e-JURNAL PENYELIDIKAN DAN INOVASI
https://ejpi.kuis.edu.my/index.php/ejpi
e-ISSN 2289-7909
UNIVERSITI ISLAM SELANGOR

VOL. 11 NO. 1 (APRIL 2024): pp 16 -27

Received: February 13, 2024 Accepted: March 9, 2024 Published: April 30, 2024

Empowering Students' Comprehension in Calculus with eCALculator

Memantapkan Pemahaman Pelajar dalam Kalkulus dengan eCALculator

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ABSTRACT

Calculus is a fundamental subject in STEM (Science, Technology, Engineering, and Mathematics) study programs. Despite the introduction of basic calculus concepts as early as secondary school, many undergraduate students still encounter difficulties in comprehending and solving differentiation and integration problems. As calculus is fundamental to fields like science and engineering, possessing a solid mathematical and calculus foundation becomes essential for STEM students. Struggling to grasp these fundamental concepts not only impacts performance in calculus but also poses challenges when tackling advanced related topics. Recognizing this challenge, the eCALculator is introduced as a comprehensive and

accessible solution. This innovative tool takes the form of a step-by-step e-manual, guiding students in determining a function's derivatives and integrals using a calculator. The e-manual can be accessed via a flipbook, encompasses instructional videos and exercises. The eCALculator was tested to 40 engineering students enrolled in Calculus courses at UiTM Cawangan Pulau Pinang. Survey results indicate that the eCALculator not only helps improving students' comprehension and accuracy in calculus problem-solving but also increases motivation and interest in learning, particularly among students who require additional support.

Keywords: Calculus; differentiation; integration; scientific calculator; STEM

ABSTRAK

Kalkulus merupakan subjek asas dalam program pengajian STEM (Sains, Teknologi, Kejuruteraan dan Matematik). Walaupun konsep asas kalkulus telah diajar sejak dari Sekolah Menengah, masih ramai pelajar Sarjana Muda berhadapan kesukaran dalam memahami dan menyelesaikan masalah yang melibatkan pembezaan dan pengamiran. Memandangkan kalkulus adalah asas kepada bidang seperti sains dan kejuruteraan, memiliki asas matematik dan kalkulus yang kukuh menjadi satu keperluan kepada pelajar-pelajar STEM. Kesukaran untuk memahami konsep asas tersebut bukan sahaja memberi kesan kepada prestasi mereka dalam subjek kalkulus tetapi juga memberi cabaran apabila mereka mempelajari topik lanjutan yang berkaitan dengan kalkulus. Menyedari cabaran tersebut, eCALculator diperkenalkan sebagai satu penyelesaian yang komprehensif dan mudah diakses. Alat inovatif ini disediakan dalam bentuk e-manual langkah demi langkah untuk membimbing pelajar menentukan pembezaan dan pengamiran bagi suatu fungsi matematik menggunakan kalkulator. e-manual dalam format interaktif ini dapat diakses melalui 'flipbook' yang mengandungi video pengajaran dan latihan. Produk eCALculator telah diuji pada 40 orang pelajar kejuruteraan yang mendaftar kursus Kalkulus di UiTM Cawangan Pulau Pinang. Analisis soal selidik menunjukkan bahawa produk ini bukan sahaja membantu pelajar meningkatkan pemahaman dan kejituan dalam menyelesaikan masalah berkaitan kalkulus, malah ia turut meningkatkan motivasi dan minat mereka dalam pembelajaran, khususnya dikalangan pelajar yang memerlukan sokongan tambahan.

Kata kunci: Kalkulus; pembezaan; pengamiran; kalkulator saintifik; STEM

INTRODUCTION

Calculus is a fundamental subject in STEM (Science, Technology, Engineering, and Mathematics) study programs. It encompasses two major branches: differentiation, which deals with rates of change and slopes of curves, and integration, which involves the accumulation of quantities and the areas under curves. Serving as the

mathematical 'backbone', calculus provides the means to tackle problems in fields such as science and engineering, facilitating the modeling of physical systems. Establishing a strong understanding of calculus is crucial for advancing in studies and developing the confidence to tackle real-world challenges in science and engineering. In Malaysia, calculus concepts have been introduced since secondary school (Awang & Zakaria, 2013). However, many undergraduate students face difficulties comprehending definitions and various representations of mathematical and calculus principles, especially concerning differentiation and integration. This could led them to experience challenges in solving advanced calculus problems involving derivative and integral topics (Hashemi et al., 2019).

