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Out-of-the-Box Learning: Digital Escape Rooms as a Metaphor for Breaking Down Barriers in STEM Education

Tatjana Sidekerskienė [1,*] and Robertas Damaševičius [2]

1 Department of Applied Mathematics, Kaunas University of Technology, LT-51368 Kaunas, Lithuania
2 Department of Applied Informatics, Vytautas Magnus University, LT-44404 Kaunas, Lithuania; robertas.damasevicius@vdu.lt
* Correspondence: tatjana.sidekerskiene@ktu.lt

Abstract: The traditional lecture-based model of teaching and learning has led to the exploration of innovative approaches including digital escape rooms. Digital escape rooms offer an immersive and engaging experience that promotes critical thinking, problem-solving, and teamwork, making them a unique opportunity to address the challenges of STEM education, which is often perceived as difficult, boring, and intimidating. In this study, the goal is to explore the application of digital escape rooms as an innovative practice in STEAM (science, technology, engineering, arts, and mathematics) education in Europe. More specifically, the study aims to evaluate the influence of digital escape rooms on student engagement and learning outcomes in mathematics education as well as to provide valuable insights into the efficacy of this approach as a means of teaching mathematics and fostering active and experiential learning in STEAM education. In order to investigate the potential of digital escape rooms as a metaphor for breaking down barriers and escaping from the "box" in STEM education, this paper proposes a conceptual framework for understanding the pedagogical value of digital escape rooms in STEM education. It outlines the design process, including learning paths and scenarios, storyline, puzzles, challenges, and feedback mechanisms, and presents a concept of escape room design patterns. An example case study of a digital escape room designed to teach mathematics to university students is also presented, providing insights into the effectiveness of this approach. By using digital escape rooms as a metaphor for breaking down barriers in STEM education, a more inclusive, engaging, and impactful learning environment can be created to prepare students for the challenges and opportunities of the 21st century.

Keywords: digital escape rooms; out-of-the-box learning; student engagement; experiential learning; problem-solving skills; STEM

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Citation: Sidekerskienė, T.; Damaševičius, R. Out-of-the-Box Learning: Digital Escape Rooms as a Metaphor for Breaking Down Barriers in STEM Education. *Sustainability* **2023**, *15*, 7393. https://doi.org/10.3390/su15097393

Academic Editors: Fezile Özdamlı, Damla Karagozlu and Şenay Kocakoyun Aydoğan

Received: 31 March 2023
Revised: 16 April 2023
Accepted: 18 April 2023
Published: 29 April 2023

1. Introduction

Digital escape rooms have become an increasingly popular tool in education, particularly in the wake of the COVID-19 pandemic and the rise of remote and hybrid learning models [1]. Digital escape rooms provide an online alternative to traditional physical escape rooms and enable students can solve puzzles and challenges from the comfort of their own home or classroom [2]. The concept of digital escape rooms is not new, as they have been used in corporate training and team building activities for several years. However, their use in education has gained momentum in recent years, particularly in the fields of science, technology, engineering, arts, and math (STEAM) education [3]. Escape rooms offer a fun and engaging way to promote active and experiential learning, and students can work collaboratively to solve problems and apply their knowledge in a real-world context [4].

Digital escape rooms can be used to support a variety of learning objectives, from teaching basic concepts to reinforcing complex theories and applications [5]. Digital escape rooms can be customized to meet the specific needs and interests of different age groups, subject areas, and learning styles [6]. For example, they can be designed to teach coding skills [7], web page design [8], software engineering [9], entrepreneurship [10], electronics [11], aerospace engineering [12], biology [13], chemistry [14–16], language [17], and mathematics [18–21], among other topics. Moreover, digital escape rooms can be used to assess and evaluate students' learning progress and achievement. Educators can create quizzes or puzzles that align with the learning objectives and measure students' understanding and retention of the material [22]. Digital escape rooms can provide opportunities for the gamification of learning [23,24], where students can earn points, badges, or rewards for completing tasks and achieving learning goals. This can incentivize students to stay engaged and motivated throughout the learning process. The use of digital escape rooms has been particularly beneficial during the COVID-19 pandemic, as it has allowed educators to maintain continuity of learning and engage students in a virtual or hybrid environment [25,26]. It has also provided a way for educators to create immersive and interactive learning experiences [27,28], even in the absence of physical resources or equipment.

Traditional approaches to education may not be sufficient to prepare students for the rapidly changing job market. In order to keep up with the pace of technological innovation and industry demands, innovative practices in STEAM education are needed. Innovative practices in STEAM education refer to teaching methods and strategies that encourage active and experiential learning, foster creativity and innovation, and equip students with the skills and competencies needed for success in the STEAM fields [29]. Innovative practices in STEAM education can take many forms, such as project-based learning, inquiry-based learning, interdisciplinary learning, and collaborative learning. These practices prioritize hands-on experiences and problem-solving and encourage students to apply their knowledge and skills in real-world contexts. Innovative practices in STEAM education can enhance students' engagement, motivation, and achievement [30]. By creating engaging and relevant learning experiences, students are more likely to stay interested and invested in their learning. This can lead to higher levels of motivation and achievement, which in turn can have positive impacts on students' future academic and career success. In addition to preparing students for the workforce, innovative practices in STEAM education can also contribute to addressing global challenges such as climate change, health, and sustainability [27,31]. By fostering critical thinking, creativity, and innovation, students can develop solutions to complex problems that affect society and the environment [26,28,32].

The aim of this study is to investigate the use of digital escape rooms as an innovative practice in STEAM education in Europe. Specifically, the study aims to examine the impact of using digital escape rooms on student engagement and learning outcomes in mathematics education and to provide insights into the effectiveness of digital escape rooms as a tool for teaching mathematics and promoting active and experiential learning in STEAM education.

The novelties of this paper are threefold:

1. Out-of-the-Box learning, a novel learning approach that emphasizes the importance of engaging students in unconventional, creative, and experiential learning activities that challenge them to think critically, solve problems, and collaborate.
2. The concept of digital escape room design patterns that are commonly employed in the creation of escape room puzzles and challenges. These patterns assist designers in developing puzzles that are both intriguing and demanding for learners.
3. Six escape room design patterns (Search and Discovery, Lock and Key, Observation and Deduction, Sequence and Order, Communication and Collaboration, Red Herring), which represent a variety of possible pathways in designing digital escape rooms for learning.

This study will contribute to the existing literature on innovative practices in STEAM education by providing empirical evidence for the effectiveness of digital escape rooms in promoting student engagement and learning outcomes in mathematics education. The findings of this study can inform educators and policymakers on the potential benefits and challenges of using digital escape rooms in STEAM education, and provide insights into how digital escape rooms can be designed and implemented to maximize their effectiveness.

Additionally, this study can serve as a model for future research on the use of digital escape rooms in other subject areas and educational contexts.

The structure of the remaining parts of the paper is as follows. Section 2 will examine the theoretical frameworks for understanding the use of digital escape rooms in education and discuss the existing research on digital escape rooms in STEAM education. Section 3 discusses the out-of-the-box learning approach and its application for designing escape rooms. Section 4 presents escape room design patterns. Section 5 will discuss the design of a digital escape room for teaching math concepts. Section 6 presents the findings of the study, including the impact of digital escape rooms on student engagement and learning outcomes. Section 7 will interpret and discuss the findings in the context of the existing literature and provide implications for practice and future research. Finally, Section 8 will summarize the key findings and contributions of the study and offer recommendations for the use of digital escape rooms in mathematics education in the context of innovative practices in STEAM education.

2. Literature Review

2.1. Theoretical Frameworks for Understanding the Use of Digital Escape Rooms in Education

There are several theoretical frameworks that can be used to understand the use of digital escape rooms in education, including experiential learning theory, game-based learning theory, and cognitive load theory.

Experiential learning [33] theory posits that learning occurs through a cycle of experience, reflection, and abstraction. In the context of digital escape rooms, students are presented with a challenging and immersive experience during which they must use critical thinking and problem-solving skills to solve puzzles and complete tasks. The process of reflection and abstraction occurs as students work together to make sense of the experience, develop new insights and understanding, and apply their knowledge and skills in real-world contexts.

Game-based learning [34] theory suggests that game elements such as challenge, competition, and rewards can enhance engagement and motivation in learning. Digital escape rooms often incorporate these game elements in order to create an immersive and engaging learning experience. The use of digital escape rooms can also provide opportunities for students to develop skills such as collaboration, communication, and creativity, which are important for success in the STEAM fields.

Collaborative learning [35] and team-based learning [36] are instructional approaches that involve students working together in groups to achieve shared learning goals. Digital escape rooms can be designed to support these approaches by providing opportunities for students to collaborate and work together to solve puzzles and complete tasks. In digital escape rooms, students are often presented with complex problems that require a variety of skills and perspectives to solve. By working together in teams, students can leverage their individual strengths and expertise to develop innovative solutions to these problems. This promotes collaboration and communication skills as well as the ability to work effectively in a team.

Virtual learning [37] is an instructional approach that uses digital technologies to deliver educational content and support student learning. Digital escape rooms can be easily adapted for virtual learning environments, allowing students to participate in immersive and engaging learning experiences from anywhere in the world, such as from home, school, or other locations, making it a convenient and accessible option for virtual learning. Virtual digital escape rooms can be designed to incorporate a variety of multimedia elements, such as videos, animations, and interactive simulations, to support student learning and engagement.

Multimodal learning [38] is an instructional approach that recognizes that students have different learning styles and preferences, such as visual, auditory, and kinesthetic [39], and that learning is most effective when multiple modes of representation and engagement are used. Digital escape rooms can be designed to incorporate multiple modes of representation and engagement, such as videos, images, text, and audio, as well as interactive elements that require students to use a combination of visual, auditory, and kinesthetic skills to solve problems [40]. For example, students may be required to solve math problems using virtual manipulatives and listen to audio instructions. Digital escape rooms can also support personalized learning by providing opportunities for students to work at their own pace and level of challenge. This is achieved by designing puzzles and challenges that are scalable and adaptable so that they can be modified to meet the needs of individual learners.

Cognitive load [41] theory proposes that learning is influenced by the amount and complexity of information presented to learners. Digital escape rooms can be designed to optimize cognitive load by presenting information in a structured and manageable way and by providing scaffolding and feedback to support student learning. Additionally, digital escape rooms can provide opportunities for active and experiential learning, which can reduce cognitive load by allowing students to learn through doing rather than passively receiving information.

Another theoretical framework that can be used to understand the use of digital escape rooms in education is constructivism [42]. Constructivist learning theory suggests that students construct their own knowledge and understanding through active participation in learning activities. Digital escape rooms can provide opportunities for students to construct their own understanding of mathematical concepts and principles by engaging in problem solving and inquiry-based activities.

These theoretical frameworks provide a foundation for understanding the use of digital escape rooms in education. By incorporating elements of experiential learning theory, game-based learning theory, cognitive load theory, and constructivism, educators can create immersive and engaging learning experiences that promote active and experiential learning, enhance student engagement and motivation [43], and support the development of critical thinking and problem-solving skills.

2.2. Empirical Evidence of the Impact of Digital Escape Rooms on Student Engagement and Learning Outcomes

There is growing empirical evidence to suggest that the use of digital escape rooms in education can have a positive impact on student engagement and learning outcomes, particularly in the area of STEM education, including mathematics [44].

Several studies have found that digital escape rooms can improve student engagement and motivation. For example, Yllana-Prieto et al. [23] found that a BrEscapeRm could be an effective tool for teaching STEM content in primary education, with students finding it fun, interesting, motivating, and exciting. Huraj et al. [8] found that digital escape rooms can significantly increase the motivation, engagement, and satisfaction of students in technical vocational subjects, although the experiment did not confirm an increase in cognitive abilities. Kuo et al. [5] showed that combining digital and physical escape rooms could improve creative thinking and learning motivation in fifth-grade science lessons. Finally, von Kotzebue et al. [45] examined the impact of sequential scaffolding in a virtual escape room for biology classes, finding that game-based learning with escape rooms could successfully support motivation and knowledge acquisition. These studies suggest that escape rooms can be an effective tool for increasing student engagement and motivation in STEM subjects, but further research is needed to explore their impact on learning outcomes and cognitive abilities.

