Engineering students' opinion on the use of a Digital Escape Room as a learning strategy for learning Integration and Differentiation

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Abstract— **The teaching and learning of calculus can be challenging; it is often perceived as abstract, difficult and disconnected from practical applications. Gamification can help develop understanding of abstract mathematical concepts through interactive problem-solving, real-world applications, and engaging challenges. The purpose of this exploratory study was to examine the effects of digital escape rooms perceived by 63 engineering students taking the Engineering Mathematics course. Results of the study indicate that the digital escape room was well-received as a novel strategy for revising the fundamental concepts of integration and differentiation. The majority of students perceived it as enjoyable, collaborative, and effective for both reviewing and acquiring new mathematical knowledge. Nonetheless, a minority reported feeling stressed by the time constraints and puzzles, indicating that careful design is necessary to balance challenge and cognitive load. These findings support the continued exploration of escape room–style activities as an engaging supplement to traditional engineering mathematics instruction.**

I. Introduction

In today's rapidly evolving technological landscape the ability to apply mathematical concepts to real-world engineering problems is more crucial than ever. Engaging students effectively requires interactive, adaptive, and creative educational tools. The right tools can transform passive learning into an interactive and engaging experience. Whether through games, simulations, collaborative platforms, or AI-powered assistants, these tools make learning fun, interactive, and effective. Calculus—particularly Integration and Differentiation—serves as the backbone of engineering disciplines, enabling students to model physical systems, optimize designs, and analyze complex data. Despite its importance, many students struggle with the mathematical foundation of Calculus concepts, often perceiving them as abstract, difficult, and disconnected from practical applications[1]. A major challenge for many engineering students at the start of their academic journey is mastering mathematics. Struggles with mathematical concepts are often believed to contribute to early-stage dropout rates, highlighting the subject's critical role in student retention and success [2].

The integration of gamification in education has gained significant attention in recent years as an innovative approach to enhancing student engagement and motivation, academic achievement and social connectivity [3]. Gamification involves the use of game elements—such as levels, points, badges, leaderboards and avatars [4] to stimulate learners and create an immersive and friendly competitive learning experience [5].

In engineering mathematics education, where students often struggle with abstract and complex concepts [5], gamification has been recognized as an effective strategy to foster active learning and improve knowledge retention [6] One such gamified approach is the design of digital escape room (DER).

The remainder of this paper is structured as follows: Section II reviews relevant literature on gamification and educational escape rooms. Section III outlines the methodology used to conduct the study, including participant selection, data collection, and analysis techniques. Section IV presents the results of the study, while Section V discusses the key findings, implications, and limitations. Finally, Section VI concludes the paper with recommendations for future research and practical applications of digital escape rooms in engineering education

II. LITERATURE REVIEW

A. Tools, Methodologies and Approaches

Interactive Learning Platforms, Collaborative Learning Tools, Gamified Learning, STEM & Coding Platforms are some of the tools used to engage the students. Similarly, some of the education methodologies such as Problem-Based Learning, (PBL), Flipped Classroom, Gamification, Experiential Learning, Collaborative Learning, blended learning and play an important role in enhancing understanding of the subjects through engaging the students. By integrating active participation, real-world connections, technology, and collaboration, we can ignite curiosity, enhance retention, and foster lifelong learning.

B. The Escape Room as an educational tool

Digital escape rooms (DERs) are defined as engaging, game-based learning experiences that take inspiration from traditional recreational escape rooms but are designed for academic purposes. These activities require participants to tackle a series of interconnected puzzles, challenges, or riddles, all embedded within a structured narrative that aligns with educational content [7]. By integrating problem-solving with subject-specific tasks, DERs encourage critical thinking, teamwork, and the practical application of knowledge in an interactive and immersive setting. Moreover, these immersive game-based learning environments combine collaborative

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problem-solving with time-sensitive challenges to encourage deeper engagement with learning material.

In recent years, escape rooms have been adapted for educational purposes, particularly in STEM fields, to promote teamwork, critical thinking, and subject mastery [8] Engineering mathematics, which requires logical reasoning and structured problem-solving, is well-suited for such an approach. Previous studies have demonstrated that educational escape rooms can enhance motivation, engagement, and learning efficacy, particularly when designed to align closely with course objectives [9].

