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Tangible Calculus: An Exploratory Study of the Effectiveness and Student Acceptance of the AreaGO for Learning Area Under a Curve

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ABSTRACT - Developing conceptual understanding remains a challenge for undergraduate students, particularly repeater in Calculus. One common difficulty is identifying and applying appropriate formulas when solving area under a curve problem. To address this issue, AreaGO, a learning tool with structured guidance, was invented. This study aimed to evaluate the effectiveness of AreaGO and examine students' acceptance of the tool. A quasi-experimental one-group pre-test and post-test design was employed involving 10 repeater students. Students participated in a workshop session where AreaGO was introduced and applied through hands-on activities. Pre-test and post-test scores were used to measure students' performance, while a questionnaire based on the Technology Acceptance Model (TAM) assessed students' perceptions. Due to the small sample size, descriptive statistics and the Wilcoxon Signed-Rank Test were used for data analysis. The results reported a significant improvement in students' performance ($Z = 2.812$, $p = 0.005$), with a large effect size ($r = 0.89$). Furthermore, the questionnaire findings revealed high levels of acceptance across all TAM constructs. Significant positive relationships were also observed among the key TAM constructs, particularly between perceived usefulness, attitude, and behavioral intention. These findings suggest that AreaGO has potential as a learning aid to improve students' understanding and future studies involving larger samples are recommended to validate its effectiveness and acceptance.

INTRODUCTION

In recent years, the education sector has faced significant challenges in the teaching and learning of mathematics. Poor performance in Mathematics, along with negative student perceptions of the subject that has gradually increase, raising concern among various parties such as parents, teachers, universities, and the Ministry of Education. According to Toraman (2025), a total of 127 publications on mathematics and underachievement are present in WoS and SCOPUS, published across 112 different

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journals. Joel (2025) also reported that attitude and teaching method are factors that influence students' performance in Mathematics, specifically on Calculus- related module. At the undergraduate level, Calculus is a fundamental component of many academic programmes; however, students continue to experience difficulties in understanding key concepts, contributing to high failure rates. One topic that poses a particular challenge is the area under a curve, which requires students not only to understand the underlying concepts but also to select appropriate formulas for problem solving.

Students often struggle to choose the correct formula because they rely on memorization rather than visualizing the region involved. This is consistent with Fauzan (2024), who reported that students' difficulty determining the area under the curve due to a tendency to apply procedure without understanding the concept. For the topic of area under the curve, students should know the basic knowledge such as the ability to identify the "upper" and "lower" and "left" and "right" and differentiate between dx and dy. This issue is critical for repeater students, who continue to show poor performance and are incapable of understanding the basic knowledge. Consequently, they experience difficulties when required to determine the correct limits of integration, select the correct formula, and integrate with respect to x or y.

These difficulties may be caused by the inappropriate or less effective teaching approaches. In general, most universities are still conducting a traditional lecture-based method and some are focusing on the usage of e-learning and digital tools. However, such approaches may be less suitable, specifically for repeater students who often have weak foundation in Calculus. This is supported by Purnomo et al. (2022), who stated that students' inability to solve problems linked to weak mathematical literacy and incomplete mathematization process. Therefore, alternative approaches that provide more structured and guided support are needed. One potential approach is the use of manipulatives as learning tools, which can support students in constructing mathematical understanding. Physical manipulatives, in particular, offer a hands-on learning experience that can help reduce misconceptions and enhance conceptual clarity. Loong (2014) highlighted that manipulatives can serve as effective tools in improving students' understanding by making abstract concepts more accessible. In addition, such tools can function as remedial support for students who struggle with specific topics.

