimes multiple puzzles. With each new puzzle that opened, I felt great excitement, wondering if my knowledge would be tested here and if I could apply my knowledge correctly to the puzzle. (Participant 3-Year 4)*

Escape rooms are structured with time constraints which creates a competitive environment through time and with others. Students need to be aware of how much time has passed and how much time is left during the game. The countdown timer in the games also caused excitement. One student who participated in the pilot implementation shared the following about racing against the time:

> *As the timer ticked down, the excitement was elevated. At one point during the game, I thought, 'Why did they put that timer there?' The game was already difficult, and I couldn't seem to solve the problems, I couldn't remember what I had learned. Meanwhile, the timer was counting down on the screen above, almost as if saying, "Hurry up, time is running out". (Participant 8-Year 5)*

The escape rooms engaged the students. Some students didn't want to leave the games at all. This actually proved the intriguing and motivation-boosting nature of the games in the escape rooms. Two different students who participated in the pilot implementation shared the following:

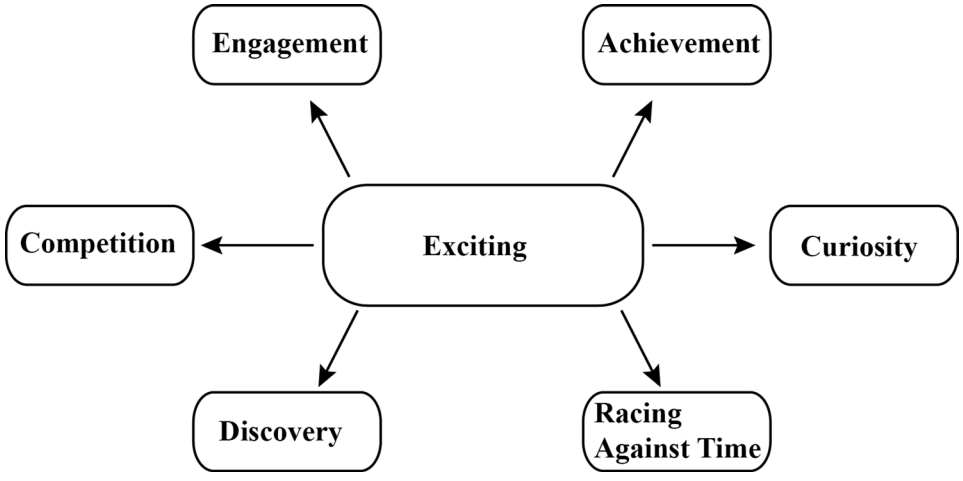


Fig. 1 The categories within Theme 1: Exciting

On the day of the pilot implementation, I had an exam. I thought the pilot would be completed within two hours, but I was wrong. I had to play two different escape rooms, but one of them took 90 min for me to finish. I had only 35 min left to get to my exam. I should have left the room and gone to the exam. But the game was so enjoyable that I asked my teacher: "I need to go to the exam, but if I enter the second escape room, I definitely won't be able to finish it. I still want to play for 25 more minutes. Is it okay if I don't finish the second one? I just want to play as much of it as I can. (Participant 12-Year 4)

In reality, the puzzles and games in the escape rooms weren't easy at all. The design team really made them challenging. At one point, I even thought: "What happens if I look at the screen of my friend sitting next to me? Or should I check the internet on my phone for some help to remember things?" The difficulty was overwhelming at times, and I could say I even got frustrated, but for some reason, I didn't want to leave the game like a masochist. (Participant 14-Year 4)

The games and puzzles sparked curiosity in most of the students. The curiosity and focus on the games were also reflected in the camera recordings that captured the entire room with the students. Two different students shared the following regarding the curiosity they experienced during the pilot implementation:

On the one hand, I was struggling, but on the other hand, I was wondering what my friends were doing. Was I playing better than them? Did they find the solutions where I struggled? Those were the questions running through my mind while playing the game. (Participant 4-Year 5)

As the puzzles progressed during the game, I kept wondering "Will all of this connect to something? What will be the outcome of all this? Are the puzzles independent, or will they connect at the end?" I kept wondering this throughout the entire pilot. The puzzles were hard. It was also difficult to understand whether they would connect or not. (Participant 11-Year 4)