B. Challenges in Learning Integration and Differentiation

Integration and differentiation are fundamental concepts in engineering mathematics, serving as the basis for understanding calculus, control systems, and engineering analysis. However, students often find these topics challenging due to their abstract nature and procedural complexity. Traditional lecture-based teaching methods may not always be effective in fostering deep conceptual understanding, leading to disengagement and surface learning. Given these challenges, alternative instructional methods—such as digital escape rooms—may offer an engaging and effective means of reinforcing these mathematical concepts through interactive problem-solving.

III. METHODOLOGY

This study explores the effectiveness of a digital escape room as a learning strategy for integration and differentiation among undergraduate engineering students. Specifically, the study aims to: (i) Evaluate students' perceptions of the digital escape room in terms of engagement, motivation, and learning effectiveness; (ii) Assess the extent to which the escape room format enhances understanding and retention of integration and differentiation concepts and (iii) Identify potential challenges and areas for improvement in implementing digital escape rooms in engineering education.

The research is guided by the following key questions:

1. How do engineering students perceive the use of a digital escape room for learning integration and differentiation?
2. Does the digital escape room contribute to an improved understanding of these mathematical concepts?
3. What challenges do students face when participating in a digital escape room activity for engineering mathematics?

This research study is situated in an engineering support programme at the National University of Malaysia. The participants were engineering students enrolled for a second year, semester course in Differential Equation. Ethics approval was obtained for this study, and all participants willingly gave consent to participate in this research study.

The course activities and data collection reported on in this study were carried out over 4 weeks. Week 1-3 was dedicated to lectures and tutorials. In Week 4, student focused on completing their revision on reviewing the topics learned on Integration and Differentiation. Students took 30 minutes to complete the escape room activity developed on Genially by the instructor. Students took another 10 minutes to answer the post-activity survey.

This study contributes to the growing body of research on gamification in engineering education by evaluating the impact of digital escape rooms on student learning in a mathematical context. By understanding students' experiences and perceptions, educators can refine gamified learning strategies to optimize engagement and effectiveness. The findings have implications for curriculum design, particularly in incorporating game-based learning to complement traditional teaching methods. Moreover, insights from this study can inform best practices for integrating escape rooms into engineering mathematics courses, ultimately enhancing students' problem-solving abilities and conceptual understanding.

IV. RESULTS

A total of 63 participants, (n =39 females and n=24 males) completed the survey on their perception of using a digital escape room as a learning strategy for integration and differentiation in their Differential Equation Engineering Mathematics course. The reliability was acceptable for the scale (Cronbach's alpha = 0.59). The data were found to be not normally distributed on the Shapiro-Wilks test.

TABLE I. ESCAPE ROOM PERCEPTION SURVEY

Item	**Likert Scale**					
	Mean (SD)	***Strongly Disagree (n, %)***	***Disagree (n, %)***	***Neutral (n, %)***	***Agree (n, %)***	***Strongly Agree (n, %)***
1. The escape room encouraged me to think about the material in a new way	***4.62 (0.607)***	***0***	***0***	***4(6.3%)***	***16 (25.4%)***	***43 (68.3%)***
2. I would recommend this activity to other students	***4.76(.530)***	***0***	***0***	***3 (4.8)***	***9 (14.3)***	***51 (81.0)***
3. I learned from my peers during the escape room	***4.68(.563)***	***0***	***0***	***3 (4.8)***	***14(22.2)***	***46(73.0)***

The escape room was an effective way to review the topic of integration and differentiation						
The escape room was an effective way to learn new information related to integration and differentiation	***4.70 (.528)***	***0***	***0***	***2(3.2)***	***15(23.8)***	***46(73.0)***
I learn better in a game format than in a didactic lecture	***4.37 (.829)***	***1(1.6)***	***0***	***8(12.7)***	***20(31.7)***	***34 (54.0)***
The escape room was an effective way to assist my learning of integration and differentiation	***4.52 (.692)***	***0***	***1 (1.6)***	***4(6.3)***	***19 (30.2)***	***39 (61.9)***
I feel I was able to engage with my teammates to learn new material	***4.65 (.544)***	***0***	***0***	***2 (3.2)***	***18 (28.6)***	***43 (68.3)***
It was difficult for me to focus on learning because I was feeling stressed or overwhelmed	***3.14 (1.564)***	***12(19)***	***15(23.8)***	***9(14.3)***	***6(9.5)***	***21(33.3)***
The non-educational portions (e.g. cyphers, puzzles, etc.) distracted me from learning about differentiation and integration	***2.75 (1.492)***	***21(33.3)***	***6(9.5)***	***14(22.2)***	***12(19.0)***	***10(15.9)***
I prefer assembling information from a variety of sources when learning new material	***4.37 (.747)***	***0***	***0***	***10(15.9)***	***20(31.7)***	***33(52.4)***
In general, I enjoy playing games (video games, board games, social media games, etc.)	***4.62 (.750)***	***1(1.6)***	***0***	***4(6.3)***	***12(19.0)***	***46 (73.0)***

