ANALYZING STUDENTS' CONFUSION IN INTEGRATION AND DIFFERENTIATION TECHNIQUES IN CALCULUS

*Siti Asmah Mohamed[1], Nurhafizah Ahmad[2] and Fadzilawani Astifar Alias[3]
*sitiasmah109@uitm.edu.my[1], nurha9129@uitm.edu.my[2], fadzilwani.astifar@uitm.edu.my[3]

[1,2,3]Jabatan Sains Komputer & Matematik (JSKM),
Universiti Teknologi MARA Cawangan Pulau Pinang, Malaysia

*Corresponding author

ABSTRACT

This study investigates engineering students' confusion in mastering integration and differentiation techniques in calculus and its impact on their academic performance. A quantitative approach is employed, analyzing students' final examination responses to identify misconceptions and recurring errors. The study aims to determine the extent of confusion, examine its effect on students' mathematical competency, and propose pedagogical strategies for improvement. The findings highlight key difficulties in selecting appropriate techniques, applying differentiation rules, and handling algebraic manipulations. Addressing these challenges is crucial in enhancing students' comprehension and problem-solving skills in calculus.

Keywords: Calculus, Integration, Differentiation, Student Confusion

Introduction

Calculus serves as a fundamental component in engineering education, essential for mathematical modeling and technical problem-solving. Despite its significance, many students struggle with integration and differentiation due to conceptual misunderstandings, leading to persistent academic challenges. Research suggests that confusion arises from weak foundational knowledge, ineffective pedagogical approaches, and difficulty in contextualizing calculus within real-world engineering applications (Engelbrecht et al., 2020; Clements et al., 2019).

This study aims to explore the sources of confusion in integration and differentiation, assess its impact on academic performance, and propose targeted strategies for pedagogical enhancement. Addressing these issues can refine instructional methodologies, equipping students with stronger analytical skills necessary for success in engineering disciplines.

Research on students' confusion in mastering integration and differentiation techniques in calculus has gained considerable attention in higher education. This literature review aims to critically identify similarities, differences, gaps, and strengths of previous studies and their implications for engineering students. A study by Solfitri et al. (2019) found that students experience significant confusion in understanding and interpreting integration problems, leading to failure in solving calculus problems accurately. The strength of this study lies in its use of Newman's classification, which systematically analyzes student errors. However, it does not thoroughly explore the direct impact of confusion on the long-term academic performance of engineering students.

Similar to Solfitri et al. (2019), Kairuddin (2017) also found that the biggest confusion among students occurs in understanding basic mathematical concepts. This study makes a significant contribution by providing strong empirical evidence on the primary cause of students' confusion. However, it does not directly emphasize the long-term implications for engineering students, which is its major limitation.

On the other hand, Prakitipong and Nakamura (2006) focused more on errors in algebraic processes and the transformation of mathematical information. Their research highlights the importance of mastering algebraic processes, which serve as a crucial foundation in understanding calculus. However, this study does not sufficiently address the affective aspects of students, which also influence the learning process.

Meanwhile, Clements et al. (2019) examined the impact of confusion in learning calculus specifically on engineering students. They concluded that engineering students often struggle to apply calculus concepts in real engineering situations due to fundamental confusion in integration and differentiation techniques. The key strength of this study is its specific focus on the academic and professional implications for engineering students.

Additionally, the study by Engelbrecht et al. (2020) highlighted the advantages of using technology in calculus teaching to address student confusion. However, a significant limitation of this study is the lack of strong empirical evidence on the long-term effectiveness of technology in overcoming confusion in integration and differentiation techniques.

Overall, there are several similarities and differences among previous studies. The main similarity is that student confusion primarily stems from weak fundamental mathematical concepts. However, a key difference lies in the focus of each study some emphasize problem interpretation, while others focus on algebraic processes and technical skills. The most apparent gap is the absence of a comprehensive study that integrates affective factors, pedagogy, and the long-term implications of confusion for engineering students.

Therefore, this study aims to fill this gap by focusing on engineering students' mastery of integration and differentiation techniques and identifying the impact of this confusion on their academic performance and professional competence. his study is designed to achieve three primary objectives. First, it seeks to identify the most common sources of confusion experienced by engineering students in integration and differentiation. Second, it aims to analyze how these difficulties impact students' academic performance and problem-solving abilities. Finally, it proposes pedagogical interventions that can help mitigate these issues and enhance conceptual understanding, ultimately leading to better learning outcomes in calculus.

Methodology

This study employs a quantitative approach to analyze the confusion experienced by first-year engineering students in applying integration and differentiation techniques in calculus. A sample of 40 students from a public university was selected, and data were collected from their final semester examination answers, specifically focusing on questions related to these techniques. The primary objective is to identify the most common errors and misconceptions that hinder students' understanding and application of integration and differentiation in problem-solving.

The data is analyzed through a structured process. Firstly, errors are categorized based on mathematical concepts, including issues related to integration technique selection, algebraic manipulation, and notation inaccuracies. Descriptive statistical analysis is then applied to determine the frequency and severity of each error type. Lastly, a comparative assessment is conducted by relating the findings to existing literature to contextualize students' difficulties and establish a more comprehensive understanding of the problem.