The teaching and learning of calculus should balance emphasizing conceptual understanding while incorporating graphical, numerical, algebraic, and verbal representations (Parrot & Leong, 2014). The integration of hand-held technology into mathematics education has been recognized as a promising approach to reinforce and expand mathematical reasoning and comprehension. This integration provides access to mathematical content and problem-solving scenarios, while also improving computational proficiency (Parrot & Leong, 2018). Utilizing tools like scientific and graphing calculators allows students to investigate and simulate mathematical problems, thus enhancing their proficiency in acquiring a comprehensive understanding of mathematics.

Initially confined to arithmetic calculations, scientific calculators have shown the potential to go beyond basic operations, enhancing the conceptual grasp of complex mathematical concepts and methods. Past research has demonstrated that students across various educational levels, spanning from secondary school to university, have gained advantages from incorporating calculators into solving mathematics and calculus problems (Abdul Rahman et al., 2022; Dagan et al., 2020; Radzuan et al., 2021). Studies by Parrot and Leong (2018) and Septian et al. (2021) agree that incorporating technologies into mathematics learning encourages students to devote more attention to problem-solving, emphasizes reasoning, and improves problem-solving skills.

Acknowledging the potential of scientific calculators, the eCALculator has been developed as a user-friendly e-manual aimed at aiding students in learning calculus, particularly in determining derivatives or integrals of functions. This innovative tool takes the form of an interactive flipbook, encompassing manuals, exercises, and instructional videos to accommodate students with diverse learning preferences. Our goal is that by using this tool, students can elevate their comprehension of calculus and improve their precision in solving calculus problems. This, in turn, equips them to tackle more advanced calculus topics with greater confidence.

LITERATURE REVIEW

As supported by Hohenwarter et al. (2008), integrating technology into daily mathematics lessons can enhance students' competencies on the course. When it comes to the field of mathematics, one of the technological options available is a scientific calculator. A scientific calculator is a technological device which can perform complex and scientific calculations. It is equipped with advanced features which are beyond the basic arithmetic operations typically present in standard calculators. In general, the appropriate use of a scientific calculator can indeed assist students and contribute to a higher motivation in learning mathematics and calculus concepts. Satianov (2015) discussed the utilisation of an advanced scientific calculator in calculus education. The author concluded that a scientific calculator can be effectively used for quick computations and as a valuable tool to improve students' comprehension of the fundamental calculus concepts. Research based on descriptive survey design which was conducted by Ochanda and Indoshi (2011) also supported the theory. According to the authors, a scientific calculator can benefit in mathematics education in terms of providing better understanding of mathematical concepts, improving computational skills and efficiency, displaying accurate answers for confirmation, and encouraging students to explore more on the course.

Zhu et al. (2021) asserted that it is crucial to provide comprehensive guidance on the proper use of technological tools implemented in a course in order to facilitate students' learning through the technologies. Since a scientific calculator is a technological tool, therefore its usage requires a specific instruction manual or module in order to explain how to use it. According to Nardo (2017), modules promote self-directed learning by guiding students to practice and review information on their own. The students may actively immerse themselves in comprehending the concepts presented within the module. With minimal guidance from the teacher, they may advance independently. Once the students become proficient in using a scientific calculator, they can save time when applying mathematical concepts (Darling-Hammond et al., 2020).

The findings of a study conducted by Algani and Eshan (2019) revealed that the teaching methods employed by teachers are one of the factors that significantly influence students' mathematics achievement. Teachers are recommended to utilize multiple teaching methods in order to successfully enhance students' understanding of new mathematical concepts. They need to be flexible and tailor their teaching approach based on the specific situations they come across. Additionally, past research suggested that the teaching quality in mathematics and statistics is related to the students' motivation (Wong & Wong, 2017). These studies indicated that it is possible to improve students' performance in mathematics through innovation in teaching strategies as innovative teaching methods often involve interactive and hands-on experience that capture students' attention and make learning more enjoyable.