In terms of learning outcomes, several studies have found that digital escape rooms can improve students' problem-solving skills. For example, studies have shown that digital escape rooms can be effective in promoting learning and improving problem-solving skills. Buchner et al. [46] found that playing a digital escape room after explicit instruction was more effective for knowledge retention and domain-specific self-efficacy with lower cognitive load. Fraguas-Sánchez et al. [47] established and implemented escape rooms in the classroom successfully in pharmacy students, which promoted teamwork and improved the problem-solving skills of the students. Huraj et al. [8] also found that using a digital educational escape room lead to problem-solving skills and teamwork and significantly increased the motivation, engagement, and satisfaction of students in vocational schools. Mystakidis and Christopoulos [30] explored in-service teachers' views on the use of a digital educational escape room in virtual reality and found that it can enhance the cognitive benefits and learning outcomes. Avargil et al. [48] built an escape room-based educational assessment for high school chemistry teachers and found that the puzzles required the implementation of significant chemical knowledge, high-order thinking skills, and creative thinking for their solution. Brady and Andersen [49] described an escape room-inspired review game for an advanced genetic analysis class at Northwestern University, which improved learning outcomes. Huang et al. [50] found that a teaching approach involving a digital escape room improved students' learning motivation and problem-solving ability scores. Chou et al. [17] investigated students' overall learning process during the implementation of educational escape-the-room games in classrooms and found that students actively collaborated with their team members to address problem-solving tasks during the activity. Ouariachi and Wim [27] conducted a qualitative content analysis of climate change-related escape rooms and found that escape rooms can offer experiential and immersive learning, problem-solving and critical thinking skills, and a sense of collaboration and urgency. In summary, these studies suggest that digital escape rooms can be an effective and engaging way to promote problem-solving skills in students. These activities allow students to actively engage in problem-solving tasks, collaborate with their peers, and apply theoretical learning outcomes in real-world scenarios.

Other studies have also reported positive effects of digital escape rooms on learning outcomes in subjects such as science and engineering. For example, Fraguas–Sánchez et al. [47] found that escape rooms allowed pharmacy students to apply theoretical learning outcomes of each subject, promoted teamwork and improved problem-solving skills. Kuo et al. [5] found that combining digital and physical escape rooms improved students' creative thinking and learning motivation. Videnovik et al. [51] found that digital escape room-style games could engage students in the learning process and achieve learning outcomes. Mystakidis and Christopoulos [30] found that digital educational escape rooms can potentially enhance cognitive benefits and learning outcomes. Brady and Andersen [49] developed an escape room-inspired review game that had a positive impact on learning outcomes. Charlo [52] reported evidence of learning processes and horizontal mathematization in an educational escape room. These studies demonstrate that digital escape rooms can be effective tools for enhancing student engagement, learning outcomes, and problem-solving skills in various STEM subjects.

Digital escape rooms in education can have a positive impact on student engagement and learning outcomes in a variety of subject areas, particularly in the area of mathematics education. However, it is important to note that some studies have also reported mixed results or no significant impact of digital escape rooms on learning outcomes, and further research is still needed to fully understand the potential benefits and limitations of digital escape rooms as an educational tool. Digital escape rooms can provide a fun and engaging way for students to develop their math skills and understanding within the context of STEAM education.

3. Methodology

3.1. Theoretical Framework of Out-of-the-Box Learning

Out-of-the-Box Learning is a novel learning approach that emphasizes the importance of engaging students in unconventional, creative, and experiential learning activities that challenge them to think critically, solve problems, and collaborate with their peers. This approach recognizes that traditional, lecture-based teaching methods may not be sufficient to promote deep learning and meaningful engagement among students, particularly in fields such as math and science.

Out-of-the-Box Learning draws on several theoretical perspectives, including constructivism, social learning theory, and experiential learning theory. Constructivism emphasizes the active role of the learner in constructing knowledge and meaning from their experiences rather than simply receiving information from a teacher. Social learning theory emphasizes the importance of social interactions and collaborative learning, as students work together to solve problems and share (transfer) their knowledge and skills [53]. Experiential learning theory emphasizes the importance of hands-on, immersive learning experiences, where students learn by doing and reflecting on their experiences. The main constituent concepts of Out-of-the-Box Learning are constructivism, social learning theory, and experiential learning theory, which are interrelated and complement each other in order to promote deeper, more meaningful learning experiences as follows:

- Constructivism emphasizes that learning is an active process in which learners actively construct their own understanding of the world based on their prior knowledge and experiences. In Out-of-the-Box Learning, this means that learners are encouraged to use their existing knowledge and skills to solve problems and construct new knowledge through experiential learning activities.
- Social learning theory [54] emphasizes the importance of social interactions and collaborative learning, as learners work together to solve problems and share their knowledge and skills. In Out-of-the-Box Learning, this means that learners are encouraged to work in groups, discuss their ideas, and learn from each other in a supportive, collaborative environment.
- Experiential learning theory emphasizes the importance of hands-on, immersive learning experiences, where learners learn by doing and reflecting on their experiences. In Out-of-the-Box Learning, this means that learners are provided with opportunities to apply their knowledge and skills in real-world scenarios, and to reflect on their experiences to deepen their understanding and refine their skills.

The relationship between these constituent concepts is dynamic and iterative. In Out-of-the-Box Learning, learners construct their own understanding of the world by interacting with their peers and with the environment and by reflecting on their experiences. This process is facilitated by the use of unconventional and experiential learning activities that challenge learners to think critically, solve problems, and collaborate with their peers.

Table 1 provides an overview of the constituent concepts of Out-of-the-Box Learning, including the learning approach (constructivism, social learning theory, and experiential learning), the component of the learning approach, the relationship to other components, and the use in Out-of-the-Box Learning. The table can be further expanded or customized based on specific needs and requirements.

Table 1. Constituent Concepts of Out-of-the-Box Learning.

Learning Approach	Component of Learning Approach	Relationship to Other Components	Use in Out-of-the-Box Learning
Constructivism	Active learning	Interacts with prior knowledge	Encourages learners to use existing knowledge to construct new understanding
	Knowledge construction	Collaborative learning	Emphasizes that learners actively construct their own understanding of the world
Social learning theory	Collaborative learning	Social interaction	Emphasizes the importance of social interactions and collaborative learning
	Peer learning	Learning from peers	Encourages learners to work in groups and learn from each other
Experiential learning	Hands-on learning	Active experimentation	Emphasizes the importance of hands-on, immersive learning experiences
	Reflection	Deepens understanding and refines skills	Encourages learners to reflect on their experiences to deepen their understanding and refine their skills

We evaluated Out-of-the-Box Learning using aspects of the learning process, such as the acquisition of knowledge, the development of skills, or the formation of attitudes and values. The results are summarized in Table 2.

Table 2. Evaluation of the Out-of-the-Box Learning.

Criterion	Description
Acquisition of Knowledge	Out-of-the-Box learning encourages learners to engage in active exploration, discovery and problem-solving, which can help them to acquire a deeper and more meaningful understanding of the subject matter. By breaking away from traditional classroom-based learning, students are exposed to a wider range of perspectives and real-world applications that can broaden their knowledge and understanding.
Development of Skills	Out-of-the-Box learning is designed to foster a wide range of skills, including critical thinking, creativity, collaboration, communication, and self-directed learning. By placing learners in unfamiliar situations and environments, it challenges them to think creatively and to develop problem-solving skills. Students also learn how to work effectively in teams, communicate their ideas clearly, and take responsibility for their own learning.
Formation of Attitudes and Values	Out-of-the-Box learning promotes a growth mindset and encourages learners to embrace challenges and take risks [55]. It also fosters a sense of curiosity and a passion for lifelong learning, and encourages students to take responsibility for their own learning. In addition, it can help students to develop empathy, respect for diversity, and a sense of social responsibility.
Applicability to Different Educational Contexts	Out-of-the-Box learning can be applied in a wide range of educational contexts [56], from formal classroom-based learning to informal learning in community settings. It can also be adapted to suit learners of different ages, backgrounds, and abilities, and can be used to teach a wide range of subjects and skills. However, it may require different resources and support structures depending on the context in which it is used.

Digital escape rooms can be seen as an example of Out-of-the-Box Learning, as they provide students with an unconventional and experiential learning experience that challenges them to think critically, work together, and apply their knowledge in new and creative ways. By engaging students in this way, digital escape rooms can promote deep learning, enhance student engagement, and foster the development of critical thinking and problem-solving skills necessary to face 21st century challenges [57].

3.2. Learning Aims and Expected Outcomes

The learning aims and expected outcomes of using digital escape rooms for a university math course focusing on the theory of integration and calculus could include:

- To engage students in a fun and interactive learning experience that promotes active learning and problem-solving skills.
- To reinforce the concepts and principles of integration and calculus and provide students with opportunities to apply these concepts in real-world scenarios.
- To foster teamwork and collaboration among students, as they work together to solve math problems and escape the digital room [58].
- To develop critical thinking skills, as students analyze and evaluate mathematical problems and use logic and reasoning to solve them [59].
- To improve students' confidence in their math abilities, as they experience success in solving challenging math problems.
- To encourage creativity and innovation, as students explore different approaches to solving problems and develop their own unique solutions.
- To provide opportunities for formative assessment, as students receive feedback on their progress and understanding of the material.

3.3. Design of Learning Paths and Scenarios

Designing learning paths and scenarios for Out-of-the-Box Learning using digital escape rooms can involve the following methodology:

1. Identify the learning objectives: The first step is to identify the learning objectives and desired outcomes for the digital escape room experience. This involves understanding the knowledge, skills, and competencies that learners are expected to acquire through the experience.

2. Choose the digital escape room platform: There are various digital escape room platforms available, such as Breakout EDU, Escape Classroom, EdPuzzle, and Gdevelop. Select the platform that best aligns with the learning objectives and desired outcomes.
3. Create the storyline and theme: Design a storyline and theme that aligns with the learning objectives and desired outcomes. This could involve creating a narrative that engages learners and sets the context for the escape room experience.
4. Design the puzzles and challenges: Develop puzzles and challenges that are aligned with the learning objectives and desired outcomes. These should be challenging enough to promote critical thinking and problem-solving skills but not too difficult that they become frustrating for learners.
5. Map the learning path: Map out the learning path that learners will follow during the escape room experience. This involves creating a sequence of puzzles and challenges that build on each other and progress towards the learning objectives.
6. Incorporate feedback mechanisms: Incorporate feedback mechanisms, such as hints or clues, to help learners progress through the escape room experience. These mechanisms should be designed to provide just enough support to keep learners engaged and motivated.
7. Test and evaluate: Test the learning paths and scenarios with a sample group of learners to evaluate their effectiveness. This involves collecting feedback on the engagement, motivation, and learning outcomes of learners.

By following this methodology, educators can design effective and engaging learning paths and scenarios for Out-of-the-Box Learning using digital escape rooms. The methodology can be adapted and customized based on the needs and requirements of specific learning contexts and audiences.