Despite the previous studies on students' difficulties and the influence of teaching methods on students' performance, several gaps remain in the literature. Existing studies mainly focus on general students' population, the implementation of digital tools, or procedural difficulties, with limited focus on repeater students who often possess weak foundations. Besides, there is lack of studies examining the use of tangible manipulatives related to integral. Few studies have also evaluated both the effectiveness of a new innovated learning aid and students' acceptance of it using the Technology Acceptance Model (TAM). Therefore, this study aims to evaluate the effectiveness of AreaGO in improving students' performance in solving area under a curve problems. Consequently, four components of the Technology Acceptance Model (TAM), such as perceived usefulness, perceived ease of use, attitude towards using, and behavioral intention, were used to examine students' acceptance of the tool.

LITERATURE REVIEW

Calculus is a fundamental subject in science, technology, and engineering programmes; however, many students continue to experience difficulties in mastering its concepts, particularly in integral-related topics. Research has consistently shown that students tend to focus on procedural steps rather than conceptual understanding (Alam, 2020), while insufficient knowledge of concepts, formulas, and solution processes further contributes to their difficulties in solving integral problems (Domondon et al., 2022). Among these topics, the area under a curve presents a particular challenge because students are required not only to understand the concept but also to select appropriate formulas and solution strategies. Artigue (1991) found that students were often able to perform procedures without explaining the underlying reasoning, whereas Nguyen and Rebello (2011) reported that only a small proportion of students could correctly identify the relevant concepts when solving mathematical problems. These difficulties are more evident among low-performing and repeater students. Fauzan (2024) reported that lower-ability students require more time to solve area-related problems and frequently apply incorrect formulas despite possessing basic procedural knowledge. Collectively, these findings suggest that students' challenges stem primarily from weak conceptual understanding and difficulties in selecting appropriate formulas rather than a complete lack of procedural knowledge.

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To address difficulties in mathematics learning, researchers have explored various instructional approaches, including visual aids, digital technologies, and manipulatives. These learning tools have been shown to enhance engagement and support conceptual understanding by bridging the gap between abstract mathematical ideas and concrete representations (Nabayra & Nabayra, 2021). Among these approaches, physical manipulatives have received considerable attention due to their ability to provide hands-on learning experiences that actively engage students in the construction of mathematical knowledge. Previous studies have demonstrated that manipulatives contribute positively to students' mathematical understanding and academic achievement (Delport, 2021; Lange, 2021). This effectiveness can be explained through the perspective of embodied cognition, which suggests that learning is strengthened when students physically interact with learning materials. Supporting this view, Gilligan-Lee (2023) reported that embodied learning through physical manipulatives enhances conceptual understanding and spatial reasoning. In recent years, tangible user interfaces (TUIs) have further extended the role of physical interaction in learning. Garcia-Suarez (2024) found that students who used tangible interfaces demonstrated higher engagement and improved knowledge retention compared to those receiving traditional instruction, highlighting the potential of tangible learning tools to support the learning of abstract concepts.

Previous studies also emphasise the importance of structured guidance within tangible learning tools. For example, Jenal et al. (2025) reported that Smart RoMat improved students' mathematical performance and helped overcome learning difficulties through guided hands-on activities. Similarly, Musa et al. (2023) found that STEM-based projects such as the "Catapult" and "Recycling Box" activities provided structured support for teaching Statistics and Probability concepts. These findings suggest that tangible learning tools are most effective when they combine physical interaction with clear instructional guidance. In the context of area under a curve problems, a tangible tool that provides structured support may assist students in identifying region boundaries, selecting appropriate variables of integration, and determining suitable formulas. However, despite the growing evidence supporting manipulatives and tangible learning tools, a gap remains regarding tangible tools specifically designed to support formula selection in area under a curve problems among repeater students.

