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BRIDGING THE GAP: ADDRESSING FOUNDATIONAL MISTAKES IN ENGINEERING CALCULUS EDUCATION

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ABSTRACT

This observational study investigates common errors made by engineering students in a calculus course at Universiti Teknologi MARA, focusing on their performance during a test covering various calculus topics, including L'Hôpital's Rule, improper integrals, total differentials, and first-order differential equations. The analysis reveals that the most frequent errors are related to basic mathematical concepts and careless mistakes, particularly in solving simultaneous equations and rewriting differential equations. The findings suggest that students' difficulties stem from inadequate foundational knowledge and insufficient practice, emphasizing the need for targeted instructional interventions to improve their understanding and application of calculus. This study provides insights that can guide educators in developing more effective teaching strategies to enhance student success in calculus.

Keywords: Calculus, engineering education, student errors, mathematical concepts, instructional strategies

Introduction

Calculus is essential in engineering as it provides the mathematical framework for analyzing and solving complex problems. It allows engineers to model and predict system behaviors, optimize processes, and understand changes in physical quantities. Differential calculus helps in determining rates of change, crucial for motion and force analysis, while integral calculus is used for computing areas, volumes, and total quantities. Mastery of calculus enables engineers to design and analyze structures, circuits, and systems with precision, ensuring functionality and safety. Overall, calculus is foundational in advancing technological innovations and practical applications in various engineering disciplines.

In the field of higher education, the accurate assessment of students' understanding, and application of mathematical principles is crucial for shaping effective teaching strategies and improving learning outcomes. Given the high failure rates in mathematics, it is important to address the errors and misconceptions students make (Voon et al., 2017). These errors can stem from misunderstanding of concepts, theorems or formulas, mistakes in applying basic techniques, incorrect presentation of solutions, or a lack of understanding of a problem’s assumption (Othman et al., 2018). This observational study examines the types of mistakes made by students in Calculus for Engineers course, MAT435. The test, conducted on June 14, 2024, encompassed a range of topics including L'Hôpital's Rule, improper integrals, total differentials, chain rule, implicit differentiation, extremum points, and first-order differential equations. By analyzing the errors committed by students, this study aims to

identify common pitfalls and areas that require targeted instructional interventions, thereby contributing to the enhancement of calculus education.

Literature Review

Mathematics, particularly calculus, which was once exclusively taught at the university level, has increasingly become part of the secondary school curriculum. In secondary school, many students study mathematics with the aim of applying it in fields such as science, engineering, and commerce. However, with the rapid development of new technologies and their diverse applications, there has been growing pressure to modify the mathematics curriculum (Tall, 1978). Another concern among secondary teachers is the limited time available to meet syllabus requirements (Simmonds, 1989). When students enroll in university, courses related to calculus expect them to have a solid understanding of basic mathematical concepts. Without strong foundational knowledge from school, it is challenging for students to succeed in engineering courses.

A study of 30 engineering undergraduates found that errors related to basic calculus concepts were prevalent, indicating a moderate level of achievement that needs improvement (Alias et al., 2023). Supporting this, Torbett and Cordella (2017) note that engineering curricula are typically structured around a core mathematics curriculum, from Calculus to Differential Equations. Therefore, it is crucial to understand how engineers apply analytical thinking and mathematical practices in their tasks. Furthermore, a study at the Coimbra Institute of Engineering found a moderate correlation between performance in Introductory Programming and Differential and Integral Calculus among first-semester engineering students (Bigotte et al., 2021). Success in programming is often mirrored by success in mathematics. Additionally, research at Universitas Banten Jaya identified that careless calculations and insufficient practice were major issues among undergraduate students (Sari, 2023). By identifying the types of mistakes students make, preventive actions can be taken to help them pass their examinations (Moradi et al., 2023).

Methods

The sample test was taken from MAT435 class of semester March 2024 – July 2024. A total of 9 answer papers were included in this observational study. This test was taken on 14th June 2024. Students were given 90 minutes to answer the test. In this test, there are 7 questions. Table 1 summarizes the types of questions asked during the test.

Upon reviewing the completed test papers, five common types of mistakes were identified. The first type of mistake involved incorrect concepts or formulas, such as using the wrong formula for solving L'Hôpital's rule or applying the formula for total differentials when solving implicit problems. The second type of mistake was classified as careless errors. These included instances where a student's

solution unexpectedly changed from negative to positive. Errors in solving simultaneous equations or rewriting equations into the standard form of a differential equation were categorized as basic mathematics mistakes. The fourth group of mistakes involved incorrect techniques for either differentiation or integration, despite the provision of relevant formulas during the test. For the analysis, only the first mistake made by students in each question was recorded. The results indicated that most students' errors were conceptual and computational. These mistakes stemmed from an inadequate understanding of fundamental mathematical concepts and insufficient quality of education in secondary school.