3.4. Creation of Storyline

Creating the storyline of a digital escape room using the Mechanics-Dynamics-Aesthetics (MDA) [60] framework and elements of gameplay can involve the following methodology:

1. Define the learning objectives: The first step is to define the learning objectives of the escape room experience. This will guide the development of the storyline and ensure that the experience aligns with the desired learning outcomes.
2. Identify the target audience: Identify the target audience for the escape room experience, such as students of a certain age group or learners with specific interests. This will help in creating a storyline that is engaging and relevant to the target audience.
3. Choose the game mechanics: Choose the game mechanics that align with the learning objectives and the desired experience. This could involve elements such as puzzles, challenges, hidden clues, or timed challenges.
4. Determine the dynamics: Determine the dynamics of the escape room experience, such as the pace of the game, the level of difficulty, and the degree of collaboration required among players. This will help in creating an experience that is engaging and challenging for learners.
5. Establish the aesthetics: Establish the aesthetics of the escape room experience, such as the theme, the visual elements, and the sound effects. This will help in creating an immersive and engaging experience for learners.
6. Develop the storyline: Using the chosen game mechanics, dynamics, and aesthetics, develop a storyline that aligns with the learning objectives and engages the target audience. This could involve creating a narrative that sets the context for the escape room experience and ties together the various game mechanics.
7. Playtest and refine: Playtest the escape room experience with a sample group of learners to evaluate its effectiveness and identify areas for improvement. Refine the storyline based on the feedback received and make adjustments to the game mechanics, dynamics, and aesthetics as necessary.

By following this methodology, educators can create engaging and effective digital escape room experiences that are aligned with the desired learning outcomes and the target audience. The methodology can be adapted and customized based on the specific needs and requirements of different learning contexts and audiences.

3.5. Designing Puzzles and Challenges

Designing puzzles and challenges for digital escape rooms requires a systematic and iterative approach that balances creativity with pedagogical objectives. The following methodology outlines a general framework for designing puzzles and challenges for Out-of-the-Box Learning-based digital escape rooms:

1. Based on the learning objectives and storyline, develop a series of puzzles and challenges that progressively build in difficulty and complexity. The puzzles and challenges should be creative, engaging, and challenging but also aligned with the learning objectives. For example, you could create puzzles that involve coding, logical reasoning, or pattern recognition.
2. Use a variety of puzzle types to keep students engaged and to cater to different learning styles. Some examples include logic puzzles, math problems, code-breaking puzzles, and visual puzzles.
3. Scaffold the difficulty level of the puzzles and challenges so that students gradually increase in difficulty. This helps students build confidence and ensures that they do not get frustrated and give up.
4. Once you have developed a prototype of the escape room, test it with a small group of participants to get feedback on the puzzles and challenges. Use the feedback to refine and improve the puzzles and challenges, ensuring that they are appropriately challenging and aligned with the learning objectives.
5. Finally, implement the escape room with a larger group of participants and evaluate its effectiveness in achieving the learning objectives. Collect feedback from participants and use it to further refine and improve the escape room for future use.

By following this methodology, you can design puzzles and challenges for digital escape rooms that promote out-of-the-box learning while also meeting specific pedagogical objectives. The iterative nature of the methodology allows you to continuously improve and refine the puzzles and challenges based on feedback from participants, ensuring that the escape room is both engaging and effective.

3.6. Feedback Mechanisms

In designing feedback mechanisms for Out-of-the-Box Learning-based digital escape rooms, it is important to consider both the immediate feedback provided during the game and the post-game feedback that can be used to improve future versions of the escape room. The following are some key considerations when designing feedback mechanisms for digital escape rooms:

- Immediate feedback: During the game, it is important to provide immediate feedback to players on their progress, performance, and problem-solving strategies. This can include feedback on whether a puzzle has been solved correctly, hints or guidance to help players progress, and feedback on the effectiveness of different strategies used to solve puzzles.
- Reflection and metacognition: In addition to immediate feedback on performance, it is important to encourage reflection and metacognition among players. This can include prompts for players to reflect on their problem-solving process, strategies, and decision-making. It can also include prompts for players to articulate their understanding of key concepts and how they are applying them in the game.
- Post-game feedback: After the game, it is important to collect feedback from players on their experience, including what they liked and disliked about the game, what they learned, and how the game could be improved. This feedback can be used to improve future versions of the escape room, including refining the puzzles and challenges, improving the storyline and theme, and enhancing the feedback mechanisms.

- Analytics and data tracking: Digital escape rooms can also incorporate analytics and data tracking to provide insights into player behavior and performance [61]. This can include tracking the time taken to solve puzzles, the number of hints used, and the number of attempts it takes to solve a puzzle. This data can be used to further refine and improve the escape room, as well as to assess the effectiveness of the game in achieving the learning objectives.

By incorporating immediate feedback, reflection and metacognition [62], post-game feedback, and analytics and data tracking, designers can create effective feedback mechanisms for out-of-the-box learning-based digital escape rooms. These mechanisms can enhance the learning experience, improve player performance, and provide valuable insights for improving future versions of the escape room.

3.7. Lifecycle of Digital Escape Rooms

The lifecycle of an educational escape room for teaching math at a university course involves careful planning, development, testing, implementation, facilitation, assessment, and improvement to ensure that it is effective in achieving the desired learning outcomes as follows:

1. Planning: This stage involves identifying the learning goals, selecting the math concepts to be taught, and designing the puzzles and challenges that will be included in the escape room.
2. Development: In this stage, the escape room is developed, including the creation of the puzzles, clues, and room design. The room design should be carefully planned to support the learning goals and ensure that the puzzles are engaging and challenging.
3. Testing: In this stage, the escape room is tested to ensure that it is engaging, challenging, and aligned with the learning goals. Feedback from test participants is used to make improvements to the escape room.
4. Implementation: Once the escape room is finalized and tested, it is implemented in the math course. Students are provided with an introduction to the escape room and the learning goals it is designed to achieve.
5. Facilitation: During the escape room session, the facilitator plays an important role in providing support and guidance to students, answering questions, and ensuring that the students are making progress through the puzzles.
6. Assessment: After completing the escape room, students may be assessed through traditional methods such as exams or through alternative methods such as self-reflection or group reflection. Assessment can be used to evaluate student learning outcomes and to identify areas for improvement in future escape rooms.
7. Improvement: Based on assessment data and feedback from students and facilitators, improvements can be made to the escape room to make it more effective for teaching math concepts in the future.

4. Escape Room Design Patterns

4.1. Outline

Escape room patterns refer to common design elements, structures, and sequences that are used in creating escape room puzzles and challenges. These patterns help designers create puzzles that are engaging and challenging for players while also ensuring that they are solvable within a reasonable amount of time.

There are several different types of escape room patterns that designers can use to create puzzles, including:

- Search and Discovery, a pattern which involves players searching a room or area for clues and items that will help them solve puzzles and progress through the game.
- Lock and Key, a pattern which involves players finding and using keys or combinations to unlock locks and open doors or containers that contain clues or items needed to progress through the game.

- Observation and Deduction, a pattern which involves players observing their surroundings and using their powers of deduction to solve puzzles based on visual and audio clues.
- Sequence and Order, a pattern which involves players determining the correct sequence or order in which to perform a series of actions or solve a set of puzzles.
- Communication and Collaboration, a pattern which involves players working together and communicating effectively to solve puzzles and progress through the game.
- Red Herring, a pattern which involves including misleading clues or dead ends that divert players' attention from the true solution to a puzzle or challenge.

Escape room patterns can be used in combination with one another or individually to create puzzles that are challenging, engaging, and enjoyable for players. Designers can also create their own unique patterns and variations on existing patterns to create new and exciting challenges.

4.2. Escape Room Pattern Specification

We use the following specification template, the elements thereof were adopted from the specification template used to describe design patterns in software engineering [63].

1. Pattern Name: The name of the escape room design pattern.
2. Learning Objective: The learning objective of the pattern.
3. Difficulty Level: An indication of the difficulty level of the pattern, including any prerequisites or skills required to successfully complete the challenge.
4. Description: A brief explanation of the pattern, its purpose, and how it contributes to the Out-of-Box Learning.
5. Solution: A description of when and how the pattern is used, including any variations or modifications that may be applied.
6. Examples: A few examples of how the pattern has been used in existing escape rooms, with a brief explanation of the puzzle or challenge.
7. Variations: Any potential variations or modifications that could be made to the pattern, including how they might affect the difficulty level or gameplay experience.
8. Design Considerations: Any specific design considerations that should be taken into account when using the pattern, such as the amount of space required, the necessary equipment, or the level of player interaction.
9. Tips: Any helpful tips or suggestions for designers looking to implement the pattern in their own escape rooms, including common mistakes to avoid or creative ways to make the challenge more engaging.
10. Notes: Any additional notes or comments that may be relevant to the pattern, including feedback from players or designers who have used it in the past.

Further we apply this specification template to specify the digital escape room design patterns.

4.3. Search and Discovery Pattern

1. Pattern Name: Search and Discovery
2. Learning Objective: This pattern aims to challenge players' problem-solving and observation skills as well as their ability to work together and communicate effectively.
3. Difficulty Level: Moderate to Difficult. Players must search the room for clues and hidden objects and use their observations to solve puzzles and piece together the solution.
4. Description: In this pattern, players must search the room for hidden clues or objects that will help them solve a larger puzzle or challenge. These clues may be hidden in plain sight or require some creative thinking to uncover. Once all of the necessary clues have been found, players must use them to piece together the solution to the challenge and escape the room.
5. Solution: The solution to this pattern will vary depending on the specific challenge, but it generally involves using the clues or objects found throughout the room to solve a larger puzzle or reveal a hidden key or code.

6. Examples: One example of the Search and Discovery pattern in action is a room where players must search for hidden symbols or codes that will help them unlock a series of locks or puzzles. Another example might involve searching for hidden objects or clues that reveal the location of a hidden key or map.
7. Variations: Variations on this pattern might include changing the type of clues or objects that players must find, or adding additional layers of complexity to the overall puzzle. For example, players might need to use a black light or other specialized equipment to find hidden clues, or they might need to work together to decode a series of clues or puzzles.
8. Design Considerations: Designers should take care to hide the clues or objects in a way that is not too obvious, but not too difficult to find. It is also important to consider the amount of space required for players to search, and to ensure that there are enough clues or objects to keep players engaged and challenged.
9. Tips: To make this pattern more engaging, designers might consider adding additional layers of complexity to the overall puzzle, such as requiring players to solve multiple smaller puzzles or challenges before they can move on to the larger challenge. It is also important to encourage players to communicate and work together, as this will help them to find and solve the clues more quickly and effectively.
10. Notes: Feedback from players who have participated in rooms using this pattern indicates that it can be a very engaging and rewarding challenge, but that it is important to strike the right balance between difficulty and accessibility. Additionally, designers should take care not to make the clues or objects too difficult to find, as this can be frustrating and can detract from the overall experience.

4.4. Lock and Key Pattern

1. Pattern Name: Lock and Key
2. Learning Objective: Problem-solving, critical thinking, collaboration, and communication skills.
3. Difficulty Level: Intermediate
4. Description: The Lock and Key escape room pattern involves a series of challenges or puzzles that require players to find keys to unlock various locks or devices. The pattern is based on the idea that each lock has a corresponding key, and players must use their problem-solving skills to identify the keys and unlock the locks.
5. Solution: The solution to the Lock and Key escape room pattern is to locate and use the correct keys to unlock all of the locks or devices. The keys may be hidden in various places throughout the room or provided as part of other puzzles.
6. Examples: One example of the Lock and Key pattern involves using a key to unlock a padlock on a box that contains a clue to the next puzzle. Another example could be finding a key hidden in a book and using it to unlock a cabinet that contains additional clues.
7. Variations: One variation of the Lock and Key pattern is to have multiple keys that are not labeled, and players must identify which key corresponds to which lock. Another variation is to have keys that are hidden in a specific order, requiring players to solve puzzles in a particular sequence.
8. Design Considerations: When designing a Lock and Key escape room, it is important to make sure that the locks and keys are challenging but not impossible to solve. The puzzles should be logical and have clear solutions. The designer should also consider the number and types of locks and keys to use, as well as the complexity of the puzzles.
9. Tips: It is important to provide players with clear instructions on how to use the locks and keys. The designer should also ensure that the locks and keys are in good working order and that the keys are not too difficult to handle.
10. Notes: The Lock and Key pattern is a popular and effective method for engaging players in an escape room. However, it’s important to balance the challenge level with the players’ skills and abilities to ensure a fun and rewarding experience.

