Digital Game-Based Learning to Reduce Mathematics Anxiety

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ABSTRACT

Mathematics anxiety is a persistent challenge among engineering students, often hindering motivation, retention, and performance in Calculus, particularly in the topic of differentiation. This study introduces an innovative digital game-based learning (DGBL) approach using Canva to address these issues by fostering engagement and active participation. Unlike traditional lecture-based methods that may contribute to passive learning and heightened anxiety, this interactive platform incorporates clickable elements, drag-and-drop activities, and visual guides that support hands-on practice and deeper conceptual understanding. The games are designed to be flexible for blended, flipped, or independent learning, and can be easily accessed via QR codes or online platforms. Early implementation involving undergraduate students demonstrated positive outcomes, with evidence suggesting that integrating DGBL alleviates mathematics anxiety, improves attitudes toward Calculus, and strengthens mastery of differentiation. This initiative aligns with Malaysia's SDG Goal 4 on Quality Education by promoting inclusive, technology-enhanced learning and supports the National Philosophy of Education's goal of developing confident, intellectually capable individuals. Overall, the project demonstrates that digital game-based learning can transform traditional mathematics instruction into an engaging, student-centered experience that reduces psychological barriers and enhances STEM learning outcomes.

Keywords: mathematics anxiety, interactive learning, digital game-based learning, STEM Innovation

INTRODUCTION

Calculus, particularly topics such as differentiation and integration, is widely perceived as abstract, complex, and intimidating by students. Global studies report that over half of students experience difficulty in grasping Calculus concepts, with a significant proportion facing mathematics anxiety that negatively affects academic performance (Soni & Kumari, 2017; Wang et al., 2022). Mathematics anxiety not only reduces motivation and confidence but also contributes to avoidance behaviors, thereby compounding poor achievement in STEM-related courses.

In Malaysia, research similarly reveals that tertiary students experience moderate to high levels of math anxiety, leading to decreased classroom participation and problem-solving ability (Gopal et al., 2020). To address these challenges, this study integrates a set of Canva-based interactive educational games designed to reduce mathematics anxiety and enhance understanding. Theoretical and empirical studies affirm that digital game-based learning fosters motivation, lowers anxiety, and improves problem-solving through interactive and hands-on practice (Ibrahim & Jaafar, 2023; Zhang et al., 2023). This research explores both cognitive and affective benefits of DGBL for Calculus instruction.

Research Questions

1. Does the integration of Digital Game-Based Learning (DGBL) significantly reduce mathematics anxiety

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among undergraduate engineering students?

2. How does DGBL impact students' conceptual understanding and problem-solving skills in differentiation?

3. What are students' perceptions and attitudes toward the use of Canva-based educational games in their learning process?

Hypotheses

H_0 (Null Hypothesis): There is no significant reduction in mathematics anxiety among students after the implementation of DGBL.

H_1 (Alternative Hypothesis): There is a significant reduction in mathematics anxiety among students after the implementation of DGBL.

Objectives

This project aims to integrate DGBL through Canva as an innovative approach to enhance the teaching and learning of Calculus, specifically in differentiation. It seeks to improve student engagement, strengthen conceptual understanding, and develop problem-solving skills while simultaneously reducing mathematics anxiety. Additionally, the project aligns with the lecturer performance evaluation system (e.g., PROPENS), which emphasizes student-centered, technology-enhanced, and multimedia-based teaching practices.

LITERATURE REVIEW

Theoretical Perspectives. Game-based learning draws upon constructivist learning theory, where knowledge is actively constructed through interaction, problem-solving, and reflection. In mathematics education, constructivism underpins the design of interactive tasks that encourage deeper engagement (Lee et al., 2016). Moreover, cognitive load theory suggests that carefully designed digital interfaces reduce extraneous load and help students focus on essential problem-solving processes.

Practical Evidence. Numerous empirical studies highlight the effectiveness of DGBL in reducing math anxiety and improving learning outcomes. A meta-analysis by Zhang et al. (2023) reported that digital games in STEM education yield substantial learning gains compared to traditional methods. Similarly, Pan et al. (2021) found that 84% of studies involving game-based mathematics learning reported increased motivation and engagement. In Malaysia, Ibrahim and Jaafar (2023) demonstrated that gamification reduced mathematics anxiety among students by providing a non-threatening environment for practice. Together, these studies confirm the promise of DGBL as both a cognitive and affective intervention.