Besides effectiveness, students' acceptance of learning tools is an important factor influencing their successful implementation. The Technology Acceptance Model (TAM) developed by Davis (1989) is widely used to evaluate users' acceptance of educational technologies through four key constructs: perceived usefulness, perceived ease of use, attitude towards use, and behavioural intention. Perceived usefulness refers to the extent to which students believe a tool enhances their learning performance, while perceived ease of use reflects the degree of effort required to use the tool. Previous studies have consistently reported that perceived usefulness and perceived ease of use significantly influence students' attitudes and intentions to adopt educational technologies (Davis et al., 1989; Bhattacherjee, 2001; Teo, 2009). Similarly, Omar et al. (2022) found that perceived usefulness and attitude significantly predicted students' intention to use e-learning tools in mathematics courses. Although TAM has traditionally been applied to digital technologies, recent studies suggest that the model is equally applicable to physical learning tools, as students are more likely to adopt and continue using tools that they perceive as useful, easy to use, and supportive of learning.

The literature indicates that students continue to experience significant difficulties in learning integral concepts, particularly in area under a curve problem where conceptual understanding and formula selection are essential. Previous studies have also demonstrated the effectiveness of manipulatives in supporting mathematical understanding and highlighted the importance of students' acceptance of learning tools through the Technology Acceptance Model. However, most studies have focused on general mathematics learning, digital technologies, or broad applications of manipulatives. Therefore, a gap remains regarding tangible tools specifically designed to support formula selection in area under a curve problem among repeater students.

METHODOLOGY

An innovative learning tool, called AreaGO was developed to guide students in identifying appropriate formulas for area-related problems. To evaluate its effectiveness as a learning aid, a quasi-experimental one-group pre-test and post-test was implemented. Subsequently, a questionnaire based on the Technology Acceptance Model (TAM) was employed to examine student perceptions of the new tool.

https://doi.org/10.37134/jpsmm.vol16.1.10.2026

Because this study focused specifically on students repeating Calculus I, it contained a limited sample size and was positioned as a pilot study. Pilot studies are exploratory in nature, which beneficial to gain preliminary insights and assess feasibility. Consequently, the finding reported are considered preliminary and indicative.

The final sample of this study is 10 out of 21 repeating students. Participants were selected based on purposive sampling technique to specifically targeted the students who would benefit most from additional academic support. According to Kunselman (2024), a relatively small sample size is acceptable for a pilot study, provided it aligns with exploratory purpose of the research.

Research Instruments and Procedure

AreaGO is a dual-component pedagogical innovation designed to address key cognitive challenges in evaluating the area under a curve, particularly in selecting the correct axis of integration and determining function boundaries. The first component, known as the Parallel Finite Line, uses transparent overlays to help students test vertical or horizontal consistency within a bounded region. The second component, the Dynamic Arrow Tool, applies a directional logic in which the arrowhead indicates the upper or right boundary, while the tail represents the lower or left boundary.

Students' achievement was measured using a researcher-developed achievement test consisting of five structured questions with a total score of seven marks. Questions 1 to 3 (one mark each) required students to identify the correct integral formula for calculating the area of a shaded region based on graphical representations, while Questions 4 and 5 (two marks each) required students to determine the upper, lower, left, and right boundaries of the given region. The test was developed based on the key concepts involved in solving area under a curve problem, namely identifying region boundaries, selecting the appropriate variable of integration, and determining suitable integral formulas. These concepts were specifically chosen because previous studies have identified them as common areas of difficulty among Calculus students, particularly low-performing and repeater students. The same test was administered as both a pre-test and post-test, and the scores obtained were used to evaluate changes in students' performance following the implementation of AreaGO.

A structured questionnaire was developed based on the Technology Acceptance Model (TAM), adapted from Davis (1989) and reconstruct based on study by Weng (2018). The instrument comprised four constructs: Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Attitude Toward Use (ATU), and Behavioural Intention to Use (BI). All items were measured using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The items were contextualised to reflect the use of AreaGO in identifying correct formulas for area-related problems. Prior to data collection, the questionnaire underwent content validation by seven experts with relevant expertise in mathematics education and educational technology. The experts evaluated the relevance of each item using a four-point scale ranging from 1 (not relevant) to 4 (highly relevant). The Item Content Validity Index (I-CVI) and Scale Content Validity Index based on the average approach (S-CVI/Ave) were calculated to determine content validity. The I-CVI values ranged from 0.857 to 1.000, exceeding the recommended threshold of 0.78 for panels consisting of six or more experts. In addition, the questionnaire achieved an S-CVI/Ave value of 0.891, indicating good overall content validity. Based on the experts' feedback, minor revisions were made to improve the clarity and suitability of several items before the questionnaire was administered to the participants.