The games and puzzles triggered the excitement of exploration. Exploration served as an important source of motivation. One student shared the following about the curiosity they felt:

I tried to understand how the puzzle could be solved. I kept searching for clues. The clues were well hidden, and sometimes, the clues were obtained gradually. That is, to unlock one clue, you needed to solve the previous puzzle first. Honestly, I found the work done to be very clever. (Participant 9-Year 4)

The games and puzzles have triggered a sense of success and competition. Regarding the success focus, one student shared the following:

When the results were announced, would I be the most successful student? I wish the rules for scoring had been written in detail from the very beginning. I wish the point loss for using a clue in each puzzle had been written in the beginning. I wish that at the end of the game, not just my score, but my rank and score among all participants were displayed. (Participant 6-Year 5)

Theme 2: overwhelming

Analysis revealed that fourth and fifth-year students found the escape rooms overwhelming. Categories related to this theme are presented in Fig. 2.

Medical students struggled within the escape rooms. These rooms were designed to be somewhat complex and challenging, adhering to principles of game-based learning, enhancing motivation, and fostering a competitive spirit. However, the difficulty level was carefully structured to ensure that the required knowledge did not exceed the students' learning outcomes.

Some students understood the escape room as a game and embraced the competitive aspect, refraining from providing feedback under that theme. Conversely, others perceived the escape rooms as an online learning tool and provided feedback emphasizing the difficulty of the puzzles. The following are remarks from two students who participated in the pilot study of the escape rooms:

It was very difficult… At one point, I thought I wouldn't be able to solve it despite the hints. The clues were well hidden in some parts of the screen. At one point, after a hint helped solve a puzzle, I later found new hints embedded in the same spot after progressing further. I could never have anticipated this—it was very surprising. (Participant 2-Year 5)

I'm not sure if it was just me… but I couldn't solve some puzzles. I realized that I hadn't learned as well as I thought. I couldn't recall the information and ended up just staring blankly at the screen, waiting for the next puzzle to open as the time ticked away. (Participant 13-Year 5)

Some students in the pilot study found the escape rooms very complex. However, as discussed later in this text, while some students suggested that the themes needed simplification, others emphasized that the escape rooms

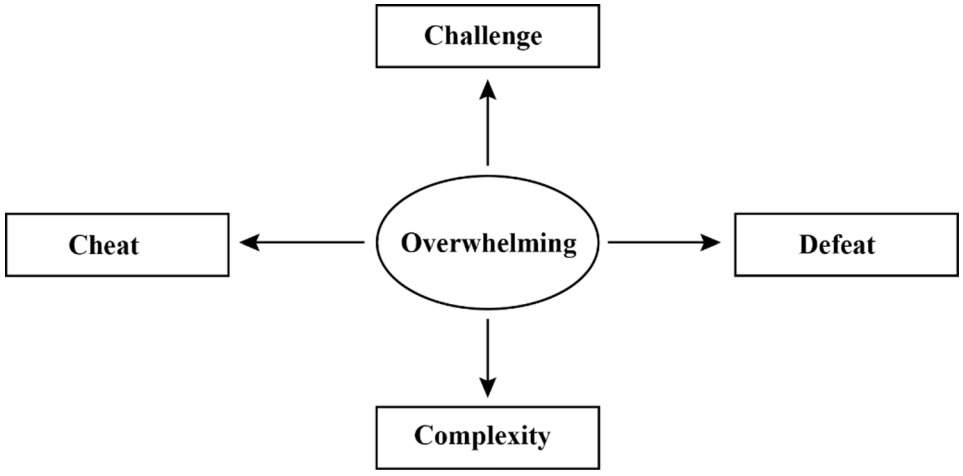


Fig. 2 The categories within Theme 2: *Overwhelming*

and puzzles should be even more complex. One participant commented on the complexity as follows:

> *The escape room and its puzzles were too complex. I struggled, and I was confused… It took me too much time to understand what to do. In short, it was too complicated. I think it shouldn't be this complex. What's required should be explained clearly. I feel like it was unnecessarily difficult—after all, it's just a game. What's the big deal? (Participant 1-Year 4)*