4.5. Observation and Deduction Pattern

1. Pattern Name: Observation and Deduction
2. Learning Objective: Attention to detail, critical thinking, deduction, and problem-solving skills.
3. Difficulty Level: Advanced
4. Description: The Observation and Deduction escape room pattern is based on the idea of providing players with a set of clues that they must use to deduce a hidden message or solve a puzzle. The pattern requires players to carefully observe and analyze their surroundings, paying attention to even the smallest details.
5. Solution: The solution to the Observation and Deduction escape room pattern is to use the clues provided to deduce a hidden message or solve a puzzle. The clues may be hidden in various locations throughout the room or provided as part of other puzzles.
6. Examples: One example of the Observation and Deduction pattern involves using a series of clues to determine the correct combination to unlock a safe. Another example could be identifying a pattern in a series of numbers or letters to reveal a hidden message.
7. Variations: One variation of the Observation and Deduction pattern is to have multiple sets of clues that lead to different solutions, requiring players to choose the correct path. Another variation is to have clues that are hidden in a specific order, requiring players to solve puzzles in a particular sequence.
8. Design Considerations: When designing an Observation and Deduction escape room, it is important to provide a variety of clues that challenge players' deductive reasoning skills. The designer should also ensure that the clues are not too obscure or difficult to find and that there is a clear logic to the solution.
9. Tips: It is important to provide players with a clear understanding of how the clues fit together and how to use deductive reasoning to solve the puzzle. The designer should also consider the pacing of the game and the difficulty level, making sure that players have enough time to solve the puzzle without becoming frustrated.
10. Notes: The Observation and Deduction pattern can be challenging but rewarding for advanced players. The pattern encourages players to think outside the box and use their critical thinking skills to solve complex puzzles.

4.6. Sequence and Order Pattern

1. Pattern Name: Sequence and Order
2. Learning Objective: To teach participants how to identify and organize sequential patterns in order to solve a problem.
3. Difficulty Level: Intermediate
4. Description: In this escape room pattern, participants must identify a specific sequence or order of items, symbols, or clues in order to progress through the game. The challenge is to recognize the pattern and apply it correctly to the clues or objects in the room.
5. Solution: The solution to this pattern is usually a specific order or sequence of items, numbers, symbols, or colors that must be followed to unlock a door, solve a puzzle, or reveal a hidden clue.
6. Examples: An example of this pattern would be a room with several objects scattered around, each with a number or symbol on it. Participants must identify the correct order of the symbols in order to unlock a box that contains the key to escape the room. The escape room can be designed in such a way that requires students to solve a series of math problems in a specific order. Each problem provides a clue to the next problem, and the final solution can only be achieved by correctly solving all the problems in the correct order. For instance, in a geometry class, the escape room can be designed to test the students' knowledge of geometric shapes and their properties. The students can be given a set of problems that involve identifying the properties of various geometric shapes and using them to solve a series of puzzles. The escape room can be designed in such a way that the solution to each puzzle provides a clue

to the next puzzle, and the final solution can only be achieved by solving all of the puzzles in the correct order.
7. Variations: This pattern can be varied by changing the type of sequence or pattern used (e.g., alphabetical order, chronological order, Fibonacci sequence, etc.), or by increasing the complexity of the pattern.
8. Design Considerations: Designers should consider the level of difficulty of the pattern and ensure that it is solvable without being too obvious or too obscure. It is important to provide enough clues to allow participants to discover the pattern while also challenging them to think critically and logically.
9. Tips: To create a successful Sequence and Order escape room, designers should pay close attention to the clues and objects used in the game. Clues should be presented in a clear and organized manner, and the pattern should be consistent and logical.
10. Notes: This pattern can be combined with other escape room patterns, such as Lock and Key, Search and Discovery, or Observation and Deduction, in order to create a more complex and challenging game experience.

4.7. Communication and Collaboration Pattern

1. Pattern Name: Communication and Collaboration
2. Learning Objective: Encourage communication and collaboration among team members.
3. Difficulty Level: Medium to Hard
4. Description: This pattern is designed to challenge players to work together and communicate effectively to solve a series of puzzles. The room may be divided into different areas or sections, each containing a puzzle or clue that requires collaboration to solve. Players must share information and work together to make progress.
5. Solution: The solution to each puzzle may provide a clue or piece of information that is necessary to solve another puzzle in the room. Players must communicate effectively to piece together the information and solve all the puzzles to escape the room.
6. Examples: One example of this pattern may be a room with multiple locked boxes that can only be opened by solving different puzzles in different sections of the room. Each box may contain a clue or piece of information that is necessary to solve another puzzle in the room.
7. Variations: This pattern can be modified to suit different themes or settings. For example, in a laboratory-themed escape room, players may need to work together to solve a series of scientific puzzles to find the cure for a deadly virus.
8. Design Considerations: This pattern requires careful design of the puzzles and clues to ensure that they are interconnected and require collaboration to solve. The room should be designed in a way that encourages communication and collaboration among team members.
9. Tips: The room should be designed to accommodate a team of players, with enough space for everyone to work together comfortably. The puzzles should be challenging enough to require collaboration, but not so difficult that they become frustrating.
10. Notes: This pattern is ideal for team-building exercises or as a group activity for friends or family members. It is also a great way to encourage communication and collaboration among players, which can be useful in many real-world situations.

4.8. Red Herring Pattern

1. Pattern Name: Red Herring
2. Learning Objective: To encourage critical thinking and attention to detail by including misleading information.
3. Difficulty Level: Medium to Hard.
4. Description: In this pattern, the player encounters one or more clues that appear to be important to solving the puzzle but are, in fact, misleading or irrelevant. These clues can distract the player from the correct solution, leading them to waste time

or resources. The goal of the pattern is to encourage players to carefully examine all clues and to think critically about their relevance.

5. Solution: The solution to this pattern is to identify the misleading information and eliminate it as a possible solution. Players need to pay close attention to the details of the clues and to consider how they fit together to form a coherent solution.
6. Examples: A puzzle might include a code that appears to be essential to unlocking a door but is actually a red herring. The code could be a decoy to throw players off the real solution, which might involve finding a hidden key or using a different code altogether.
7. Variations: This pattern can be varied by including multiple red herrings, each leading players down a different path. The red herring could be used to create a false sense of security, leading players to believe they have solved the puzzle when they have not.
8. Design Considerations: To design a successful Red Herring pattern, designers must carefully balance the misleading information with the true clues. Too much misleading information can frustrate players and detract from the overall experience, while too little can make the puzzle too easy.
9. Tips: Designers should provide players with a clear indication when they have identified a red herring, such as a warning message or a penalty for choosing the wrong solution. This can help prevent players from becoming too discouraged or frustrated.
10. Notes: The Red Herring pattern is a useful tool for encouraging critical thinking and attention to detail. It can be particularly effective when combined with other patterns, such as the Observation and Deduction pattern, to create complex and challenging puzzles.

5. Implementation of Digital Escape Room

5.1. Research Questions

To guide our research further, we raise the following research questions:

1. How can digital escape rooms be designed and implemented to maximize their effectiveness in promoting student engagement and learning outcomes in mathematics education?
2. What are the potential benefits and challenges of using digital escape rooms in STEAM education, and how can they be addressed?
3. How can the Out-of-the-Box Learning approach be applied to the design of digital escape rooms for mathematics education?
4. How can digital escape rooms be used to foster teamwork, critical thinking, creativity, and self-directed learning in mathematics education?
5. What is the effectiveness of digital escape room design patterns in promoting student engagement and learning outcomes in STEM education, and how can these patterns be designed and implemented to maximize their effectiveness?

5.2. Course Content, Aims and Description

The example escape room was created and implemented by lecturers from the Kaunas University of Technology, Faculty of Mathematics and Natural Sciences for the Mathematics 2 course. The main aim of the course is to introduce knowledge about indefinite, definite, multiple, and linear integrals, differential equations, and series. Sections and themes of this university mathematics course are complex numbers, integrals, and infinite series. In this course, university students are taught to understand the concept of complex numbers; perform operations on complex numbers; master methods for finding indefinite integrals and for computing definite, double, and linear integrals; derive and classify differential equations; and find general and particular solutions to differential equations of the first and second orders while gaining knowledge of series applications.

5.3. Description of Escape Room

The designed escape room covers part of the "Mathematics 2" university course. The game was created using Google Forms. The escape room is intended to repeat all knowledge related to integrals: indefinite integrals, define integrals, improper integrals, and double integrals. The aim is to complete all challenges and puzzles within 100 min.

The playing process in the locked rooms is illustrated in Figure 1. The designed escape room is based on the Lock and Key pattern. This escape room pattern involves a series of challenges or puzzles that require players to find keys in order to unlock doors. The scenario starts with the player starting the game by interacting with the puzzle. The escape room consists of a series of challenges or puzzles, and most of the puzzles require the players to find a key in order to unlock a door and move on to the next puzzle. This is represented by the Lock and Key pattern. The loop in the diagram represents the series of challenges or puzzles in the escape room. For each puzzle, the player must solve it by interacting with the puzzle. The player is required to find the key to unlock the door to move on to the next puzzle. The alt statement in the loop represents the two possible outcomes of the puzzle-solving process. If the solution is correct, the key unlocks the door, and the player moves on to the next puzzle. The sequence diagram then goes to the next puzzle, represented by the NextPuzzle participant. If the solution is wrong, then the player must repeat the process of solving the puzzle until they find the correct solution. This is represented by the key going back to the puzzle in order to repeat solving.

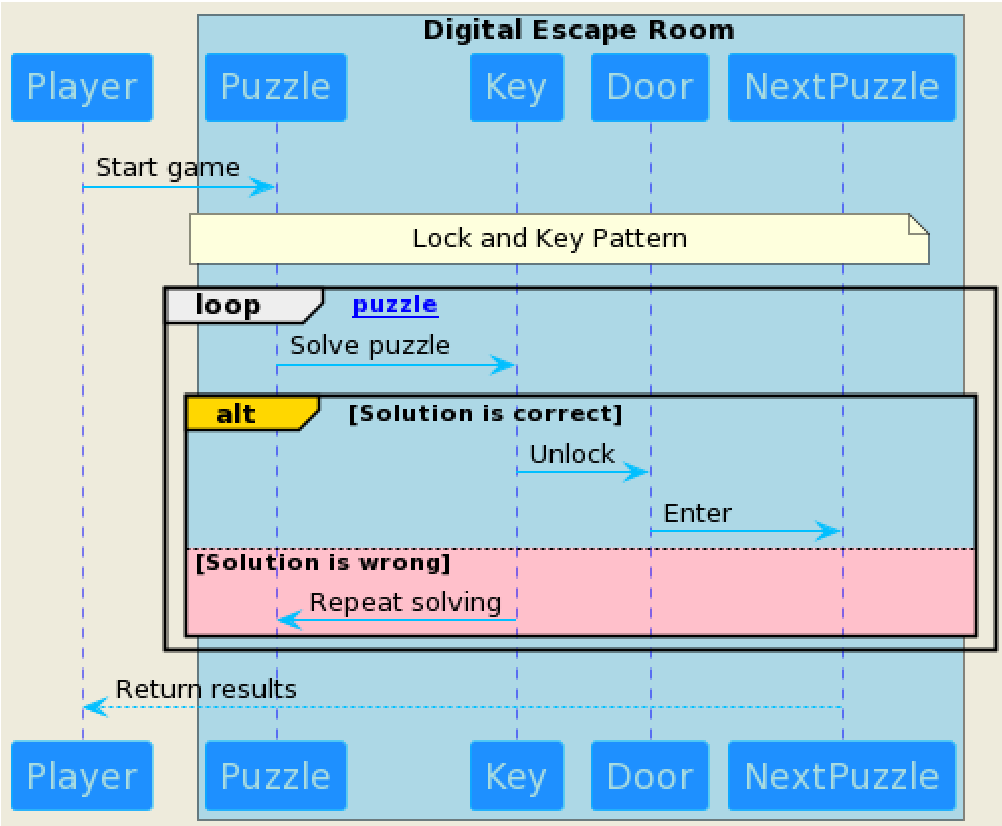

Figure 1. Sequence diagram of the playing process in the locked rooms.

