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Analysis of Course Learning Outcomes: Student Errors in The Calculus Subject among Engineering Students

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Abstract
Calculus is an important subject in engineering that requires a high level of mastery of basic mathematics. However, since the last phase of the Covid 19 pandemic, most students have not really mastered the basics of mathematics as well. The weakness of students in mastering the theory and basic concepts of mathematics is one of the causes of this problem. This will affect the examination results obtained once they are at the IPTA level. Therefore, this study was conducted to find out whether the evaluation of Course Learning Outcomes (CLO) for the subject of Calculus can be achieved or not. This evaluation is based on students' mistakes in answering the basic mathematic questions related to the topic of differentiation and integration. A total of 30 students in Bachelor's Degree in Engineering were involved in this study. Errors from student answers are seen. This study found that the percentage of students error related to the basics of calculus and the students achievement in the assessment test given are in a moderate level and need to be improved. Therefore, the findings from this study are very useful for lecturers in improving their teaching and learning techniques, especially in the lecture room.
Keywords: Course Learning Outcome, Error, Learning, Basic, Calculus

Introduction
Calculus has been considered one of the supporting components of the intellectual development of students. Sunandar (2008) states that there are several aspects related to learning outcomes in calculus. Aspects of contextual learning strategies, problem-solving approaches, giving regular formative tests, and remedial teaching can improve the learning outcomes of calculus. Research conducted by Wamington (2016) has explained the link between the basic aspects of mathematical competence of students, student attitudes

towards calculus, and the teaching competence of the faculty of calculus and student learning outcomes. From the findings that have been concluded, it appears that ability in basic Mathematics is also one of the factors that determines the achievement of Calculus learning outcomes. Students who have weaknesses in mastering the theory and basic concepts of mathematics towards learning calculus will have a huge influence on the results of learning Calculus. It is showing a positive relationship between basic mathematics learning and calculus learning outcomes.

Nowadays, the understanding of basic mathematical concepts is very much emphasized in the field of engineering. A good level of mathematical mastery is very important to help students improve their achievements in the academic field, especially in the field of engineering. Differentiation and Integration are subtopics contained in calculus learning. It is a topic that requires students' basic skills in solving problems.

Integration is important in human daily life and the concept of integration has been widely used around the world in various fields such as education, engineering, physics and others. However, there are students who lack mastery of these topics. Angco (2011) holds the view that the students had the same level of difficulty dealing with the three topics in Integral Calculus. According to the qualitative data, most of the errors committed were classified as Transformation Errors. Algebraic operations and trigonometric identities should be remembered by students. While teachers should emphasize the correct usage of integration formulas and offer some fundamental algebraic concept reviews.

Based on research findings from Mohd Fauzi et al. (2021) found that among the factors that cause student failure in answering test questions is that students do not understand the requirements of the question and are not able to translate the question in the form of calculations and students who are weak in the basic concepts of mathematics have affected the answers given in the solution of differentiation topics. Taken together, Othman et al. (2018) revealed that students' errors and misunderstandings in differentiation were caused by a lack of fundamental mathematical knowledge. Furthermore, it was discovered that students frequently did not make full use of their previous learning but instead relied on memorizing strategies to study, which contradicts 21st-century learning approaches.

A broadly similar point about differentiation topic has also recently been made by Chikwanha et al. (2022), who view that common errors made by students when applying the power rule, including adding a one to the power part rather than subtracting, bringing down the power and accidentally adding a one to the power, failing to integrate functions, incorrectly separating variables, failing to find the derivative, and applying the incorrect laws to solve differentiation problems. These misunderstandings may have resulted from students' ignorance of differentiation, rules of logarithms, proportionality, integration, and rate of change. Traditionally, it has been argued that student performance on algebra problems is better than student performance on differentiation problems (Mohd Nasir et al., 2013). This study also links misconceptions to simple technical errors made in solving the first derivative. Despite this, little progress has been made in learning on the topic of differentiation and integration. According to Zehra & Abbasi (2019), the sample is divided into two groups: the first group is taught using traditional methods and the second group is taught first with the topic of limit before the derivative chapter, holds tutorial classes, uses mathematics software during lectures, and provides a practice sheet for polishing mathematics skills related to differentiation and integration. The research found that when compared to the second group, which conducts learning in a more interesting and interactive way, the first group's score levels are relatively low. The findings of this study will highlight the students' concerns and provide them with a clear understanding of how to improve their technology-aided learning skills. Based on Kwadzo (2021), descriptive content error analysis found that students made several conceptual, procedural, and technical errors when solving differential calculus exercises. The findings also revealed a difference between student teachers in the experimental group who used Maple software to learn differential calculus and control groups who used traditional methods. As a result, it was suggested that Maple assisted education be used in the teaching and learning of differential calculus.