METHODOLOGY

This project introduces an innovation in the form of interactive educational games developed using Canva. It designed to enhance students' understanding of Calculus particularly differentiation skill through a structured and student-centred approach. The development process involved five key phases, each aligned with educational theory and informed by findings from recent research. Controlled lab experiment with undergraduate Calculus students found that game-based learning significantly improved conceptual understanding over quiz-based practice (Lee et al., 2016). These findings strongly support the design rationale of this innovation, particularly its ability to reduce mathematics anxiety and promote active engagement (Nadeem et al., 2023; Wang et al., 2022).

In Phase 1, the core concepts in differentiation were identified based on curriculum standards and known learning difficulties reported by students in both local and international contexts (Soni & Kumari, 2017). These concepts served as the foundation for game content development, ensuring curriculum alignment and topic relevance. Phase 2 focused on designing problem-solving activities within Canva, applying principles from constructivist learning theory to encourage deeper engagement. Previous studies, such as by Gopal et al. (2020), used the Mathematics Motivation and Anxiety Questionnaire (MMAQ) to assess students' anxiety and

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motivation levels in similar settings. This tools which informed the design intent to reduce affective barriers and improve learning experiences.

In Phase 3, the games were enhanced with interactive elements including clickable options, drag-and-drop functionality, and visual guidance. These features increase interactivity and reduce cognitive load by providing scaffolded, hands-on learning. Similar game-based learning environments have been evaluated using tools like the Game-Based Learning Evaluation Tool (GBLET), as referenced in studies by Ibrahim and Jaafar (2023), who reported increased motivation and reduced anxiety when such digital tools were used. Phase 4 involved pilot testing in tutorial and lab sessions. Students participated in pre-test and post-test adapted from validated achievement-based assessments, and feedback was gathered through a simplified version of the Mathematics Attitudes and Perceptions Survey (MAPS). The implementation confirmed the games' potential in improving engagement, problem-solving confidence, and participation.

Finally, in Phase 5, findings were analysed and discussed, culminating in the production of an extended abstract for knowledge dissemination. The analysis showed early indications of positive impact on student motivation, understanding, and reduced anxiety particularly highlighting the usefulness and practicality of this innovation. The Canva-based games are highly practical for classroom and digital learning environments. They can be embedded in blended learning models, shared via LMS platforms or QR codes, and customized for different learning levels. The visual, game-like structure aligns well with the learning preferences of Generation Z, and the format supports inclusive, flexible, and engaging instruction. The design and development of this project are shown in Fig. 1 below.

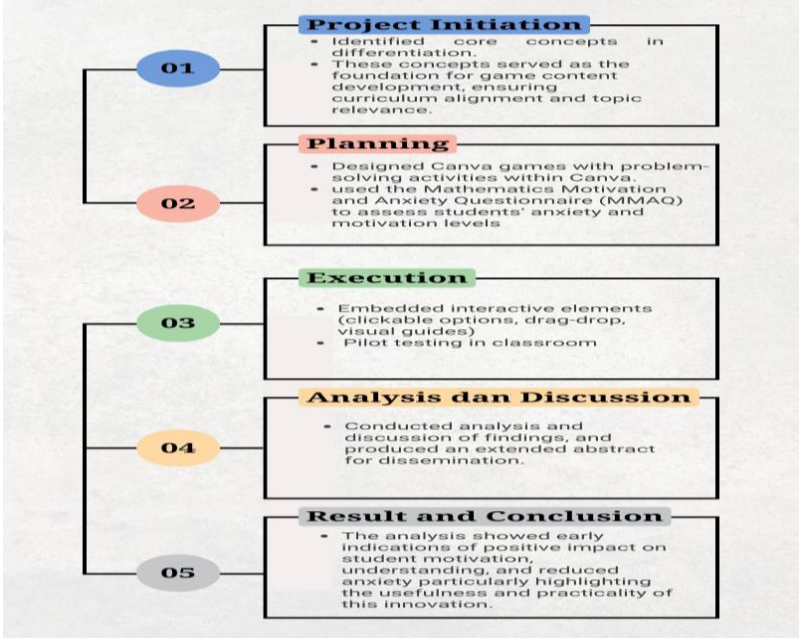

Fig. 1 Flowchart for Calculus Mastery Quest.