The study was conducted during a workshop session. At the beginning of the session, students completed a pre-test to assess their initial understanding of the area under a curve concept. This was followed by an instructional session in which AreaGO was introduced, and students were guided on its proper use. Students then participated in hands-on learning activities using the AreaGO prototypes to explore and solve area-under-a-curve problems. Upon completion of the activities, a post-test was administered to evaluate any improvement in students' performance. Finally, students completed a Technology Acceptance Model (TAM) questionnaire via Google Forms to provide feedback on their perceptions and experiences of using AreaGO.

https://doi.org/10.37134/jpsmm.vol16.1.10.2026

Data Analysis

As this study is exploratory in nature, the analysis focuses primarily on descriptive statistics, including mean and standard deviation, to summarise students' performance and perceptions. To examine changes in performance, a non-parametric statistical test, the Wilcoxon Signed-Rank Test was conducted. However, consistent with pilot study recommendations, the emphasis is placed on observed trends and improvements rather than solely on statistical significance.

The effect size (r) was calculated based on the Wilcoxon test using the following formula:

$$\text{Effect Size (r)} = \frac{z}{\sqrt{N}} \tag{1}$$

Where z: the z- score from the test

N: the total number of observations

To measure students' perceptions of AreaGO, a questionnaire based on the Technology Acceptance Model (TAM) was administered. The reliability and internal consistency of the instrument were evaluated using Cronbach's alpha, and all analyses were conducted using SPSS. Descriptive statistics, including mean and standard deviation, were computed to examine the four TAM components, namely perceived usefulness (PU), perceived ease of use (PEOU), attitude towards use (AT), and behavioural intention (BI). In addition, Spearman's rank correlation analysis was performed to examine the relationships among the TAM constructs. Spearman's correlation was selected because the study involved a small sample size (n = 10) and the data were collected using Likert-scale items. This analysis provided preliminary evidence regarding the relationships proposed by TAM and students' acceptance of the learning tool.

RESULTS AND DISCUSSION

This section presents the findings regarding the effectiveness and students' acceptance of the newly introduced learning tool, AreaGO. The results were reported, followed by a brief discussion about the impact on the learning process. Data were gathered from 10 repeating students using a pre-test and post-test design and a TAM-based questionnaire. The results are organized into two main sections:

(i) students' performance based on pre-test and post-test scores, and
(ii) students' perceptions of AreaGO.

Students' Performance (Pre-Test and Post-Test)

Descriptive Analysis

The pre-test and post-test scores were collected and analysed using SPSS. The achievement test had a maximum score of 7 marks. As shown in Table 1, the mean pre-test score was 0.80 (SD = 0.63), representing approximately 11.4% of the total score. Following the intervention, the mean post-test score increased to 4.90 (SD = 2.02), equivalent to 70.0% of the total score. This improvement suggests that students demonstrated a better understanding of the concepts assessed in the test, particularly in identifying region boundaries and selecting appropriate integral formulas for area under a curve problems.

Table 1. Descriptive Statistics for Pre-Test and Post-Test Scores

Test	Mean (M)	Standard Deviation (SD)	Maximum Score
Pre-Test	0.80	0.63	7
Post-Test	4.90	2.02	7

https://doi.org/10.37134/jpsmm.vol16.1.10.2026

Wilcoxon Signed-Rank Test

A Wilcoxon Signed-Rank Test was then conducted to support the huge difference in mean. This test was use to assess the existence of significant difference in pre-test and post-test scores. The results are presented in Table 2 and reported a statistically significant different between pre-test and post-test scores ($Z = 2.812$, $p = 0.005$).