Most of the puzzles not only demand math content but are also constructed such that university students need to use another skill like logic or even search for information on the Internet. For example, in the digital corridor, university students not only have to know how to solve the problem, but also have to know how to convert the answer into the right key for the next door. In this case, they should convert the decimal number into a binary number. This question also has misleading information (Figure 2). The word "MATH" is provided in a binary system during the task, but it is not related to the real task. As a result, most of the university students spend additional time converting this note and waste more time.

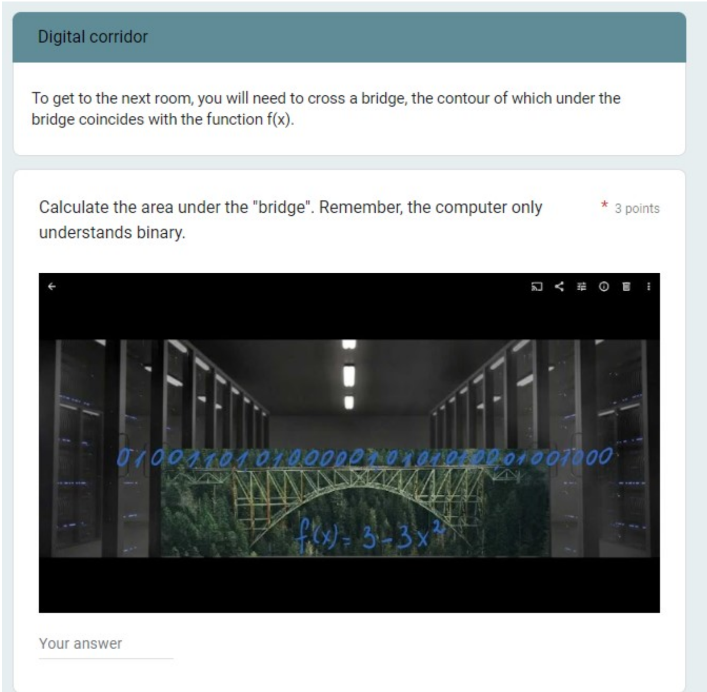

Figure 2. Digital corridor: The university students should find the area under a curve using a definite integral. The key of the locked door is that number converted into a binary number. The red asterisk denotes the number of points awarded for the correct answer.

The second example could be the yellow room (Figure 3). The university students should not only adapt their knowledge about symmetric bounds and odd and even functions in definite integrals, but should also know how the gotten answer converts into the right key using double factorials.

Figure 3. Yellow room: The university students should apply the rules for integrating odd functions for definite integrals with symmetry bounds and multiply the numbers of those integrals. The key should be written using double factorials. The red asterisk denotes the number of points awarded for the correct answer.

The scheme of the escape room is presented in Figure 4 and explained in Table 3. Most of the rooms are locked, but the game has unlocked rooms also.

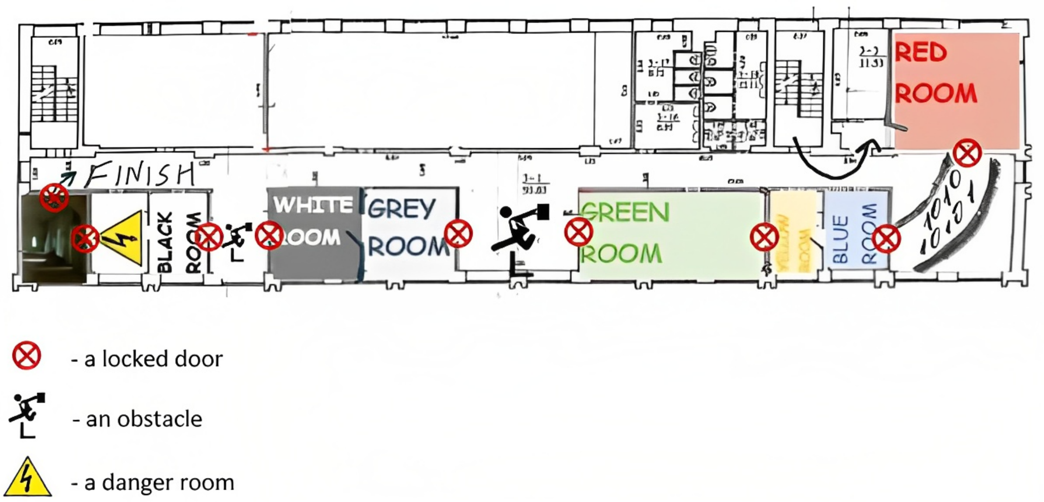

Figure 4. Map of the implemented digital escape room.

Table 3. Description of rooms and corresponding table content.

Levels	**Learning Content**
Warm-up	Indefinite integrals by parts
Red room	Parametric curves (Astroid)
Digital corridor (Figure 2)	Finding the area under a curve using definite integration
Blue room	Indefinite integrals by substitution
Yellow room (Figure 3)	Definite integrals with symmetry bounds of odd and even functions
Green room	Applications of definite integrals: the area between curves, length of curves, the volume of a solid of revolution
Obstacle	No math task
Grey room (Figure 5)	Definite integrals with symmetry bounds of odd and even functions
White room	Applications of definite integrals: length of curves (parametric curves)
Obstacle: Pirate (Figure 6)	Wallis' integrals; Definite integrals with symmetry bounds of odd and even functions
Black room (Figure 7)	Applications of Double Integrals (Mass)
Danger room (Figure 8)	Improper integral with one infinite bound (convergent, divergent)
The last room	Indefinite integrals by w-substitution

The example of an unlocked room is presented in Figure 5. In this task, there are lots of graphs of even, odd, and neither even nor odd functions. The university students have to know the rules of how to calculate definite integrals with symmetry bounds of even or odd functions. Therefore, university students should match A, B, C, and etc. with 1, 2, or 3 formulas. As this room does not have a key, university students can leave this room without selecting the correct answers. However, in this case, if they select the wrong choice, they will lose points.

More examples of locked puzzles are shown in Figures 6–8. In the first example, the university students should solve Wallis' integrals and multiply the answers, except zero. Furthermore, they have to figure out that it means a mathematical constant that expresses the ratio of the length of the circle to the diameter and should divide by that constant. This means π. The format of the key is also presented.

In the second example, the university students should use their knowledge about double integrals and the applications of double integrals. Specifically, they need to know how to calculate the mass of a plate when the plate shape and density are given. To escape the black room, they should calculate the weight of the scale, which they have to put on the scale so that the door will open.

In the third example, the university students have to choose convergent integrals and write their numbers in increasing order.

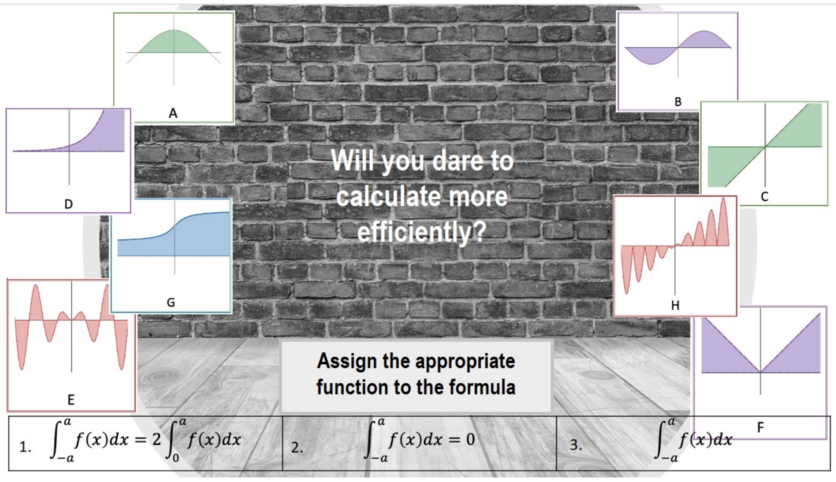

Figure 5. Grey room: The university students should link the given odd, even, and neither even nor odd functions with the right formulas. Letters A–H denote the answer options.

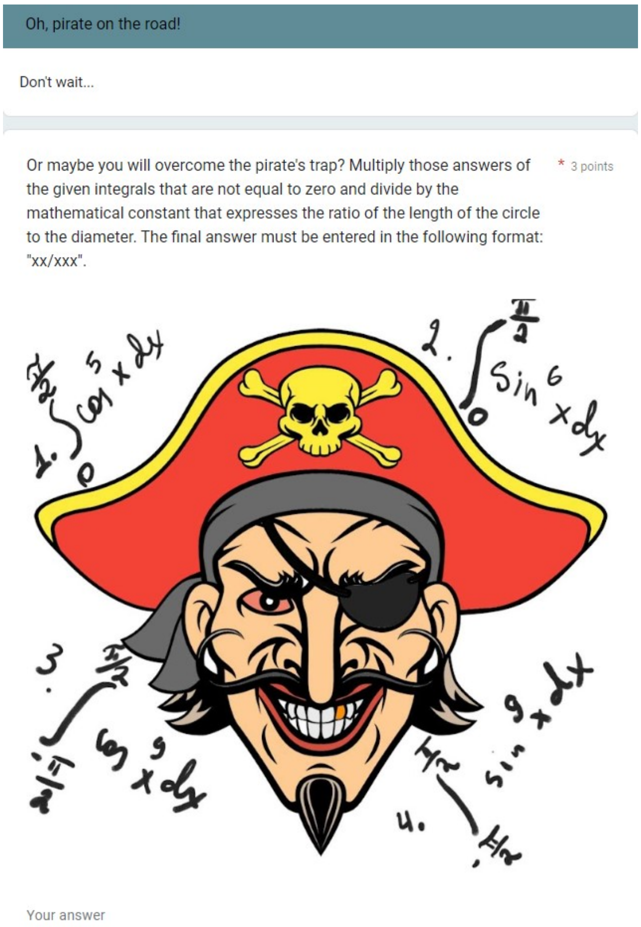

Figure 6. Obstacle—Pirate : The university students should solve Wallis' integrals and multiply the answers, except zero, and divide by π. The red asterisk denotes the number of points awarded for the correct answer.

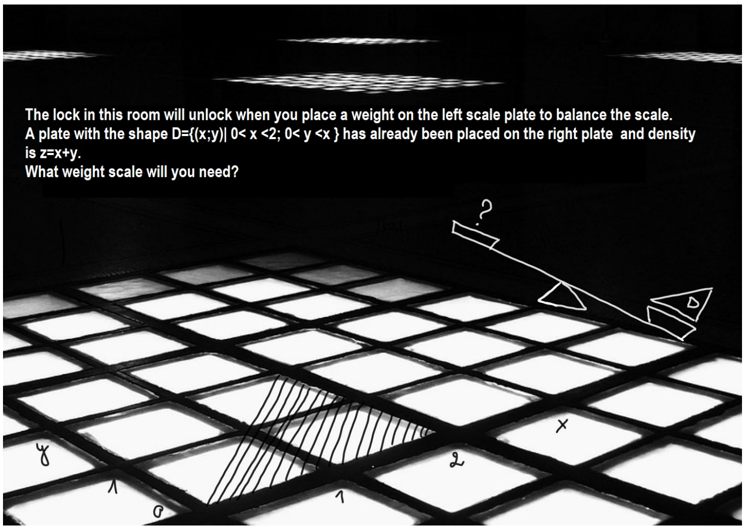

Figure 7. Black room: The university students have to calculate the weight which they need to put on the left plate of the scale. For that task, they should know how to calculate double integrals, and they should know that the mass of the plate is calculated by double integrals.