Digitalgame-Based Learning (Dgbl)

Digital Game-Based Learning (DGBL) refers to the use of digital games as instructional tools that incorporate educational content with game elements such as problem-solving tasks, interactivity, and immediate feedback. This approach promotes active, student-centred learning and is particularly effective in abstract or complex subjects like mathematics and science. Recent research supports the effectiveness of DGBL in improving both cognitive and affective learning outcomes. A large-scale meta-analysis by Zhang et al. (2023) found that digital games in STEM education produced a medium to large effect size ($g \approx 0.62$) compared to traditional methods, indicating substantial learning gains. Similarly, Anggoro et al. (2025) reported that game-based learning had a positive, statistically significant effect ($g \approx 0.13$) on students' higher-order thinking skills (HOTS), such as critical thinking, reasoning, and problem-solving in mathematics.

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In addition to cognitive benefits, DGBL also helps address affective barriers like mathematics anxiety and disengagement. A systematic review by Pan, Ke, and Xu (2021) revealed that 54% of studies on game-based learning in mathematics measured affective outcomes, and among those, 84% reported improvements in student motivation, engagement, and enjoyment. These findings highlight that DGBL is not only a practical and scalable instructional approach, but also a powerful tool for supporting both conceptual understanding and emotional well-being in learners. Some example of interfaces of DGBL using Canva are shown in Fig. 2-4 below.

Fig. 2 Main interface of the DBGL

Fig. 3 There are three level of the DBGL: beginner, intermediate and mastery

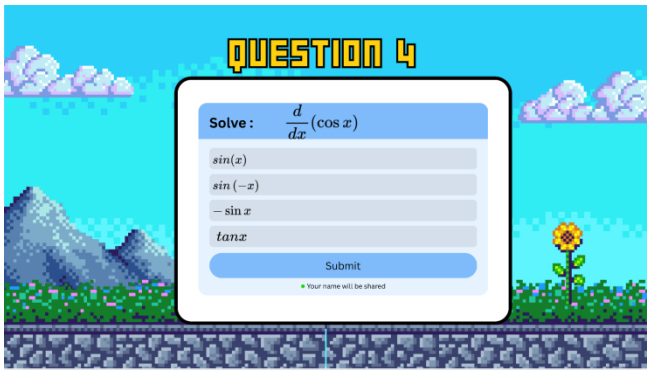

Fig. 4 Examples of question in the DBGL

RESULT

This section presents the results of a statistical analysis conducted to evaluate whether Digital Game-Based Learning (DGBL) which known as Calculus Mastery Quest effectively reduces mathematics anxiety among students enrolled in Calculus courses. Anxiety scores were recorded before and after implementing DGBL using a standardized scale between 0 and 100, with higher scores indicating more anxiety. The sample consisted of 30 undergraduate students in the Faculty of Mechanical Engineering. The instruments used to measure the math anxiety level and math motivation is Mathematics Motivation and Anxiety Questionnaire (MMAQ). Students' anxiety scores were grouped into intervals (class ranges of 10 points), and the frequency

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of students falling within each interval was calculated. The data is divided into two categories: (1) Before DGBL Intervention: Students' math anxiety levels were measured prior to implementing Digital Game-Based Learning activities. Data involving students' anxiety scores shown in Table 1. (2) After DGBL Intervention: The same students' anxiety levels were measured after participating in interactive game-based Calculus learning sessions using Canva. Data involving students' anxiety scores shown in Table 2.

This side-by-side comparison allows us to observe how the distribution of anxiety scores shifted after the intervention.

Table 1: Students' anxiety score before DGBL intervention

Score Range	**Frequency**
40-50	0
51-60	6
61-70	12
71-80	9
81-90	3

Table 2: Students' anxiety score after DGBL intervention

Score Range	**Frequency**
40-50	10
51-60	12
61-70	7
71-80	1
81-90	0

Prior to the DGBL intervention, the majority of students had moderate to high anxiety, mostly in the 61–80 range. After introducing DGBL activities, most scores shifted toward lower ranges (40–60), indicating a reduction in reported anxiety levels. To support the findings, this study applies descriptive statistical analysis. It provides a summary of the data by highlighting measures of central tendency (mean, median, mode) and variability (variance and standard deviation) which shown in Table 3. This analysis helps compare students' anxiety levels before and after the DGBL intervention, identify shifts in patterns, and determine whether the game-based approach produced a meaningful impact on their learning experience.