The utilization of interactive learning materials, such as e-books or e-manuals, represents an innovative approach in education. E-books are digital resources that go beyond text, incorporating multimedia elements like images, learning videos, animations, and even manipulative media like Augmented Reality (AR) (Indrawan et al., 2023). The integration of well-crafted interactive learning materials within e-books, including video and audio components, infographics, and embedded activities, has the potential to significantly enhance student engagement. This approach facilitates a better understanding of new concepts and complex issues (Ren-Kurc et al., 2018). Awaludin et al. (2020) further emphasize the effectiveness of integrating multimedia elements in e-books, particularly for subjects like integral calculus, aiding students in visualizing and comprehending abstract concepts.

In developing interactive learning environments for mathematics, Fitriani et al. (2021) have designed an e-book-based blended learning approach that incorporates YouTube for teaching geometry. Their study concluded that the e-book innovation was effective in achieving the desired learning outcomes for students. In different research, Siano and Potane (2022) investigated the efficacy of using e-books as a teaching tool in improving students' academic performance in mathematics. Based on the quantitative and qualitative analyses conducted, the results of the study claimed that the students attained a satisfactory level of performance when they utilised the interactive e-book. Another research using meta-analysis carried out by Wijaya et al. (2022) discovered that the utilisation of mathematics e-books had a substantial positive impact on students' performance. The study also suggested that e-books may enhance the teaching and learning of mathematics more effectively than traditional printed books.

Based on past studies, theoretically, the effectiveness of eCALculator which is the interactive e-manual used in our study may empower students' comprehension in calculus which is one of the branches of mathematics.

METHODOLOGY

The eCALculator is designed to offer a comprehensive and accessible solution for undergraduate students studying calculus, with a particular focus on differentiation and integration topics. The development of this innovative tool follows four main phases: analysis, design, development, and evaluation.

The development of the eCALculator

To ensure accessibility, we have chosen to develop the eCALculator materials in the form of an e-manual. This manual includes step-by-step instructions on using scientific calculator functions to determine derivatives or integrals of functions.

In consideration of diverse learning styles, such as auditory, visual, kinesthetic, and reading or writing preferences, we have integrated instructional videos into the e-manual. These videos offer both visual and auditory cues to aid students in comprehending how to solve calculus problems using a calculator. This dynamic approach enhances students' grasp of concepts and problem-solving techniques.

For seamless incorporation of the instructional videos, the eCALculator has been designed as an interactive flipbook. This arrangement of the e-manual, instructional videos, and exercises is facilitated through a free website application called Heyzine Flipbooks. This choice ensures a user-friendly and engaging platform for students to effortlessly access the e-manual, instructional videos, and exercises. Figure 1 shows the design of the interactive flipbook of the eCALculator.

Figure 1: **The Interactive Flipbook of the eCALculator**

The Evaluation of The Effectiveness of eCALculator

An evaluation is done using constructed questionnaire on the usage of scientific calculator among engineering students in Universiti Teknologi MARA, Cawangan Pulau Pinang during their learning in secondary school years and the applicability of eCALculator manual in helping the students solved simple Calculus questions during their calculus class. Table 1 shows the questions in the questionnaire.

Table 1: The Evaluation

Category	Questions
The usage of scientific calculator	I am proficient in using scientific calculator. I think it is important for students to be proficient in using scientific calculator. I had learned most of the functions in the scientific calculator during school.
The effectiveness of using eCALculator	Previously I knew how to solve differentiation and integration using a scientific calculator. This e-manual helps me in learning Calculus. I was able to complete differentiation and integration much faster after using this manual.

FINDINGS AND DISCUSSIONS

Presented are the results from data collection from a questionnaire among engineering students in Universiti Teknologi MARA, Cawangan Pulau Pinang. A total of 40 students were introduced to eCALculator manual during class and responded to the questionnaire. The results in Table 2 indicate the total number of students who are involved in the study, divided by gender and their engineering studies, with 62.5% female and 37.5% male. Cronbach's alpha for the items was 0.703.