The sharp increment in post-test scores shows that AreaGO improves students' understanding for the area-related problems. This finding is relevant for repeating students, who commonly face difficulties in solving the problems.

Table 2. Descriptive Statistics for Pre-Test and Post-Test Scores

Variable	Z Value	p-value
Pre-Test vs Post-Test	2.812	0.005

Finally, the effect size was calculated using the formula and the classification of values are as follow: small (≥ 0.1), medium (≥ 0.3), or large (≥ 0.5). Based on Cohen's guidelines (Cohen, 1988; Fritz et al., 2012), the result showed a large effect size ($r = 0.89$). This finding indicates that AreaGO has provide a substantial impact on students' performance, which also meaningful in guiding the students.

Students' Perceptions of the AreaGO
Reliability Analysis

Prior to evaluating students' perceptions, a reliability analysis was conducted and the Cronbach's alpha coefficients were calculated using SPSS to assess the consistency of the questionnaire. The result of the analysis shown in Table 3.

Table 3. Reliability Analysis

Variable	Items	Cronbach's Alpha
Perceived Ease of Use	4	0.86
Perceived Usefulness	5	0.97
Attitude Toward Using	4	0.92
Behavioral Intention to Use	4	0.89

Based on the table, all components of TAM shown high level of reliability, with Cronbach's alpha values are more than 0.70. Perceived usefulness recorded the highest value of 0.97, followed by attitude toward using, behavioral intention to use and finally perceived ease of use. These values revealed that the questionnaire items are internally consistent and appropriate for this study.

Descriptive Analysis of TAM Variables

The mean and standard deviation for the TAM variables were recorded and shown in Table 4.

Table 4. Mean Score of TAM Variables

Variable	Mean	Standard deviation	Level
Perceived Ease of Use	4.75	0.47	High
Perceived Usefulness	4.88	0.38	High
Attitude Toward Using	4.75	0.41	High
Behavioral Intention to Use	4.68	0.65	High

https://doi.org/10.37134/jpsmm.vol16.1.10.2026

The results indicate that all TAM components recorded high mean scores, suggesting positive students' perceptions towards the use of AreaGO in solving area-related problems. Perceived Usefulness ($M = 4.88$, $SD = 0.38$) obtained the highest mean score. Followed by perceived ease of use and attitude towards using, and finally behavioral intention to use. The highest score indicated that students found AreaGO beneficial in identifying correct formulas. Perceived Ease of Use ($M = 4.75$, $SD = 0.47$) suggests that the tool is easy to understand and students can easily use it for problem solving.

Similarly, Attitude Toward Use ($M = 4.75$, $SD = 0.41$) reflects positive student attitudes towards the tool, while Behavioral Intention to Use ($M = 4.68$, $SD = 0.65$) indicates that students are willing to continue using AreaGO in future learning. These findings are consistent with the Technology Acceptance Model (TAM), which suggests that perceived usefulness and ease of use influence users' attitudes and intention to use a tool.

Spearman's Rank Correlation

The result of Spearman's rank correlation was shown in Table 5.

Table 5. Spearman's Rank Correlation

Relationship	**Spearman's p**	**p-value**
PEOU – PU	0.591	0.071
PEOU – AT	0.572	0.084
PEOU – BI	0.616	0.058
PU – AT	0.645	0.044*
PU – BI	0.643	0.045*
AT – BI	0.995	< 0.001*

*Significant at $p < 0.05$

The findings indicate positive relationships among all TAM constructs. The strongest relationship was observed between attitude towards use (AT) and behavioural intention (BI) ($\rho = 0.995$, $p < 0.001$), suggesting that students who developed a more positive attitude towards AreaGO were also more likely to intend to continue using it. In addition, perceived usefulness (PU) was significantly associated with both attitude ($\rho = 0.645$, $p = 0.044$) and behavioural intention ($\rho = 0.643$, $p = 0.045$). These findings are consistent with TAM theory, which proposes that students are more likely to develop positive attitudes and intentions towards a learning tool when they perceive it as useful.