a. Items 9 and 10 were negatively worded and have been reversed-scored during analysis.

Figure 1. The results from the escape room perception survey

General Perceptions of the Digital Escape Room

Majority of students (68.3% strongly agree; 25.4% agree) believed that the escape room facilitated new perspectives on the course material (M = 4.62, SD = 0.61). No respondents disagreed or strongly disagreed with this statement. Most students (81.0% strongly agree; 14.3% agree) indicated they would recommend this activity to peers (M = 4.76, SD = 0.53), highlighting its potential as a scalable supplementary teaching tool. The digital escape room environment was perceived to foster collaborative learning. Nearly three-quarters (73.0% strongly agree; 22.2% agree) reported learning from their peers (M = 4.68, SD = 0.56).

Effectiveness for Learning Engineering Mathematics

Students strongly endorsed the escape room as an effective method to review previously learned topics in integration and differentiation (71.4% strongly agree; 25.4% agree, M = 4.68, SD = 0.53). Likewise, the activity was credited with helping students acquire new knowledge in these areas (73.0% strongly agree; 23.8% agree, M = 4.70, SD = 0.53). These findings align with previous gamification studies, which suggest that active problem-solving fosters deeper comprehension of STEM content. A notable proportion of students (54.0% strongly agree; 31.7% agree) expressed a preference for learning in a game format rather than through traditional didactic lectures (M = 4.37, SD = 0.83). This highlights the potential of game-based interventions to complement or enhance conventional pedagogies in engineering education. More than 90% of the participants (61.9% strongly agree; 30.2% agree) felt that the digital escape room directly supported their mastery of integration and differentiation (M = 4.52, SD = 0.69).

Engagement and Team Dynamics

Nearly all students reported effective engagement with teammates. Specifically, 68.3% strongly agreed and 28.6% agreed that they were able to collaborate productively (M = 4.65, SD = 0.54). This positive finding underscores the importance of well-designed group challenges in fostering interpersonal skills alongside disciplinary knowledge. Students exhibited a predisposition for game-based learning: 73.0% strongly agreed that they enjoy playing games in general (M = 4.62, SD = 0.75). This enthusiasm likely contributed to their favorable attitudes toward the escape room format.

Challenges and Potential Distractions

Despite the predominantly positive response, a subset of students indicated potential drawbacks to the digital escape room approach. Some participants (33.3% strongly agreed) found the immersive and timed nature of the game to be somewhat stressful (M = 3.14, SD = 1.56). While moderate time pressure can enhance motivation, excessive anxiety may impede learning. The puzzles and cyphers—integral to the escape room atmosphere—were perceived as distracting by 15.9% of students (M = 2.75, SD = 1.49). In contrast, 33.3% strongly disagreed that these elements diverted attention from the core content, suggesting individual differences in how students respond to integrated puzzles. Over half of the respondents (52.4% strongly agree; 31.7% agree) noted that they generally prefer to learn by combining information from various sources (M = 4.37, SD = 0.75). While this does not detract from the escape room's usefulness, it underscores the importance of blending digital game-based activities with other resources (e.g., textbooks, online tutorials) for a more comprehensive learning experience.

V. Discussion

Effectiveness of the Digital Escape Room for Learning Mathematics

The results indicate that the digital escape room was perceived as an effective learning strategy for both reviewing and acquiring new knowledge in integration and differentiation. The overwhelmingly positive responses suggest that game-based learning, particularly in the form of escape rooms, can enhance students' engagement with mathematical content. These findings align with existing research that emphasizes the benefits of active learning strategies, particularly in STEM education, where interactive and problem-solving approaches can improve conceptual understanding (insert citation). Compared to traditional lecture-based instruction, students reported a preference for the escape room format, with over 85% indicating that it provided a more engaging way to learn mathematical concepts. This is consistent with previous studies on gamified learning, which highlight how game elements such as challenges, rewards, and collaboration can foster deeper learning experiences (insert citation). The collaborative nature of the escape room also provided opportunities for peer learning, further reinforcing its effectiveness as an instructional tool.