Table 3: Descriptive statistics before and after DGBL intervention

Statistic	**Before DGBL**	**After DGBL**
Mean	68.12	53.79
Median	67.66	54.35
Mode	50.87	35.40

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Variance	81.00	86.70
Standard Deviation	9.00	9.31

The mean anxiety score dropped by 14.33 points, from 68.12 to 53.79, after the intervention. The median and mode also decreased, supporting the conclusion that most students experienced lower anxiety. Variability remained consistent, indicating a broad but improved impact across students. To statistically verify the effectiveness of DGBL in reducing anxiety, a one-sample t-test was performed. It tested whether the mean post-DGBL anxiety score was significantly lower than the threshold score of 60. This study tests the hypothesis that the mean post-DGBL anxiety score is significantly less than 60, where the null hypothesis (H_0) states that $\mu \geq 60$ (DGBL does not reduce anxiety), and the alternative hypothesis (H_1) states that $\mu < 60$ (DGBL reduces anxiety). After run the test, the result $t = -3.65$ and p-value≈ 0.0005. therefore, reject H_0. It can concluded that there is strong statistical evidence that DGBL significantly reduces mathematics anxiety among students in Calculus courses where.

In conclusion in this research we divide into three aspects which are descriptive statistics, inferential analysis and student feedback. In descriptive statistics aspect, the mean mathematics anxiety score decreased from 68.12 before the intervention to 53.79 after. The median and mode also declined, indicating consistent reductions across the cohort. Then, in inferential analysis, a one-sample t-test was conducted to test whether the mean post-intervention score was significantly below 60. Results confirmed a statistically significant reduction ($p < .01$), leading to the rejection of the null hypothesis. This provides strong evidence that DGBL significantly reduces mathematics anxiety among students. Last, as student feedback, the survey responses indicated that students found the Canva-based games engaging, less intimidating than traditional problem sets, and useful for understanding differentiation concepts. Many reported increased confidence and willingness to attempt more challenging problems.

The findings of this study reinforce the effectiveness of DGBL as both a cognitive and affective intervention. The statistically significant reduction in anxiety levels demonstrates that digital tools can mitigate psychological barriers that hinder learning. This aligns with previous studies (Pan et al., 2021; Zhang et al., 2023), which reported improvements in both motivation and achievement when students engaged in game-based environments.

The reduction in anxiety is particularly important in STEM education, where negative emotions often discourage students from pursuing further studies. By embedding interactivity and visual aids, Canva-based games provided low-pressure practice that improved confidence. This supports Ibrahim and Jaafar's (2023) findings on the role of gamification in reducing anxiety among Malaysian students. Moreover, improvements in problem-solving and conceptual understanding affirm that DGBL is not merely a motivational tool but also an effective pedagogical strategy.

CONCLUSIONS

This study provides strong evidence that Digital Game-Based Learning (DGBL) significantly reduces mathematics anxiety and enhances engagement in Calculus learning. The rejection of the null hypothesis confirms DGBL as an innovative pedagogical approach that supports both cognitive and affective outcomes. By incorporating interactive Canva-based games, students demonstrated improved conceptual understanding, greater confidence, and reduced psychological barriers, aligning with national and global goals for inclusive and student-centered education.

Despite these positive outcomes, several limitations must be acknowledged. The relatively small sample size (n = 30), the single-institution context, and reliance on self-reported measures limit the generalizability of the findings. Furthermore, the study only examined short-term effects, leaving questions about long-term knowledge retention and sustained reductions in mathematics anxiety unanswered. These constraints highlight the need for careful interpretation and future replication in broader settings.

Nevertheless, the findings carry important implications for practice and research. For educators, DGBL offers a scalable, accessible tool to reduce anxiety and strengthen mastery of challenging topics like differentiation. For institutions, its integration can advance goals related to student-centered learning, technology-driven innovation, and alignment with SDG Goal 4 on Quality Education. For future research, larger and more diverse samples, alternative digital learning tools, and longitudinal designs are recommended to deepen understanding of DGBL's impact. Overall, this study demonstrates that while limitations exist, DGBL holds considerable potential to transform mathematics instruction into a more engaging, effective, and inclusive learning experience.

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