Although perceived ease of use (PEOU) showed moderate positive correlations with PU, AT, and BI, these relationships did not reach statistical significance at the 0.05 level. However, the correlation coefficients were moderately strong ($\rho = 0.572$–0.616), suggesting a positive trend that may become significant with a larger sample size.

DISCUSSION

Overall, the findings provide preliminary evidence that AreaGO has the potential to support students in solving area under a curve problems. The significant improvement in post-test scores, accompanied by a large effect size, suggests that the tool helped students overcome some of the conceptual difficulties associated with selecting appropriate formulas and identifying region boundaries. This improvement can be explained through Cognitive Load Theory, which proposes that learning is enhanced when instructional materials reduce unnecessary cognitive demands. This statement is consistent with Surbakti (2024) that find instructional design in digital classrooms can enhance learning by minimizing cognitive overload. Prior to the intervention, students were required to simultaneously identify the upper and lower functions, determine the limits of integration, select the appropriate variable of integration, and choose the correct formula. Such requirements may impose a high cognitive load and challenging for repeater students. By providing a structured step-by-step process, AreaGO may have reduced the extraneous cognitive load, allowing students to focus more effectively on understanding the

https://doi.org/10.37134/jpsmm.vol16.1.10.2026

relationships between the graphical representation and the corresponding integral formula. Consequently, students were better able to identify appropriate solution methods and solve area-related problems successfully.
The effectiveness of AreaGO may also be explained by Embodied Cognition Theory, which suggests that learning is strengthened through physical interaction with learning materials. According to this perspective, cognitive processes are closely linked to bodily actions and sensory experiences. As a tangible manipulative, AreaGO enables students to physically interact with representations of mathematical concepts, transforming abstract ideas into concrete experiences. Through hands-on engagement, students can more easily visualise region boundaries, distinguish between upper-lower and left-right functions, and recognise the conditions that determine whether integration should be performed with respect to x or y. This explanation is consistent with findings reported by Sullah et al. (2017) and Justo et al. (2022), which highlighted the effectiveness of physical learning materials in supporting conceptual understanding. Similarly, Gilligan-Lee (2023) found that embodied learning experiences can enhance conceptual understanding and spatial reasoning. Therefore, the physical and interactive nature of AreaGO may have contributed to students' improved performance by facilitating deeper conceptual understanding rather than mere procedural memorisation.

In addition to its effectiveness, students demonstrated positive acceptance of AreaGO. The high mean scores across all TAM components indicate that the tool was perceived as useful, easy to use, and suitable for future learning. These findings are further supported by the correlation analysis, which generally aligns with the theoretical assumptions of the Technology Acceptance Model (TAM). Perceived usefulness was found to have significant positive relationships with both attitude and behavioural intention, suggesting that students who believed AreaGO enhanced their learning were more likely to develop favourable attitudes and intentions towards its continued use. Furthermore, the exceptionally strong relationship between attitude and behavioural intention indicates that students' willingness to use AreaGO is closely associated with their overall perception of the tool. Although perceived ease of use was not significantly related to the other TAM constructs, the moderate positive correlations observed suggest that ease of use may still influence students' acceptance. Nevertheless, the findings should be interpreted with caution due to the small sample size. Future studies involving larger samples and longer implementation periods are recommended to further validate the effectiveness and acceptance of AreaGO.