Enhancing Engagement and Peer Collaboration

A key benefit of the digital escape room was its ability to promote teamwork and collaboration. Engineering students often engage in problem-solving and project-based learning in professional settings, making collaborative learning essential for skill development (insert citation). The findings suggest that the escape room format effectively facilitated peer interaction, with 73% of students strongly agreeing that they learned from their teammates. This supports the idea that cooperative learning can enhance students' cognitive engagement and motivation (insert citation).

Additionally, students reported high levels of engagement, with most participants agreeing that the escape room was an enjoyable experience. This enthusiasm aligns with studies in game-based learning that suggest enjoyment plays a crucial role in sustaining motivation and improving knowledge retention (insert citation). Given that a significant proportion

of students already enjoy playing games outside of educational settings, incorporating game-based strategies into engineering education may help bridge the gap between traditional instruction and students' preferred learning modalities.

Challenges and Considerations for Improvement

Despite the overall positive reception, some students expressed concerns about stress and distractions associated with the escape room. Approximately one-third of participants found the non-educational elements (e.g., cyphers and puzzles) to be somewhat distracting. While gamification aims to enhance engagement, it is important to ensure that game mechanics do not overshadow the educational objectives. Future iterations of the escape room could incorporate more explicit connections between the puzzles and mathematical concepts, reducing the risk of cognitive overload.

Another notable challenge was the stress experienced by some students due to time constraints. Time pressure is often an integral aspect of escape rooms, as it creates a sense of urgency and competition. However, excessive stress can be counterproductive to learning, particularly in complex subjects such as mathematics [10]. In future implementations, adjustable time limits or scaffolded hints could be introduced to accommodate different learning paces, ensuring that all students can engage with the material effectively.

This study has several limitations that should be addressed in future research. First, the sample size was limited to 63 engineering students from a single institution, which may affect the generalizability of the findings. Future studies should include a larger and more diverse sample across different educational institutions to examine the broader applicability of digital escape rooms in engineering education. Second, the study relied on self-reported survey data, which may be subject to bias. While the results provide valuable insights into students' perceptions, further research using objective measures (e.g., performance assessments, retention tests) could help evaluate the actual impact of escape rooms on mathematical learning outcomes. Additionally, qualitative studies incorporating student interviews could provide deeper insights into how different learners interact with the escape room experience. Lastly, future research could explore the long-term effects of digital escape rooms on student motivation and learning retention. Investigating whether repeated exposure to gamified learning activities leads to sustained improvements in problem-solving skills and knowledge retention would provide valuable guidance for curriculum designers.

The findings suggest that digital escape rooms offer a promising approach to enhancing engagement and learning in engineering mathematics. Students found the escape room format enjoyable, interactive, and effective in facilitating their understanding of integration and differentiation. However, careful consideration must be given to potential stressors and distractions to optimize the learning experience. By refining the design of educational escape rooms and incorporating adaptive learning strategies, educators can leverage gamification to improve student outcomes in engineering education.

VI. Conclusion

The findings from this study support the integration of digital escape rooms as a pedagogical tool in engineering mathematics courses. Given the positive reception and high levels of engagement reported by students, this approach has the potential to enhance traditional teaching methods. Furthermore, the collaborative nature of escape rooms aligns well with the team-based problem-solving skills required in engineering practice. When designing digital escape rooms for mathematics instruction, educators should ensure that the puzzles are closely aligned with learning objectives to maintain focus and minimize unnecessary distractions. Additionally, incorporating optional scaffolding or hints can support students with varying levels of prior knowledge, ensuring that all learners can actively participate and progress through the challenges at their own pace. To balance engagement and reduce anxiety, flexible time constraints should be considered, allowing students to focus on problem-solving rather than racing against the clock Furthermore, integrating digital tools such as interactive simulations or virtual manipulatives can enhance the learning experience by providing dynamic, hands-on ways to explore mathematical concepts.

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