Table 1: Types of Questions Asked in the Test

Number	**Question**
Question 1(a)	**L'Hôpital's Rule**
	Use L'Hopital's Rule to evaluate $\lim_{x\to 0}\frac{\ln\left\|\cos(2x)\right\|}{x}$
Question 1(b)	**Improper Integer**
	Evaluate the improper integral $\int_e^{\infty}\frac{1}{x(\ln x)^3}dx$.
Question 2	**Total Differential**
	Use differential to estimate the change in $f(x,y)=\sqrt{x}\sin(3y)$ from (4,1) to (3.9,1.2). Give your answer in 4 decimal places.
Question 3	**Chain Rule**
	Given $z=3x^2e^{-2y}$, $x=t+1$, $y=\ln t$, find $\frac{dz}{dt}$ by using Chain Rule
Question 4	**Implicits Differentiation**
	Find the equation of the tangent line to the curve $ye^{x^2}+y^2-5x-2=0$ at the point (0, 2) using partial differentiation
Question 5	**Extremum points**
	Locate all relative extrema and saddle point(s) of $f(x,y)=x^2y-x^2-2y^2$
Question 6	**1st Order Differential Equation (1st ODE)**
	Solve the initial value problem for this separable differential equation $\frac{\cos y}{x+1}\frac{dy}{dx}=x$ at point $\left(2,\frac{\pi}{2}\right)$.

Results and discussion

The data were collected from nine undergraduate students enrolled in the MAT435 course, focusing on the types of mistakes they made during the MAT435 test. Out of nine, seven students are males, and the rest are female. Six of them are from the School of Electrical Engineering and the other three are from the School of Mechanical Engineering. The majority of them are taking MAT435 for the second time (Figure 1).