Result and Discussion

The analysis revealed common error patterns among students, as summarized in Table 1. The descriptive statistical analysis of students' errors in calculus revealed that the most common confusion was choosing the appropriate integration technique, affecting 45% of students (18 out of 40). This suggests that students struggle to differentiate between various integration methods, such as substitution, integration by parts, and partial fractions. The second most prevalent issue was a lack of understanding of fundamental differentiation concepts, with 35% (14 students) making errors in applying basic differentiation principles.

Furthermore, 30% (12 students) encountered difficulties in algebraic manipulation during both differentiation and integration processes. This indicates that a weak foundation in algebra contributes to miscalculations and incorrect steps in problem-solving. Additionally, 25% (10 students) struggled with the application of the chain rule, a crucial differentiation technique used in composite functions. Lastly, 20% (8 students) faced errors in mathematical notation, which could lead to misunderstandings and misinterpretation of problems.

Table 1: Percentage of Common Student Confusions in Integration and Differentiation

Type of Confusion	Number of Students	Percentage (%)
Error in Choosing Integration Technique	18	45%
Error in Differentiation	14	35%
Algebraic Errors in Calculus	12	30%
Transformation Function Errors	10	25%
Mathematical Notation Errors	8	20%

These findings align with previous studies that suggest integration is a major challenge among engineering students due to their struggle in selecting appropriate techniques (Solfitri et al., 2019). Similarly, differentiation errors are often linked to a lack of understanding of the chain rule, a crucial concept in advanced calculus (Engelbrecht et al., 2020). The following Table 2 presents examples of errors, their causes, and their impact on learning.

Table 2: Error Categories and Their Impact

Type of Confusion	Example of Error	Cause of Confusion	Impact on Learning
Error in Choosing Integration Technique	Student uses integration by parts for $\int e^{\wedge}x^2/ x\, dx$, while the more appropriate technique is direct integration	Lack of understanding in identifying appropriate function forms	Students need more practice in recognizing the correct integration technique
Error in Differentiation	Student writes d/dx (sin x) = cos x but makes a mistake in differentiating composite functions such as d/dx (sin 2x) = cos 2x instead of the correct answer, 2 cos 2x	Lack of understanding of the chain rule	This error leads to mistakes in solving differential equations
Algebraic Errors in Calculus	Incorrectly expands (x+2)(x-2) as x^2+4	Weak algebraic foundations before proceeding with integration or differentiation	Leads to incorrect final solutions, reducing accuracy
Transformation Function Errors	Student writes ln(1+x/1-x) as (1-x)/(1+x) in differentiation	Confusion in derivative rules and problem-solving methods	Results in significant errors in differentiation and problem-solving
Mathematical Notation Errors	Student writes $\int^3\sqrt{}(x^2+5)^2$ dx but provides the answer as $\int (x^2+5)^{3/2}$ dx	Inaccuracy in writing the final notation	This mistake can affect the entire final solution

The results of this study underscore the need for targeted instructional interventions to address students' confusion in integration and differentiation. One effective strategy is active learning, where problem-based learning and real-world applications are integrated into the curriculum. Clements et al. (2019) emphasize that engaging students in contextualized problem-solving tasks enhances their conceptual understanding. Another crucial approach is technology integration, such as utilizing digital simulations and step-by-step software guidance to reinforce learning through visualization (Engelbrecht et al., 2020). Furthermore, targeted remediation programs should be introduced, focusing on structured algebraic reinforcement and guided differentiation exercises to strengthen students' proficiency in fundamental mathematical concepts (Kairuddin, 2017). By implementing these strategies, educators can significantly improve students' comprehension and reduce persistent errors in calculus.

Conclusion

This study highlights the significant confusion that engineering students face in integration and differentiation techniques, with notable deficiencies in selecting appropriate methods, applying differentiation rules, and performing algebraic manipulations. The findings suggest that these difficulties stem from weak foundational knowledge and insufficient pedagogical reinforcement in core mathematical principles.

To address these issues, educators should focus on strengthening students' conceptual understanding through targeted interventions, including interactive learning, continuous formative assessment, and reinforcement of algebraic skills. By incorporating structured teaching methodologies that emphasize conceptual clarity and problem-solving skills, students' competency in calculus can be significantly improved, ultimately enhancing their ability to apply mathematical techniques in engineering contexts.

Future research should explore the effectiveness of various teaching methodologies in mitigating student confusion in calculus. A longitudinal study tracking students' improvement over time could provide deeper insights into the long-term benefits of specific pedagogical strategies. Additionally, qualitative approaches such as student interviews and focus group discussions could be employed to further understand the cognitive barriers affecting student learning in integration and differentiation.

References:

Clements, D. H., Sarama, J., & Germeroth, C. (2019). *Learning trajectories in mathematics education: Perspectives of psychology, curriculum, instruction, and assessment*. Educational Researcher, 48(2), 95–105.

Engelbrecht, J., Bergsten, C., & Kågesten, O. (2020). *Mathematics education in the digital age: Learning and teaching in a changing world*. Routledge.

Kairuddin, K. (2017). *Students' conceptual understanding of basic mathematics and its impact on calculus performance*. Journal of Mathematics Education, **11**(1), 45–60.

Prakitipong, N., & Nakamura, S. (2006). *Analysis of students' mathematical errors in learning fractions.* International Journal of Mathematics Education, **38**(3), 181–190.

Solfitri, T., Yusuf, M., & Rahayu, S. (2019). *Students' difficulties in solving integral calculus problems: An error analysis using Newman's theory*. Journal of Mathematics and Science Education, **7**(2), 102–115.