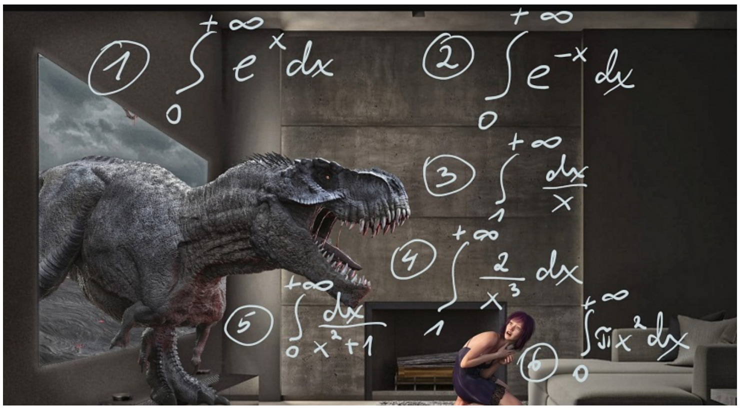

Figure 8. Danger room: The university students should solve an improper integral with one infinite bound and choose the integrals that converge. The key is the convergent integrals' numbers in increasing order. Numbers ①–⑥ denote the answer options.

This escape room is intended to be played in groups. The university students voluntarily divide themselves into teams of 5–6 people before the game. The target for the team is not only to escape but to collect as many points as possible. The winner is the team with the highest number of points, and if more than one team has the same number of points, the the winner is the team that finished the game first. During the game, university students have one free hint, and for other hints, they should pay with collected points. Using a lecturer's help more than once reduces their probability of winning.

The digital escape room is played via the zoom.us platform using breakout rooms (Figures 9 and 10). Since the teams are formed before the game, the developer creates separate (breakout) rooms for each team before the game. This is very easily implemented with the zoom.us platform. Before the game is started, the developer set the max time for the breakout room, in this case, 100 min, and all university students choose a breakout room with their own team name. During the game, the lecturer can visit each team by switching from one breakout room to another. Therefore, the lecturer can monitor the process of the game and help students if they chose to use their free hint. Using the zoom breakout rooms, university students can ask for help anytime using the breakout feature ("Ask for Help").

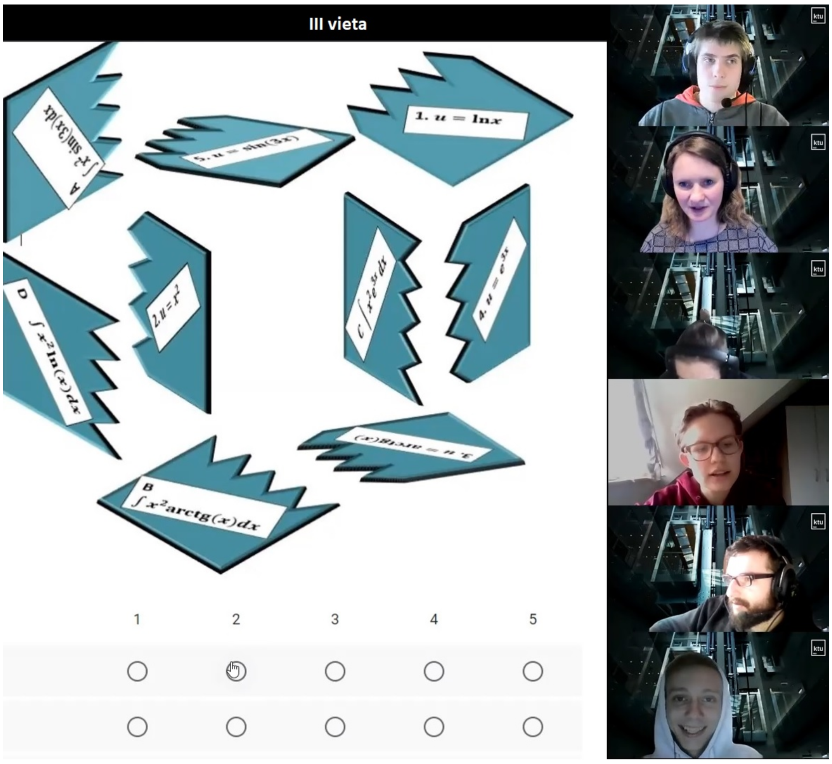

Figure 9. The university students have to link the right "u" to given indefinite integrals in integration by parts. Numbers 1–5 show the answer options.

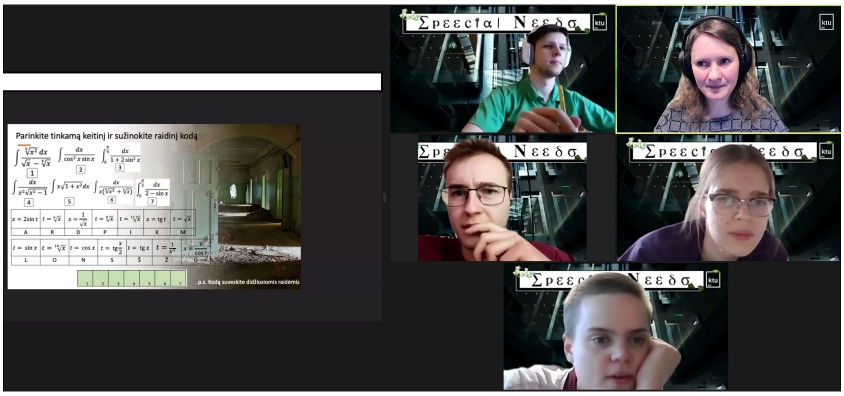

Figure 10. The link between integrals and right w-substitution helps university students to find the key to unlock the last door.

6. Results and Evaluation

The escape room was organized during the COVID-19 lockdown period in the 2021 Spring semester. The 21-student team from the Kaunas University of Technology, Faculty of Electrical and Electronics Engineering, Informatics and Mathematics, and Natural Sciences participated.

Three university lecturers were involved in the escape room organization. The idea to use an escape room in the university mathematics course came from one lecturer (main organizer). The main framework was also created by the main organizer, but puzzles were created by all three lecturers. The same three lecturers also participated online (using Zoom) remotely and helped their own university students escape. As the university students had one free possibility to ask for help, all three lecturers were walking through the breakout rooms during the game.

During this game, university students repeated the Mathematics 2 university course content that included indefinite integrals and definite integrals and their applications, improper integrals, and double integrals, and prepared for the mid-term examination. Furthermore, since the university students played in teams, they developed their teamwork and communication skills. We have distributed a questionnaire (Table 4) to the university students who participated in digital escape rooms in order to evaluate their engagement and satisfaction with the experience.

Table 4. Questionnaire for Evaluating Student Engagement with Digital Escape Rooms.

No	Question	Answer Options
1	Have you participated in a digital escape room before?	Yes/No
2	How engaging was the digital escape room experience?	1–2 (not engaging)/3 (somewhat engaging)/4–5 (very engaging)
3	Did you find escape room an appropriate form of teaching in this course?	1 (definitively no)/2 (rather no)/3 (not sure)/4 (rather yes)/ 5 (definitively yes)
4	Did the digital escape room experience improve your understanding of the subject matter?	1 (definitively no)/2 (rather no)/3 (not sure)/4 (rather yes)/ 5 (definitively yes)
5	What was the difficulty of math puzzles in escape rooms?	1 (too easy)/2 (just right)/3 (too difficult)
6	Would you like to have more such escape room based games in your studies?	1 (definitively no)/2 (rather no)/3 (not sure)/4 (rather yes)/ 5 (definitively yes)
7	Did you like the teamwork experience?	1 (definitively no)/2 (rather no)/3 (not sure)/4 (rather yes)/ 5 (definitively yes)
8	What did you like most about the digital escape room experience?	[Open ended question]
9	What did you like least about the digital escape room experience?	[Open ended question]
10	Do you have any suggestions for improving the digital escape room experience?	[Open ended question]

The results of this survey performed online in the Moodle environment were used to assess the effectiveness of digital escape rooms and to identify areas for improvement. This study aimed to evaluate university students' engagement with digital escape rooms in a university math course through a questionnaire. A total of 77 university students who had participated in a digital escape room were surveyed. The results of the questionnaire were analyzed statistically in order to draw conclusions about the effectiveness of digital escape rooms in promoting university students' engagement and learning outcomes. The majority of the respondents (97.1%) had not participated in a digital escape room before. On a scale of 1 to 5, the mean score for the engagement level of the digital escape room experience was 4.2, indicating that the majority of university students found the experience to be highly engaging. The standard deviation was 0.89, suggesting that the level of engagement varied somewhat among university students.

The results of this survey are summarized in Table 5.

Table 5. Results of the Escape Room Survey.

Question	Results	Statistics
Have you participated in a digital escape room before?	97.1%—yes 2.9%—no	
How engaging was the digital escape room experience?	1—0 2—2.6% 3—23.4% 4—24.7% 5—49.4%	avg. 4.20; stdev 0.89
Did you find an escape room an appropriate form of teaching in this course?	1—0 2—0% 3—11.8% 4—14.7% 5—73.5%	avg. 4.61; stdev 0.69
Did the digital escape room experience improve your understanding of the subject matter?	1—0 2—0% 3—8.8% 4—29.4% 5—61.8%	avg. 4.52; stdev 0.66
What was the difficulty of math puzzles in escape rooms?	1—1.3%/2—92.2%/3—6.5 %	avg. 2.05 ; stdev 0.27
Would you like to have more such escape room-based games in your studies?	1—0 2—0% 3—7.8% 4—18.2% 5—74%	avg. 4.66; stdev 0.62
Did you like the teamwork experience?	1—0 2—0% 3—6.5% 4—14.3% 5—79.2%	avg. 4.72; stdev 0.57

Regarding the effectiveness of the digital escape room experience in promoting student learning, the vast majority of respondents (91.2%) reported that it improved their understanding of the subject matter. No university students indicated that it did not improve their understanding, while 8.8% were unsure.

The feedback from university students about this activity was very positive. Some examples of university students' comments about the digital escape room:

- A great opportunity to have fun with group members and diversify the learning process!
- I really liked the idea of the game and its implementation.
- I really liked the game, there were interesting tasks. The game increased mathematical knowledge and team cooperation.
- A very original idea, unique tasks, non-standard.
- I really liked it, it brightened the mood, I would like more games like this. AWESOME!!!
- Great game, allowed repeating with the integral theme.
- An upbeat game that makes you turn your head in good company.
- I liked; I bonded more with my peers; which I think was the best part of it all!!!
- It was really fun actually; a great way to revise for tests
- I really enjoyed it and am glad I took a part in it

The results of this study suggest that digital escape rooms are highly effective in promoting university students' engagement and learning outcomes in a university math course. The study highlights the potential of digital escape rooms as a pedagogical tool for promoting active learning and enhancing student engagement in STEM education.

7. Discussion

7.1. Experiences of Lecturers Who Have Used Digital Escape Rooms for Math Teaching

Digital Escape Rooms can be defined as a metaphor for breaking down barriers in STEM education by providing an immersive and engaging learning experience that promotes critical thinking, problem-solving, and collaboration skills. The concept of an escape room involves being "locked" in a room or scenario and using clues, puzzles, and problem-solving skills to escape. In the context of education, digital escape rooms use technology to create a virtual environment in which learners can engage in interactive puzzles and challenges related to STEM topics. By using the metaphor of breaking down barriers, digital escape rooms can address the traditional view of STEM education as difficult, boring, and intimidating, promoting inclusivity and engagement among learners from diverse backgrounds. The goal is to create a more impactful and effective learning environment that prepares university students for the challenges and opportunities of the 21st century.