Students believe that learning calculus fundamentals is challenging. The causes of basic difficulties in calculus, according to a study by Domondon C. S. et al. (2023), are students' lack of understanding of fundamental mathematical ideas, their use of incorrect formulas and confusing problem-solving procedures, and their inability to comprehend mathematical concepts. While the study from Nursyahidah and Albab (2017) found that students have difficulty with critical thinking, which leads to errors in formula selection or the application of incorrect concepts in integration-related problems. They fight to recognize the significance of the information provided in addressing problems and have trouble deciding on the best course of action. A study by Sari (2023) found that the factors that cause students to make mistakes when solving math-related problems are that students do not understand the questions, students do not understand the concept of the materials provided , students are not careful in carrying out the calculation process and lack practice in trying different types of questions. Farhan and Zulkarnain (2019) also suggest that lecturers need to apply some appropriate and diverse techniques to minimize the same mistakes so as not to repeat them, study the concept of derivatives and integrals more deeply, and always provide motivation for student to keep trying and practicing solving different types of higher level calculus questions.

There is evidence that teachers play a pivotal role in regulating misconceptions in solving integral problems. According to the research findings by Juhaevah et al. (2020), S1 (who participate in the PPG; teacher professionalism program) has good skills in identifying misconceptions when using the three-tiered test, treating students who received a different answer, preventing misconceptions from occurring in students by conducting peer instruction in front of the class, and having a solid grasp of the ideas related to means of constant on indefinite integrals. When a student uses a different approach to address a problem, S2 (who do not participate in the PPG; teacher professionalism program) cannot identify the learner's misconceptions and cannot explain the various solutions. As a result, it may be said that teachers with PPG experience are more able to identify and correct the misconceptions that students may have.

Methodology

In this study, data was collected from a sample of 30 students pursuing a bachelor's degree in engineering. The data collection process involved administering a test comprising four fundamental calculus questions, two of which focused on the basic of differentiation and the other two on the basic of integration. Each student was given a time limit of 30 minutes to complete the test. The evaluation of the students' performance was based on the mistakes made in answering the test questions. This approach allowed researchers to assess the students' understanding and application of calculus concepts, with the aim of gaining insights into their proficiency in the subject. By analyzing the mistakes made by the students, the study aimed to identify whether the evaluation of Course Learning Outcomes (CLO) for the subject of Calculus can be achieved or not.

Table 1
Achievement of Course Learning Outcome

Course Learning Outcome		MOHE Learning Outcomes (LO)	Topic of Assessment
CLO1	Describe concepts and theories related to further calculus.	Knowledge	• Basic of Differentiation • Basic of Integration

Table 1 shows the achievement of course learning outcome for the Calculus subject. In this course, the primary learning outcome (CLO1) focuses on the students' ability to describe concepts and theories related to further calculus. This encompasses a comprehensive understanding of both basic of Differentiation and basic of Integration. As part of the Ministry of Higher Education (MOHE) learning outcome in the knowledge domain, students will be assessed on their knowledge and proficiency in these specific topics (Mohayidin et al., 2009). The assessments will gauge their grasp of fundamental principles in Differentiation, such as rates of change, derivatives, and related applications, as well as their comprehension of essential concepts in Integration, including antiderivatives, definite and indefinite integrals, and their practical applications. By achieving this learning outcome, students will demonstrate a strong foundation in advanced calculus concepts, empowering them to solve real-world problems and apply these principles in various Engineering and scientific disciplines (Bigotte, 2021). This acquisition of knowledge and skills will prepare them to excel in their academic pursuits and contribute meaningfully to their chosen fields.

Table 2
Classification of Error

Types of Error	Description
Concept	Do not understand the basic concept. *For example: Failure to find the derivative and integration of function*
Procedure	Improper to conduct the derivative and integration of function. *For example: Failure to perform the exponent and logarithmic rules for derivative and integration process.*
Technique	Insufficient basic knowledge. *For example: Failure to expand the indices function and split off the quotient function.*

Table 2 presented the classification of error involved in this study. In the study of calculus, students may encounter various types of errors that hinder their mastery of the subject. Concept errors arise when students fail to grasp the fundamental principles, leading to difficulties in understanding basic concepts such as finding derivatives and integrals of functions (McDowell, 2021). On the other hand, procedure errors occur when students are aware of the concepts but struggle with the correct execution of the procedures or steps involved in calculus operations. This could include improper application of exponent and logarithmic rules or misunderstanding the differentiation and integration rules for specific functions. Technique errors, the third category, stem from inadequate foundational knowledge and skills in calculus. Students might face challenges in expanding indices functions or correctly applying the quotient rule, resulting in inaccuracies during derivative and integration calculations (Kshetree, 2020). Identifying and addressing these types of errors are crucial for educators to provide targeted support and interventions, helping students overcome their challenges and improve their overall proficiency in calculus. By addressing these errors, students can gain a deeper understanding of calculus concepts and enhance their problem-solving abilities in various scientific and engineering applications.