Beyond describing the escape rooms and puzzles as challenging or complex, some students admitted to resorting to shortcuts. One participant shared the following experience:

> *It was very hard… I tried to apply the knowledge I had learned, hoping I could remember the necessary information to solve the problem within the game. But the clock kept ticking… While the instructor in the room was helping another student, I discreetly used my phone's internet to look up the information I couldn't recall. At first, I felt guilty, but then I saw the friend next to me opening another tab on a webpage to look up what they couldn't remember. Did it help? Of course, not. Because recalling the information wasn't enough to solve the problem; it required connecting information with what I already knew… (Participant 7-Year 4).*

A few students gave up within 20–25 min and asked the supervisor to leave the room. Follow-up discussions revealed that these students felt overwhelmed and therefore wanted to quit the game. One student expressed his feelings as follows:

> *I gave up and walked out of the room. It was really hard. I realized I couldn't do it. I already barely passed the class last year. I couldn't recall any of what I thought I had learned. And even if I could, it wasn't enough. The puzzles required us to integrate information from different topics. At least, that's what I think… Honestly, I'm not even sure if I understood it correctly. I decided it wasn't worth straining my mind any further… it was too hard… (Participant 1-Year 4).*

Theme 3: needs improvement

Based on the analyses, fourth- and fifth-year students indicated that modifications and adjustments were needed in the escape rooms and puzzles and provided suggestions accordingly. Findings regarding the aspects of the escape rooms and puzzles that need improvement are presented in Fig. 3.

Medical students highlighted several issues that need to be improved in the escape rooms after playing and proposed some suggestions, believing that addressing these shortcomings would be beneficial. The first suggestion was that the games could incorporate more mystery. A student participating in the pilot application stated:

> *What draws my attention about the games is the mystery. Of course, these games were designed based on the lessons we took and the knowledge we already have, or we should have. But I still expect a lot of mystery. For instance, you don't have to present all the symptoms of the disease featured in the puzzle. We, as students, should discover some of them on our own. We need to challenge ourselves a bit. Still, I generally enjoyed the games.*

During the pilot application, students were unaware that a scoring system was in place or that they would