Lecturers who have used digital escape rooms have reported positive experiences with this instructional approach. One of the key benefits of using digital escape rooms for math teaching is that it can make the subject more fun and engaging for university students, particularly for those who may struggle with traditional teaching methods. Lecturers have reported that digital escape rooms can be highly motivating for university students. When university students are immersed in a challenging and engaging task, they are more likely to stay focused and on-task and are less likely to become distracted or disengaged. The collaborative nature of digital escape rooms encourages university students to work together, which helps to develop their problem-solving and communication skills. Digital escape rooms allow lecturers to create a game-like experience in which university students are challenged to solve puzzles and tasks related to mathematical concepts. This approach helps to make learning more interactive and hands-on, which can help university students to retain information better. Lecturers have reported that their university students are highly motivated to complete the puzzles and tasks in the digital escape room, as they are incentivized to "escape" or "win" the game [64]. Moreover, digital escape rooms can provide an opportunity for university students to practice their problem-solving skills and critical thinking abilities in a low-stakes environment. As university students work through the puzzles and tasks, they are required to think creatively and logically in order to find solutions to the problems presented. This can help them to develop skills that are transferable to other areas of their academic and personal lives.

7.2. Evaluation of Skills Acquired by the Learners

Out-of-the-Box Learning is designed to foster a wide range of skills and attitudes that are essential for success in the 21st century. These skills and attitudes include:

1. Critical thinking: Out-of-the-Box Learning challenges learners to think critically and to develop problem-solving skills. By placing learners in unfamiliar situations and environments, it encourages them to think creatively and to find innovative solutions to complex problems.
2. Creativity: Out-of-the-Box Learning fosters creativity by providing learners with opportunities to explore new ideas and to think outside the box. It encourages learners to take risks and to embrace challenges, which can help them to develop a sense of curiosity and a passion for lifelong learning.
3. Collaboration: Out-of-the-Box Learning promotes collaboration by encouraging learners to work effectively in teams, communicate their ideas clearly, and take responsibility for their own learning. It emphasizes the importance of social interactions and collaborative learning, as learners work together to solve problems and share their knowledge and skills.
4. Communication: Out-of-the-Box Learning helps learners to develop effective communication skills by providing opportunities to practice communicating their ideas clearly and persuasively. It encourages learners to listen actively and to provide constructive feedback to their peers.
5. Self-directed learning: Out-of-the-Box Learning encourages learners to take responsibility for their own learning by providing opportunities for self-directed learning. It emphasizes the importance of hands-on, immersive learning experiences in which learners learn by doing and reflecting on their experiences.
6. Growth mindset: Out-of-the-Box Learning promotes a growth mindset by encouraging learners to embrace challenges and to take risks. It fosters a sense of curiosity and a passion for lifelong learning, and encourages learners to take responsibility for their own learning.

These skills and attitudes are closely related to the learning objectives of out-of-the-box learning, which include promoting active and immersive learning experiences, fostering a deeper and more meaningful understanding of the subject matter, and breaking down barriers in STEM education. By developing these skills and attitudes, learners are better equipped to succeed in the 21st century and to contribute to addressing global challenges such as climate change, health, and sustainability.

7.3. Educational Relevance and Usefulness of Digital Escape Room Design Patterns

Digital escape room design patterns have significant educational relevance and usefulness for teaching STEM subjects. These patterns can be used to design escape rooms that engage and motivate students in a variety of STEM-related topics and concepts. One of the primary benefits of digital escape room design patterns is that they promote critical thinking and problem-solving skills, both of which are essential in STEM subjects. Escape rooms require students to use these skills to solve complex puzzles and challenges, providing a hands-on learning experience that can enhance their understanding of STEM concepts. Moreover, digital escape rooms can be designed to be both engaging and challenging, providing students with a fun and interactive way to learn STEM concepts. By presenting students with complex puzzles that require them to use their knowledge of STEM concepts, digital escape rooms can help students develop a deeper understanding of these subjects. Digital escape room design patterns can also enhance collaboration and communication skills. By requiring students to work together to solve puzzles and escape the room, they promote teamwork and communication, both of which are essential skills in STEM fields. Digital escape room design patterns can be customized to meet the needs of individual students and to address specific STEM-related topics and concepts. This can be particularly useful in STEM education, where students may have different interests and abilities.

7.4. Impact of Digital Escape Rooms on Student Engagement and Learning Outcomes

Digital escape rooms have a significant impact on student engagement and positive learning outcomes. These innovative teaching tools have been found to be highly effective in promoting student engagement and motivation [65], leading to better learning outcomes across a variety of subject areas. One of the primary benefits of digital escape rooms is their ability to promote active learning and student engagement. Unlike traditional classroom settings, digital escape rooms require students to actively participate in their learning, using critical thinking and problem-solving skills to solve complex puzzles and challenges. This hands-on approach to learning has been found to be highly effective in engaging students and promoting positive learning outcomes. Digital escape rooms can be designed to be highly immersive and entertaining, creating an enjoyable learning experience for students. By presenting students with puzzles and challenges that are both engaging and challenging, digital escape rooms can capture their attention and motivate them to learn. Additionally, digital escape rooms have been found to be effective in promoting teamwork and collaboration among students. By requiring students to work together in order to solve puzzles and escape the room, digital escape rooms promote communication and collaboration, which are essential skills in today's society. Digital escape rooms also can improve student performance and academic achievement. Studies have found that students who participate in digital escape rooms have higher levels of academic achievement, improved problem-solving skills, and greater confidence in their abilities.

7.5. Benefits and Challenges Associated with the Use of Digital Escape Rooms in Math Teaching

The use of digital escape rooms in math teaching can offer a unique and engaging learning experience that promotes critical thinking and problem-solving skills. However, challenges related to technical issues, accessibility, design and implementation, assessment, and cost should also be considered. There are several benefits and challenges associated with the use of digital escape rooms in math teaching.

The benefits are as follows:

- Engaging and motivating: Digital escape rooms offer an immersive and interactive learning experience, which can engage and motivate students to learn math concepts and problem-solving skills.
- Promoting critical thinking and problem-solving: Digital escape rooms are designed to challenge students to solve complex puzzles and problems, promoting critical thinking and problem-solving skills.
- Individualized learning: Digital escape rooms can be designed to cater to different learning styles and abilities, allowing for individualized learning experiences.
- Collaborative learning: Digital escape rooms can also promote collaboration and teamwork, as students may need to work together to solve puzzles and escape the room [66].
- Flexibility: Digital escape rooms can be accessed from anywhere with an internet connection, allowing for flexible learning opportunities.

The challenges are as follows:

- Technical issues: Digital escape rooms may require a stable internet connection and up-to-date technology, which can be a challenge for some students and schools.
- Design and implementation: Designing and implementing digital escape rooms can be a time-consuming process requiring specialized knowledge and skills.
- Accessibility: Some students may face accessibility issues, such as visual or hearing impairments, which can make it challenging to participate in digital escape rooms.
- Assessment: Assessing student learning outcomes in digital escape rooms can be a challenge, as traditional assessment methods may not be applicable.

7.6. Evaluation Based on Conditions for Excellence

The Conditions of Excellence in American Higher Education [67] outline a set of principles for high-quality education. Evaluating the educational potential of digital escape rooms using these principles, we can see the following:

- Clear Goals: Escape rooms can have clear educational goals, such as promoting critical thinking, problem-solving skills, and collaboration among students.
- Adequate Preparation: Proper preparation is necessary for the design and implementation of an educational escape room. This includes ensuring that the puzzles and challenges are well-designed and aligned with the educational goals.
- Appropriate Assessment: Assessing the learning outcomes of an escape room can be challenging, but can be accomplished through methods such as formative assessments, student feedback, and self-reflection.
- Comprehensive Learning: Educational escape rooms can provide a comprehensive learning experience that engages students in problem-solving, critical thinking, and collaboration.
- Intellectual Challenge: Escape rooms can provide intellectual challenge by presenting students with complex puzzles and problems that require critical thinking and problem-solving skills to solve.
- Active Involvement: Educational escape rooms require active involvement from students, who must work together to solve puzzles and escape the room.
- Supportive Environment: Creating a supportive environment is critical for the success of an educational escape room. This includes providing students with the resources and support needed to solve puzzles and overcome challenges.

Taken together, digital escape rooms have the potential to meet the conditions of excellence in education by providing a comprehensive, intellectually challenging, and active learning experience that promotes critical thinking, problem-solving, and collaboration. However, proper preparation, appropriate assessment, and a supportive environment are necessary for the successful implementation of educational escape rooms.

7.7. Critical Perspectives on the Use of Digital Escape Rooms in Education

While the use of digital escape rooms in education has been shown to have several benefits, there are also critical perspectives to consider. One concern is that digital escape rooms may be seen as just another form of gamification, where students are rewarded for completing tasks rather than actually learning the material. Some critics argue that this approach may create a superficial understanding of the subject matter and undermine the development of deeper learning and critical thinking skills. Additionally, some argue that digital escape rooms may not be accessible to all students, particularly those who may have difficulty with technology or those who have learning disabilities. For example, some students with dyslexia or other learning difficulties may struggle to read and understand the clues presented in a digital escape room, which could further exacerbate their difficulties with math and other subjects. Another concern is that the use of digital escape rooms may reinforce the traditional "sage on the stage" approach to teaching, where the teacher provides the answers and students are expected to memorize and reproduce them. This may limit the development of independent thinking and creativity among students. Lastly, some critics argue that the use of digital escape rooms in education may distract from more fundamental issues, such as the need for more student-centered and inquiry-based learning approaches. While digital escape rooms can provide an engaging and fun way for students to learn math and other subjects, it is important to consider critical perspectives and potential limitations in their use. As with any educational tool, digital escape rooms should be used in a thoughtful and intentional manner, taking into account the needs and abilities of all students.

7.8. Recommendations for the Design and Implementation of Digital Escape Rooms in Math Teaching

Based on the findings of this study, we provide the following recommendations for designing and implementing digital escape rooms in math teaching:

- Clearly define the learning objectives: Before designing a digital escape room, it is important to have a clear understanding of the learning objectives that you want to achieve. These objectives should guide the design of the puzzles and challenges in the escape room.
- Use a variety of puzzle types: Digital escape rooms should incorporate a variety of puzzle types in order to keep students engaged and to cater to different learning styles. Some examples include logic puzzles, math problems, code-breaking puzzles, and visual puzzles.
- Scaffold the difficulty level: The puzzles and challenges in the escape room should be scaffolded so that students gradually increase in difficulty. This helps students build confidence and ensures that they do not get frustrated and give up.
- Incorporate feedback mechanisms: Digital escape rooms should incorporate feedback mechanisms that provide students with immediate feedback on their progress. This can include hints or clues that guide students towards the correct solution, or feedback on their progress towards the final objective.
- Consider accessibility: When designing digital escape rooms, it is important to consider the needs of all students, including those with disabilities. This may include providing alternative formats for puzzles or challenges, such as audio or tactile formats.
- Allow for collaboration: Digital escape rooms can be designed to encourage collaboration among students. This can include puzzles or challenges that require students to work together, or by providing opportunities for students to share their progress and ideas with one another.
- Evaluate the effectiveness of the escape room: Once the digital escape room has been implemented, it is important to evaluate its effectiveness in achieving the learning objectives. This can include collecting feedback from students and assessing their performance on related assessments. This feedback can be used to improve future iterations of the escape room.