Table 2: Summary of Students' According to Engineering Study

	Mechanical	Civil	Electric	Chemical	Total
Male	2	9	2	2	15
Female	3	11	3	8	25
Total	5	20	5	10	40

The results in Figure 2 indicate that 12.5% of the students admitted they strongly agreed and 82.5% of them agreed that they are proficient in using scientific calculators. However, 5% of the students admitted that they do not know most of the functions. A significant portion of the students believe in the importance of being proficient in using a scientific calculator, with 82.5% strongly agreeing and 17.5% agreeing. A majority of the students, 75%, feel that they have learned most of the functions of the scientific calculator during their secondary school years. But

the concern was with the 25% that disclosed they had not learned most of the functions during school.

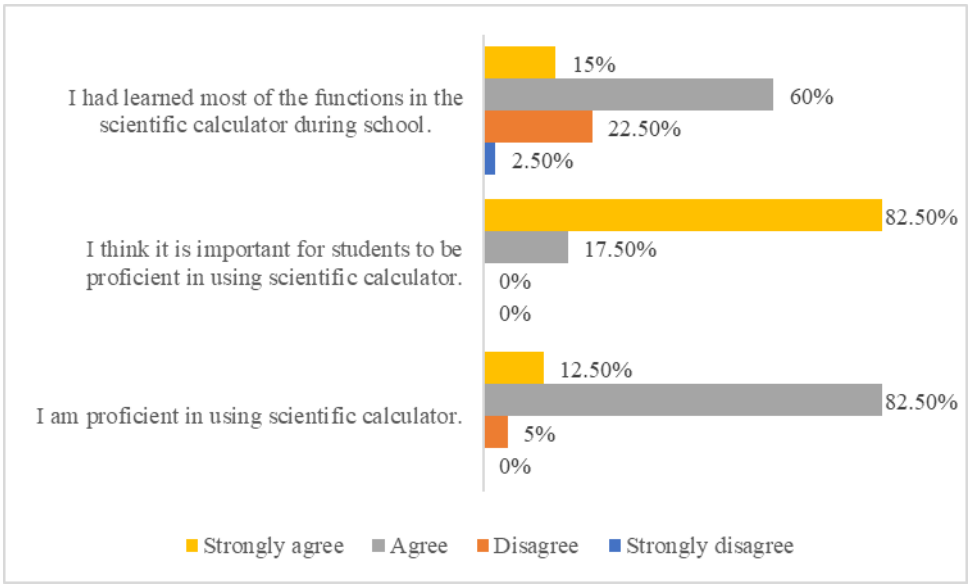

Figure 2: **The Usage of Scientific Calculator**

The results in Figure 3 demonstrate the effectiveness of using eCALculator manual. Initially, a significant number of students (30%) disagreed that they knew how to solve differentiation and integration problems using a scientific calculator before the introduction of the eCALculator manual. However, after using the manual, all the students agreed that it helped them learn calculus, and they were able to complete differentiation and integration much more efficiently with this manual.

Based on the results, it is evident that some students are not proficient in using a scientific calculator during their school learning. This suggests that while they may have some familiarity or basic understanding, the extensive array of functions and buttons on a scientific calculator can be overwhelming for beginners. The multitude of keys and symbols can be confusing, leading to difficulties in navigating the calculator's interface and locating specific functions. Understanding the correct sequence of buttons to press for complex calculations or equations may require practice and familiarity, which can pose a barrier for those who are new to using scientific calculators (Mansor et al., 2022).

Scientific calculators offer numerous benefits, but they can also present challenges to users, particularly those who are unfamiliar with their advanced features (Ochanda & Indoshi, 2011). However, there is room for improvement and further development of users' skills in utilizing the features and functions of a scientific calculator (Kissane, 2020). With practice and continued learning, individuals can

enhance their proficiency, becoming more comfortable and efficient in using a scientific calculator for mathematical calculations.