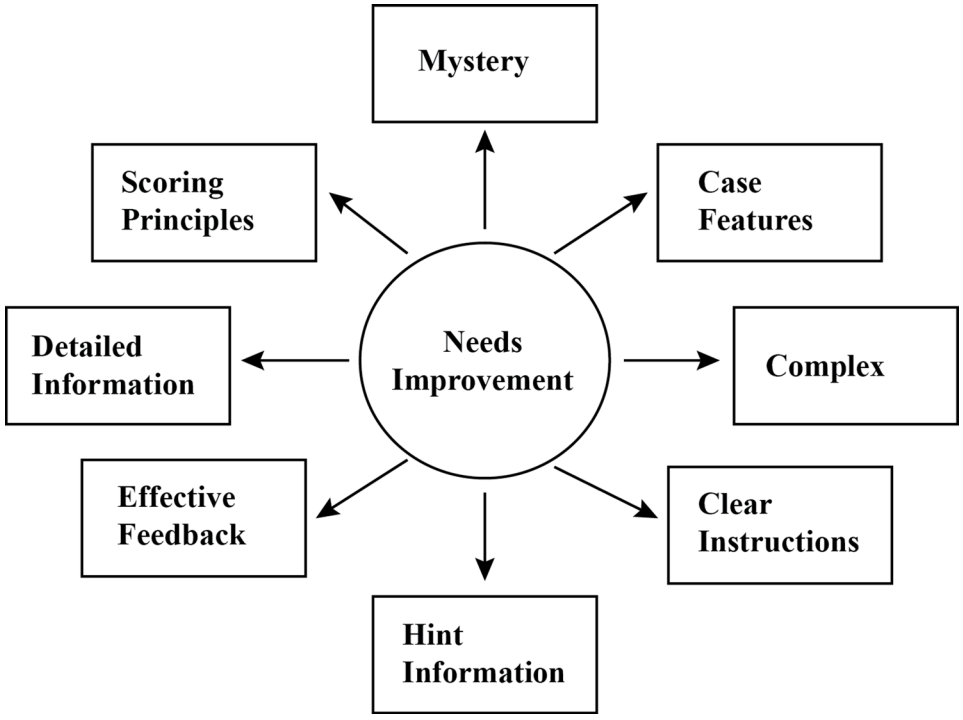


Fig. 3 The categories within Theme 3: *Needs Improvement*

lose points if they used hints in the game. They thought they were merely racing against time. A student would only see their score after completing the game, but the ranking of other participants remained undisclosed. This approach was intentional because, in the literature, escape rooms are typically not scored; the primary goal is simply to exit the room as quickly as possible. The designers planned to decide after the pilot whether scoring should be implemented and, if so, how it should be structured. Consequently, the pilot was conducted in this manner.

Many students found the scoring aspect intriguing, and feedback was collected at the end of the pilot. Two students shared their thoughts on the scoring system:

> *The scoring idea is great. I've previously participated in physical escape rooms at game venues, where the goal was just to be the first person to exit the room. I didn't know I'd receive a score at the end of this game or that penalties would be applied for each hint I used. I think this should remain in the design, but each puzzle in the escape room should have a clear and specific point value. (Participant 14-Year 5)*
> *I completed the game around the same time as my friend playing next to me. After the game, I looked at my friend's screen and saw that our scores were different. I was curious and asked the instructor in the room about it. I think this shouldn't be a surprise in the final version of the escape room that you are designing. The points deducted for hints or time loss should be clear at every stage. (Participant 18-Year 4)*

Some puzzles in the games were simpler and more familiar to students, such as crossword or word search puzzles. However, most of the escape rooms and their puzzles were structured around specific cases. Students provided suggestions regarding these cases. One student participating in the pilot stated:

> *I enjoyed the games more when they were challenging. In general, I always strive to score higher in exams within my class; I have a strong competitive side. In this context, I didn't find your cases challenging enough. Sometimes you used case scenarios that directly matched the information we learned in class or read in textbooks. Sure, we can't solve the puzzle without hints. But let's only have a portion of the symptoms presented, not all of them. I think you should make it a bit more complex...(Participant 15-Year 5).*

While some students expressed a desire for more challenging cases, others wanted the cases to delve deeper into details and be more complex. Two students shared their perspectives as follows:

> *Before the pilot implementation, you held a meeting with us and explained that the games were designed*

to support our learning. Honestly, that's why I volunteered for the pilot. But my expectations weren't met in this regard. The puzzles and cases should have been more geared towards supporting us in learning detailed information. I don't think they achieved that enough. (Participant 2-Year 4)
As the puzzles and escape rooms become more complex and intricate, they get harder. I favor difficulty. The harder it gets, the more motivated I become. In addition, they need to be challenging enough so that friends without sufficient knowledge can't solve them. Let those who deserve it solve the puzzles, not everyone…(Participant 15-Year 5).

The students who wanted effective feedback from the application made suggestions on this matter. One student shared their thoughts:

I thought I'd receive instant feedback when I gave incorrect answers or that the screen would provide feedback explaining why my answer was wrong. But that didn't happen. From what I understand, the games won't give immediate feedback on our mistakes. At the very least, I should receive comprehensive feedback at the end of the game. Please take this into consideration…(Participant 17-Year 4).

Some students requested clearer instructions to better understand the purpose of the game and puzzles. However, to maintain the element of mystery, the designers refrained from providing overly detailed instructions. Yet, the pilot revealed that students had a strong preference for clearer guidance. One student commented:

When the game started, I was staring blankly at the screen, wondering, 'What's happening in the first three minutes? What am I supposed to do now?' At one point, I asked the instructor in the room, 'What should we do now?' The instructor replied, 'That's for you to figure it out!' But that doesn't work. There's too much ambiguity. There should be clearer instructions. If the actual application will be like this after the pilot, I wouldn't want to participate. (Participant 3-Year 4)