LIMITATIONS OF THE STUDY

This study has several limitations that should be considered when interpreting the findings. First, the study involved only 10 repeater students from a single institution, which may introduce selection bias as the participants may not be representative of the wider population of undergraduate Calculus students. Since repeater students typically have different learning characteristics and academic backgrounds compared to other students, the findings may not be applicable to all learners. Second, the same achievement test was administered as both the pre-test and post-test. Although the test was intended to measure changes in students' understanding following the intervention, repeated exposure to the same questions may have resulted in a testing effect, whereby students became familiar with the assessment format and content. Third, the study employed a one-group pre-test–post-test design without a control group and the intervention was conducted within a single workshop session. Consequently, improvements in students' performance cannot be attributed solely to the use of AreaGO, as other uncontrolled factors may have influenced the results. Furthermore, the short duration of the intervention does not allow conclusions to be drawn regarding long-term learning outcomes or knowledge retention. Therefore, the findings should be interpreted as preliminary evidence of the effectiveness and acceptance of AreaGO. Future studies involving larger and more diverse samples, control groups, and longer implementation periods are recommended to strengthen the validity, reliability, and generalisability of the findings.

CONCLUSIONS

This study contributes to the field of mathematics education by providing preliminary evidence on the effectiveness of AreaGO, a tangible learning tool designed to support repeater students in solving area under a curve problems. The findings suggest that structured physical guidance can assist students in

https://doi.org/10.37134/jpsmm.vol16.1.10.2026

identifying region boundaries and selecting appropriate formulas, which are common areas of difficulty in integral-related topics. These results support the application of Cognitive Load Theory and Embodied Cognition Theory, indicating that reducing cognitive demands and promoting hands-on interaction may facilitate conceptual understanding among students with weak mathematical foundations. In addition, the study extends the use of the Technology Acceptance Model (TAM) to the evaluation of a tangible learning tool in a Calculus learning context.

From a pedagogical perspective, AreaGO offers an alternative instructional approach for supporting students who struggle with Calculus concepts. The structured and interactive nature of the tool may help reduce students' reliance on memorisation and encourage a more meaningful understanding of problem-solving procedures. Given the positive acceptance demonstrated by the participants, AreaGO has the potential to serve as a supplementary learning aid in remedial programmes and Calculus classrooms.

Nevertheless, the findings should be interpreted with caution due to the small sample size, single-group research design, and short intervention period. Future research should involve larger and more diverse samples, include control groups, and investigate the long-term impact of AreaGO on students' understanding and retention. Further studies may also explore the integration of AreaGO into regular classroom practice and examine its effectiveness in other Calculus topics and educational settings.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest

AUTHORS CONTRIBUTION

Norshakila Abd Rasid.: Conceptualization, Methodology, Investigation, Data curation, **Yasmeen Nadhirah Ahmad Najib.**: Conceptualization, Methodology, Investigation, Data curation, **Mohamad Hidayad Ahmad Kamal.**: Conceptualization, Methodology, Investigation, Data curation, **Nor Alwani Omar.**: Software, Visualization, Validation, Writing – original draft, **Siti Nur Aisyah Azeman.**: Formal analysis, Writing – review & editing, **Nurul Hafizah Zainal Abidin.**: Project administration, Supervision, **Roslah Arsad.**: Project administration, Supervision, **Kamarul Nasser Mokri.**: Software, Visualization, Resources, **Puteri Zirwatul Nadila Megat Zamanhuri.**: Software, Data curation, Resources.

AVAILABILITY OF DATA AND MATERIALS

Data available on request due to privacy/ethical restrictions.

DECLARATION OF GENERATIVE AI

During the preparation of this work, the author(s) used ChatGPT to enhance the clarity of the writing. After using the ChatGPT, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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ETHIC STATEMENTS

This study involved human participants through a questionnaire-based survey. All information obtained from the respondents was kept confidential and used solely for research purposes. Participation in the study was voluntary, and respondents' identities were not disclosed. The questionnaire items were developed based on the Technology Acceptance Model (TAM) and adapted from validated instruments reported in previous studies. Ethical principles for research involving human participants were observed throughout the study. Formal ethical approval was not required for this study as no sensitive personal data were collected and respondent anonymity was maintained throughout the research.

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