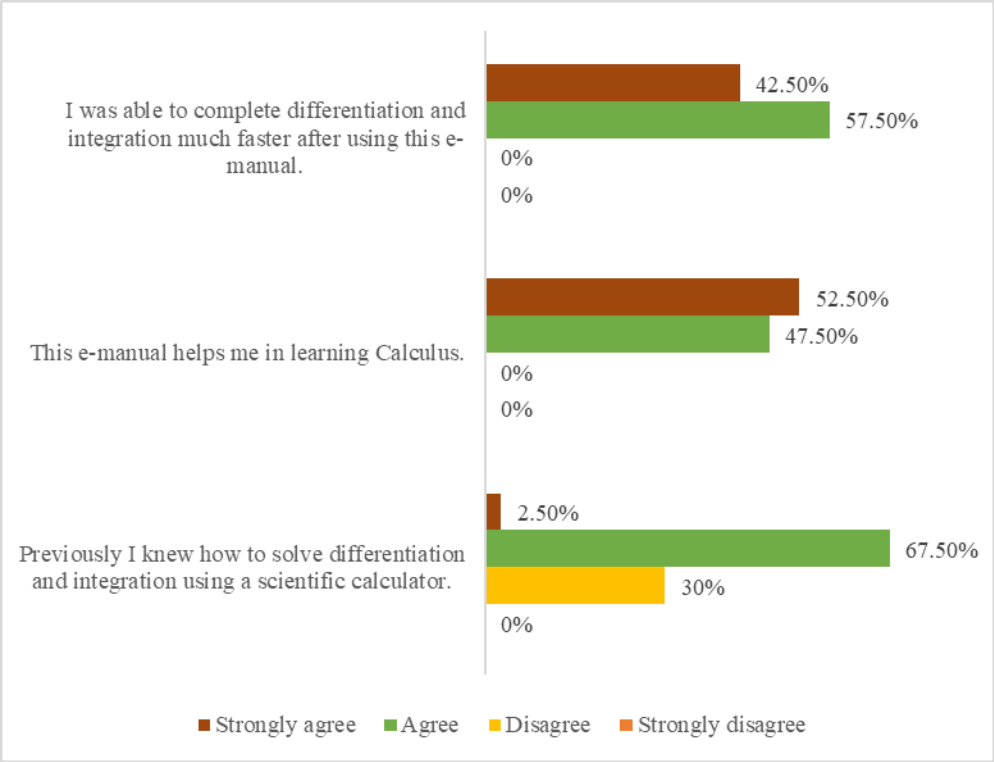

Figure 3: **The Effectiveness of Using eCALculator Flipbook**

Introducing the eCALculator manual, designed to integrate a scientific calculator into the learning of calculus, indeed aided students in solving calculus problems, particularly those related to differentiation and integration of functions. From an educator's perspective, the use of scientific calculators holds significant importance in the field of mathematics education. By harnessing the advanced functions and features of scientific calculators, educators can demonstrate real-world applications of mathematics and engage students in interactive and dynamic lessons (Lee & McDougall, 2010). This hands-on approach enables students to visualize and explore mathematical concepts, leading to a deeper understanding of the subject matter.

Scientific calculators are indispensable tools in the field of mathematics due to their diverse functions and educational benefits. They empower users to handle complex calculations efficiently, allowing for deeper exploration of mathematical concepts (Kissane, 2016). Whether it is in the classroom or during exams, scientific

calculators serve as invaluable aids that enhance mathematical proficiency, accuracy, and problem-solving skills.

CONCLUSION

In conclusion, based on the findings, the eCALculator provides a comprehensive and accessible manual to facilitate students in learning calculus, particularly in determining the derivative or integral of a function using a scientific calculator. The eCALculator is designed as an interactive flipbook, which not only includes step-by-step instructions on how to use functions in a scientific calculator to solve calculus problems but also instructional videos to cater to all students with different learning styles. With this innovation, it is hoped that the eCALculator can help empower students' comprehension in calculus, promote accuracy in calculus problem-solving, and increase students' motivation and interest in learning calculus.

ACKNOWLEDGEMENT

Authors appreciates all those who participated in the study and Universiti Teknologi MARA, Cawangan Pulau Pinang who helped to facilitate the research process.

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