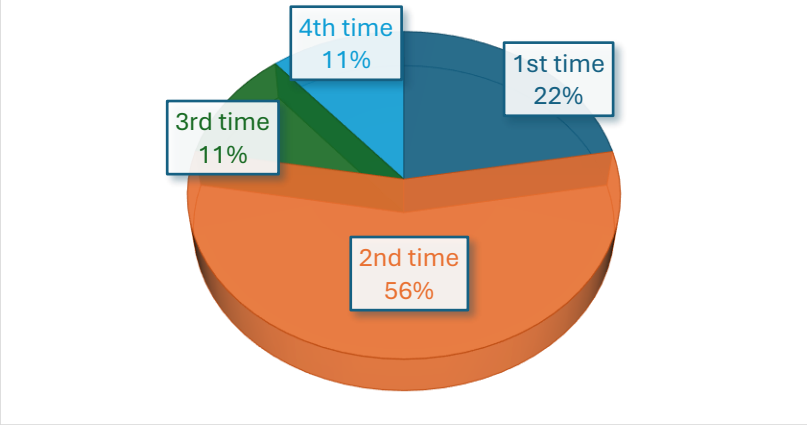

Figure 1: Number of Times Student Taking MAT435

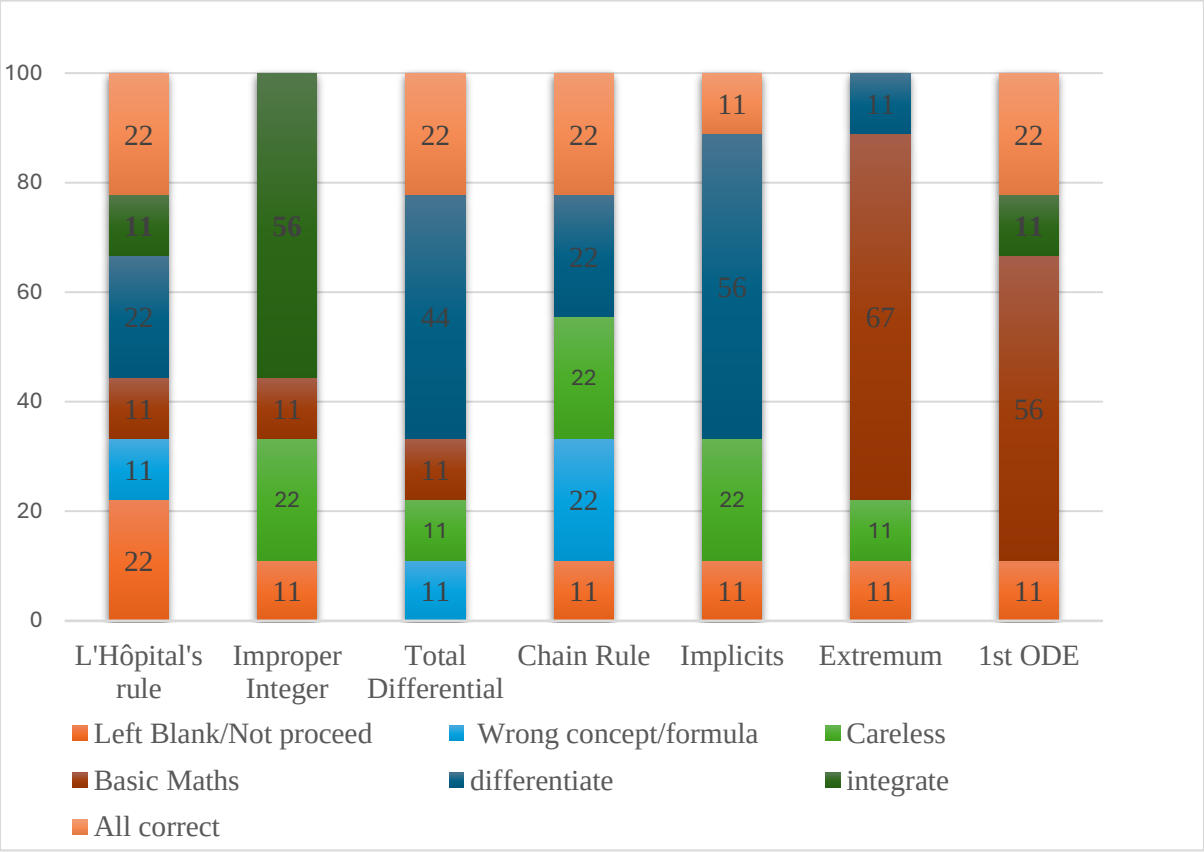

Figure 2: Type of Mistakes Made by Students (%)

The analysis revealed that the highest mistake made by students is basic mathematics. 67% of students have problem solving simultaneous equations in extremum point question while 56% students have problem rewriting the first order differential equation into the standard form of separable differential equation (Figure 2). 55.55% of the students struggled with improper integral problems. In addition, 55.55% of them have problems with differentiation in first-order differential equations, and 44.44% in extremum problems. The results of this study provide valuable insights into the common mistakes made by students during calculus tests and highlight the important basic knowledge that educational should focus on.

Careless and basic mathematics errors were prevalent among students, indicating a need for better foundational understanding and careful attention during tests. This might suggest that students are either rushing through problems or not fully understanding the basic mathematical principles required for solving calculus problems. Such errors could stem from inadequate foundational learning during secondary school years, where impractical teaching methods may have hindered students' understanding of basic mathematics. Previous studies have identified that the exam-oriented approach used by teachers in secondary schools has resulted in a focus on learning concepts, rules, or formulas solely to pass exams (Köğce, 2022; Lasheras et al., 2019).

Differentiation and integration mistakes highlight the areas where students struggle the most. A poor grasp of basic mathematics might contribute to the challenges they face in learning and understanding these two main branches of calculus. Enhanced instructional focus on these topics could help in reducing such errors. On the other hand, conceptual and formula errors indicate gaps in understanding specific calculus concepts and the application of formulas. Targeted tutoring and practice sessions could mitigate these mistakes. Furthermore, Peer Assisted Learning Strategies (PALS) could be implemented to help less skillful students reduce their errors by learning from more competent peers. This approach is one of several strategies summarized in the study by Othman et al. (2018).

Conclusion

The findings of this study reveal that basic mathematical errors and careless mistakes are predominant among students in the MAT435 calculus course. These errors suggest a need for reinforced foundational knowledge and greater attention to detail during problem-solving. Additionally, difficulties with differentiation and integration indicate specific areas where students struggle, highlighting the necessity for improved instructional focus on these topics. Conceptual and formula errors further underscore gaps in understanding that could be addressed through targeted tutoring and practice sessions. Overall, this study provides valuable insights into the common mistakes made during calculus tests, offering

guidance for educators to develop more effective teaching strategies aimed at reducing these errors and enhancing student comprehension in mathematics.

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