Hints were included in the design to assist players struggling to solve puzzles. However, students also provided feedback regarding the hints. One student remarked:

The games were already difficult, and even the hints were hard to find… Why make it so challenging? It's called a hint, isn't it? I think hints should be more obvious. I should be able to find them easily, and they should significantly help me solve the puzzle quickly. There were times when I found and examined a hint but still couldn't solve the problem. (Participant 4-Year 4)

From the abovementioned comments, we can conclude that some participants expressed preference for clearer instructions and transparent scoring; this may reflect expectations shaped by common digital learning interfaces. Further work is needed to examine whether these preferences vary by learner characteristics. Nevertheless, the pilot implementation also revealed many valid and justified demands for improvement.

Discussion

The pilot implementation of digital escape rooms in medical education offers a nuanced understanding of their potential as innovative teaching tools. While the study's findings affirm the excitement and engagement these activities generate, they also highlight challenges related to complexity, emotional responses, and the need for refinement.

One of the most striking findings from this study was the excitement students experienced during the escape room activities. The interactive and time-constrained nature of the puzzles created an environment that many participants found thrilling and intellectually stimulating. These observations are consistent with research showing that game-based learning enhances student engagement and motivation by introducing novelty and competition [2, 3]. Similarly, the countdown timer and progressively challenging puzzles generated a sense of urgency and curiosity, which encouraged students to immerse themselves in the learning process. One student remarked on the anticipation of seeing how their knowledge would apply to the game, describing it as a unique way to experience real-time learning application. This gamified approach aligns with findings that emphasize the motivational power of escape rooms in fostering active participation and sustained focus [29].

Another finding was the connection between the puzzles and real-world clinical scenarios that further amplified the excitement. The ability to solve puzzles using curriculum-aligned knowledge reinforced the applicability of theoretical concepts to practical problems, a critical competency in medical education [10, 30]. For instance, students expressed curiosity about how different puzzles linked together, mimicking the interconnectedness of medical diagnoses in clinical practice.

The competitive aspect of the games also played a significant role in maintaining engagement. Students described racing against the clock as exhilarating, with many expressing a strong desire to outperform their peers. This competitive element mirrors the intensity of healthcare environments, where time-sensitive

decision-making is crucial [31]. However, excitement alone is not without its challenges. As discussed below, the competitive and complex nature of the escape rooms created an experience that some students found overwhelming, revealing a need for more balanced design strategies. While the escape rooms succeeded in engaging students, they also elicited feelings of frustration and stress, particularly among those who struggled with the puzzles. The overwhelming nature of the games reflects a delicate balance between challenge and accessibility that must be carefully managed in educational game design [32].

The puzzles were intentionally designed to be challenging, requiring students to integrate knowledge across disciplines. While this complexity aligns with findings that highlight the effectiveness of escape rooms in enhancing critical thinking and problem-solving, it also exposed gaps in students' foundational knowledge [33]. Some participants reported feeling unprepared to connect disparate concepts, which led to cognitive overload and diminished their ability to progress through the game. To address this, future escape room designs could incorporate scaffolding strategies, gradually increasing the difficulty of puzzles while providing early-stage guidance. Adaptive difficulty levels, where the game adjusts based on the player's performance, could also prevent less confident students from becoming overwhelmed [34].

The countdown timer, while a source of excitement for some, heightened anxiety for others. Participants described the pressure of solving puzzles within a limited timeframe as stressful, particularly when they were unable to recall information or make connections between clues. These findings align with research showing that while time constraints can enhance focus and motivation, they can also exacerbate stress in high-stakes environments [35, 36]. Introducing optional time extensions or relaxation intervals between puzzles could help mitigate stress while maintaining the challenge of the activity. Additionally, embedding stress-reduction mechanisms, such as encouraging collaborative problem-solving, may help students feel more supported during gameplay.

Some students reported difficulty recalling foundational knowledge, which they attributed to gaps in prior learning or inadequate preparation. These barriers highlight the importance of aligning escape room content with students' current knowledge levels and providing pre-game resources to refresh relevant concepts. For example, a short review session or preparatory material before the escape room could help students feel more confident and prepared.