7.9. Answers to Research Questions

7.9.1. How Can Digital Escape Rooms Be Designed and Implemented to Maximize Their Effectiveness in Promoting Student Engagement and Learning Outcomes in Mathematics Education?

In order to maximize the effectiveness of digital escape rooms in promoting student engagement and learning outcomes in mathematics education, several design and implementation strategies can be employed. First, digital escape rooms should be designed to align with the learning objectives and outcomes of the mathematics curriculum. This can involve developing puzzles and challenges that are relevant to the specific mathematical concepts and skills being taught. The puzzles should be appropriately challenging but not overwhelming for learners, and they should be designed to promote critical thinking and problem-solving skills. Second, digital escape rooms should incorporate feedback mechanisms that provide students with immediate feedback on their progress. This can include hints or clues that guide students towards the correct solution, or feedback on their progress towards the final objective. This feedback can help students stay motivated and engaged throughout the learning process, and can also help them identify areas where they need to improve. Third, digital escape rooms should be designed to encourage collaboration among students. This can include puzzles or challenges that require students to work together, or by providing opportunities for students to share their progress and ideas with one another. Collaboration can help students develop teamwork and communication skills, and can also promote a sense of community and engagement in the learning process. Fourth, digital escape rooms should be designed to be accessible to all students, including those with disabilities. This may involve providing alternative formats for puzzles or challenges, such as audio or tactile formats. Accessibility can help ensure that all students have an equal opportunity to engage with the learning material and achieve the learning outcomes. Finally, digital escape rooms should be evaluated in order to assess their effectiveness in promoting student engagement and learning outcomes in mathematics education. This can involve collecting data on student performance, engagement, and satisfaction, and using this data to refine and improve the design and implementation of the escape rooms. Evaluation can help ensure that digital escape rooms are meeting the needs of students and promoting effective learning outcomes.

7.9.2. What Are the Potential Benefits and Challenges of Using Digital Escape Rooms in STEAM Education, and How Can They Be Addressed?

Digital escape rooms have the potential to offer several benefits in STEAM education, including promoting student engagement, critical thinking, problem-solving, and collaboration. However, there are also several challenges associated with the use of digital escape rooms in STEAM education that need to be addressed. One potential benefit of using digital escape rooms in STEAM education is that they can provide an immersive and interactive learning experience that engages and motivates students to learn. By presenting students with puzzles and challenges that are both engaging and challenging, digital escape rooms can capture their attention and motivate them to learn. Additionally, digital escape rooms can promote critical thinking and problem-solving skills, which are essential skills in STEAM fields. Another potential benefit of using digital escape rooms in STEAM education is that they can promote collaboration and teamwork among students. By requiring students to work together to solve puzzles and escape the room, digital escape rooms promote communication and collaboration, which are essential skills in STEAM fields. However, there are also several challenges associated with the use of digital escape rooms in STEAM education. One challenge is related to technical issues, such as the need for reliable internet connectivity and access to appropriate hardware and software. Another challenge is related to accessibility, as digital escape rooms may not be accessible to all students, particularly those with disabilities. Design and implementation challenges also need to be addressed. Digital escape rooms need to be designed to align with the learning objectives and outcomes of the STEAM curriculum. The puzzles should be appropriately challenging but not overwhelming for learners, and they should be designed to promote critical thinking and problem-solving skills. Additionally, digital escape rooms should incorporate feedback mechanisms that provide students with immediate feedback on their progress. Finally, cost is another challenge associated with the use of digital escape rooms in STEAM education. Developing and implementing digital escape rooms can be expensive, and schools and educators may not have the resources to invest in this technology. In order to address these challenges, educators can work to ensure that digital escape rooms are accessible to all students and that they are designed to align with the learning objectives and outcomes of the STEAM curriculum. Additionally, educators can explore low-cost options for developing and implementing digital escape rooms, such as using open-source software or collaborating with other educators to share resources and expertise.

7.9.3. How Can the Out-of-the-Box Learning Approach Be Applied to the Design of Digital Escape Rooms for Mathematics Education?

The Out-of-the-Box Learning approach can be applied to the design of digital escape rooms for mathematics education in several ways. First, digital escape rooms can be designed to promote active exploration and discovery, which are key components of the Out-of-the-Box Learning approach. This can involve developing puzzles and challenges that require students to actively engage with mathematical concepts and apply their knowledge to solve problems. By promoting active learning, digital escape rooms can help students develop a deeper understanding of mathematical concepts and skills. Second, digital escape rooms can be designed to foster collaboration and teamwork among students, which is another key component of the Out-of-the-Box Learning approach. This can involve developing puzzles and challenges that require students to work together to solve problems and escape the room. By promoting collaboration, digital escape rooms can help students develop communication and teamwork skills, which are essential skills in mathematics and other STEAM fields. Third, digital escape rooms can be designed to encourage creativity and innovation, which is another key component of the Out-of-the-Box Learning approach. This can involve developing puzzles and challenges that require students to think creatively and develop unique solutions to problems. By promoting creativity, digital escape rooms can help students develop problem-solving skills and a passion for lifelong learning. Fourth, digital escape rooms can be designed to provide opportunities for formative assessment, which is another key component of the Out-of-the-Box Learning approach. This can involve incorporating feedback mechanisms, such as hints or clues, to help students progress through the escape room experience. By providing feedback, digital escape rooms can help students identify areas where they need to improve and develop a growth mindset. Finally, digital escape rooms can be evaluated to assess their effectiveness in promoting Out-of-the-Box Learning in mathematics education. This can involve collecting data on student performance, engagement, and satisfaction, and using this data to refine and improve the design and implementation of the escape rooms. Evaluation can help ensure that digital escape rooms are meeting the needs of students and promoting effective learning outcomes.

7.9.4. How Can Digital Escape Rooms Be Used to Foster Teamwork, Critical Thinking, Creativity, and Self-Directed Learning in Mathematics Education?

Digital escape rooms can be used to foster teamwork, critical thinking, creativity, and self-directed learning in mathematics education in several ways. First, digital escape rooms can be designed to require teamwork and collaboration among students. By working together to solve puzzles and escape the room, students can develop communication and collaboration skills, which are essential skills in mathematics and other STEAM fields. Additionally, teamwork can help students learn from one another and develop a sense of community and engagement in the learning process. Second, digital escape rooms can be designed to promote critical thinking and problem-solving skills. By presenting students with challenging puzzles and problems, digital escape rooms can encourage students to think creatively and develop unique solutions to problems. This can help students develop critical thinking skills that are essential for success in mathematics and other STEAM fields. Third, digital escape rooms can be designed to encourage creativity and innovation. By providing students with opportunities to explore different approaches to solving problems, digital escape rooms can help students develop their creativity and innovation skills. This can help students develop a passion for lifelong learning and a desire to explore new ideas and concepts. Finally, digital escape rooms can be designed to promote self-directed learning. By providing students with opportunities to explore and discover new concepts and ideas, digital escape rooms can help students develop a sense of ownership and responsibility for their own learning. This can help students develop self-directed learning skills that are essential for success in mathematics and other STEAM fields. Overall, digital escape rooms can be a powerful tool for promoting teamwork, critical thinking, creativity, and self-directed learning in mathematics education. By designing and implementing digital escape rooms that align with the learning objectives and outcomes of the mathematics curriculum, educators can help students develop the skills and knowledge they need to succeed in mathematics and other STEAM fields.

7.9.5. What Is the Effectiveness of Digital Escape Room Design Patterns in Promoting Student Engagement and Learning Outcomes in STEM Education, and How Can These Patterns Be Designed and Implemented to Maximize Their Effectiveness?

This study aimed to investigate the effectiveness of digital escape room design patterns in promoting student engagement and learning outcomes in STEM education, specifically in mathematics. The study found that digital escape rooms designed using the six escape room design patterns (Search and Discovery, Lock and Key, Observation and Deduction, Sequence and Order, Communication and Collaboration, and Red Herring) were effective in promoting critical thinking, problem-solving, collaboration, and communication skills among students. The study also found that digital escape rooms were engaging and challenging, providing students with a fun and interactive way to learn STEM concepts. To maximize the effectiveness of digital escape room design patterns, the study recommends incorporating feedback mechanisms that provide immediate feedback on student progress, considering the accessibility needs of all students, and allowing for collaboration among students. The study also recommends using an iterative design methodology that involves testing and refining the puzzles and challenges based on feedback from participants. Overall, the findings of this study suggest that digital escape room design patterns can be an effective tool for promoting student engagement and learning outcomes in STEM education, and can be designed and implemented in a way that maximizes their effectiveness. These findings can inform educators and policymakers on the potential benefits and challenges of using digital escape rooms in STEAM education, and provide a model for future research on the use of digital escape rooms in other subject areas and educational contexts.

7.10. Suggestions for Future Research

Some suggestions for future research on digital escape rooms as a means of Out-of-the-Box Learning could include investigating the effectiveness of different types of puzzles and challenges in promoting critical thinking and problem-solving skills, exploring the impact of digital escape rooms on student motivation and engagement, and studying the potential of incorporating digital escape rooms into formal educational settings as a supplementary tool for teaching math and other subjects. Additionally, it may be worthwhile to examine how different cultural and social backgrounds influence the design and implementation of digital escape rooms, as well as to explore the possibilities of using digital escape rooms to promote cross-cultural collaboration and exchange. Further research could also investigate how the use of feedback mechanisms in digital escape rooms affects the learning experience and outcomes.

8. Conclusions

The study aimed to examine the impact of digital escape rooms on student engagement and learning outcomes in mathematics education and to evaluate their effectiveness as a tool for teaching mathematics and promoting active and experiential learning in STEAM education. The findings suggest that digital escape rooms can significantly enhance student engagement and motivation, resulting in better learning outcomes. They provide an alternative assessment method that allows students to demonstrate their understanding of course material in an engaging and interactive way. In addition, digital escape rooms promote critical thinking and problem-solving skills, which can be applied in real-world situations, and improve collaboration skills by requiring students to work together to solve puzzles. Personalized learning is also supported, as the puzzles and challenges can be customized to meet the needs of individual learners. Digital escape rooms are versatile and can be used to teach a wide range of subjects. Therefore, careful planning and development of digital escape rooms can be an effective tool for enhancing student learning outcomes, promoting academic success, and providing a more personalized learning experience.

There are several areas of future work that could be pursued in relation to the use of digital escape rooms in education. One area of potential future work is the development of more sophisticated and personalized puzzles and challenges that can be adapted to the needs of individual learners. This could involve the use of artificial intelligence and machine learning algorithms [68] to develop puzzles that are tailored to each student's abilities and preferences. Another area of future work is the development of more rigorous assessment methods to evaluate the effectiveness of digital escape rooms in promoting student learning outcomes. This could involve the use of standardized assessments or the development of new assessment tools that are specifically designed for digital escape rooms. Future work also could focus on exploring the potential of digital escape rooms for promoting specific learning outcomes, such as critical thinking, problem-solving, or collaboration. This could involve the development of new escape room patterns or the adaptation of existing patterns to target specific learning outcomes. Finally, there is a need for more research on the use of digital escape rooms in diverse educational contexts and with a variety of student populations. This could involve studying the effectiveness of digital escape rooms in different subject areas, at different grade levels, and with students from diverse cultural backgrounds.

Author Contributions: Conceptualization, R.D. and T.S.; methodology, R.D. and T.S.; validation, R.D. and T.S.; formal analysis, R.D. and T.S.; investigation, R.D. and T.S.; writing—original draft preparation, R.D.; writing—review and editing, T.S.; visualization, R.D. and T.S.; supervision, R.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The first author acknowledges support from colleagues in creating a digital escape room: Rasa Šmidtaitė and Daiva Petkevičiūtė-Gerlach. The authors also acknowledge the use of artificial intelligence tools for grammar checking and language improvement.

Conflicts of Interest: The authors declare no conflict of interest.

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