Although students recognized the educational value of the escape rooms, they identified specific areas for improvement that could enhance their overall effectiveness and user experience. One of the most frequently mentioned limitations was the lack of immediate feedback during gameplay and the opacity of the scoring system. Many participants were unaware that using hints would result in point deductions, leading to frustration and a sense of unfairness. This aligns with research emphasizing the importance of clear feedback and transparent scoring in gamified learning environments [37]. Incorporating real-time feedback mechanisms could help students understand their mistakes and adjust their strategies during gameplay. Additionally, providing clear instructions on scoring rules at the start of the game could enhance motivation and prevent confusion. Displaying scores and rankings at the end of the game may also tap into students' competitive instincts, further driving engagement.

Students also reported that the initial instructions for the escape rooms were insufficiently clear, leaving them uncertain about the game's objectives and mechanics. While maintaining an element of mystery is central to the escape room experience, clearer guidelines could help students understand what is expected of them without diminishing the challenge [38]. To address this, future iterations should include a brief tutorial or introductory stage to familiarize players with the game mechanics. This approach could help reduce initial confusion and ensure that all participants begin on equal footing.

The individual format of this pilot implementation missed an opportunity to foster teamwork and communication, which are critical competencies in medical education. Research has shown that escape rooms designed for team-based gameplay can simulate real-world healthcare dynamics, promoting interprofessional collaboration and problem-solving [39, 40]. Incorporating collaborative elements, such as group puzzles or roles requiring interdependence, could enhance the educational value of escape rooms by preparing students for the collaborative nature of clinical practice. This approach would also address the emotional challenges of solo gameplay by providing peer support and shared problem-solving responsibilities.

Strengths and limitations

This study has several limitations. First, it was conducted at a single medical school in Türkiye. In terms of practical implementation, the escape rooms took approximately 12 weeks to design and 6 weeks to test. To design the escape rooms (both scenario development and creating the escape rooms in digital environment), the team had 20 meetings (both in person and online). The development team consisted of 5 clinical teachers, 3 medical educators, 2 experts from the department of computer education and instructional technologies, 3 software company members and 2 staff members who supported the technical setup and logistics. Overall, about 13 people were

involved in the creation process. Therefore, design and implementation process was intensive and resource-demanding, requiring significant coordination across different areas of expertise. However, these considerations provide important insights for educators who may wish to adopt escape rooms in medical education.

Conclusion

The pilot implementation of digital escape rooms revealed that participants perceived the escape rooms as engaging and as an opportunity to apply prior learning; some also reported overload and frustration, indicating the need for design refinements. While the excitement generated by the games underscores their effectiveness as motivational tools, the challenges related to complexity, emotional responses, and clarity highlight areas for refinement. By incorporating adaptive difficulty levels, providing clear feedback and instructions, and introducing collaborative gameplay elements, digital escape rooms can become a potentially useful supplementary strategy of experiential learning in medical education. As institutions continue to refine and integrate these innovative tools, they offer a promising avenue for preparing students to meet the demands of modern healthcare practice.

Abbreviation

ADDIE Analyze, Design, Develop, Implement, and Evaluate

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

Planning: M.T, G.K., M.G.K, Ç.T, E.T, T.Ç, S.G.M.A, T.A, E.S.S, M.K.A; Data collection: M.T, M.G.K, Ç.T; Data Analysis: M.T, G.K., M.G.K., Ç.T., E.T., S.G.M.A., M.O.Y.; Writing original draft: M.T, G.K., M.G.K., Ç.T.; Reviewing and editing: M.T, G.K., M.G.K., Ç.T., E.T., T.Ç., S.G.M.A., T.A., E.S.S., M.K.A., M.O.Y., Y.A. All authors read and approved the final version of the manuscript.

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Data availability

The data of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This research was conducted with the approval of the Scientific Research Ethics Committee of Çanakkale Onsekiz Mart University, October 5, 2023, with decision number 12/37, and the permission of the Faculty of Medicine at Çanakkale Onsekiz Mart University, October 11, 2023, with document number E-30566003-100-2300247108. Written informed consent was also obtained from participants. This study was performed in line with the principles of the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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