Result and Discussion

The finding of the data analysis was carried out to identify the achievement of course learning outcome (CLO1) for the Calculus subject. Research data is the result of the assessment test. Based on the results of the tests that have been processed, the details of error in Table 3 are obtained.

Table 3
Details of Error for Basic Differentiation

Question	**Error**		
	Concept	Procedure	Technical
Q1 Find the derivative of the function $y=(1+x^2)^{\frac{2}{3}}$	Error for using the integration method. For example: $y=(1+x^2)^{\frac{2}{3}}$ $y=(1+x^2)^{\frac{2}{3}+1}$	Do not differentiate the function in the bracket. For example : $y=(1+x^2)^{\frac{2}{3}}$ $y=\frac{2}{3}(1+x^2)^{\frac{-1}{3}}$	Error in expand the function. For example: $y=(1+x^2)^{\frac{2}{3}}$ $y=1^{\frac{2}{3}}+x^{\frac{4}{3}}$
Q2 Find the derivative of the function $y=\ln(3x^2)$	Wrong concept. For example : $y=\ln(3x^2)$ ***or*** $\frac{dy}{dx}=\ln(6x)$ $\frac{dy}{dx}=\frac{1}{6x}$	Do not differentiate the function in the bracket. For example : $y=\ln(3x^2)$ $\frac{dy}{dx}=\frac{1}{3x^2}$	Use the product rule: $u\frac{dv}{dx}+v\frac{du}{dx}$ For example : $y=\ln(3x^2)$ $u=\ln \quad v=3x^2$

Table 3 shows the details of the basic differentiation error made by students. There are 3 types of errors that have been stated, for Q1 the first error is the conceptual error where the students is wrong in using the differentiation method. There are students who use the integration method where they add 1 to the indices. For Q2, students also do the wrong concept. Even though they understand the basics of differentiation, when it comes to the logarithmic function, students start to get confused in solving the question. The second error is a procedure error. Students answer the questions incompletely. They do not differentiate the function in the bracket and there are a few students who use the logarithmic rule incorrectly. As for the technical error, the student made a mistake in expanding the function for Q1. Students can differentiate directly without expanding the functions. And for Q2 there are also students who use the product rule formula for logarithmic questions.

Table 4
Details of Error for Basic Integration

Question	Error		
	Concept	Procedure	Technical
Q3 Find the integration of the function $\int \frac{2}{e^{3x}} dx$	Use the quotient rule for differentiation. For example: $\frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$	Do not raise the exponent function up. For example: $\int \frac{2}{e^{3x}} dx = 2\int \frac{1}{e^{3x}} dx$ $= 2\ln(e^{3x}) + C$	If they raise the function exponent up but use the wrong method. For example : $\int \frac{2}{e^{3x}} dx = \int 2e^{-3x} dx$ $= 2e^{-3x+1} + C$
Q4 Find the integration of the function $\int \frac{x}{x+4} dx$	Use the quotient rule for differentiation method. For example: $\frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$	Directly integrate the numerator and denominator separately. For example: $\int \frac{x}{x+4} dx$ $= \frac{\frac{x^2}{2}}{\frac{x^2}{2} + 4x} + C$	Fail to split off the quotient function. For example: $\int \frac{x}{x+4} dx = \int \frac{x}{x} + \frac{x}{4} dx$ $= x + \frac{x^2}{8} + C$

Table 4 shows the details of errors for questions involving the basics of integration. It was found that error involving concepts were students use the quotient rule for differentiation for Q3 and Q4. For the procedure error, some students do not raise the exponent function up. Students are still confused if the question involves a logarithmic or exponent function. At this level, students should know that integration involving exponent or logarithmic function have their own rules. For technical error in Q3, if they raise the exponent function up, students still make a mistake because use the wrong method. They do not understand the integration exponent rule because they add 1 to the indices. For Q3, students failed to split off the quotient function. To solve Q4, students should use the substitution method or can use the long division technique.

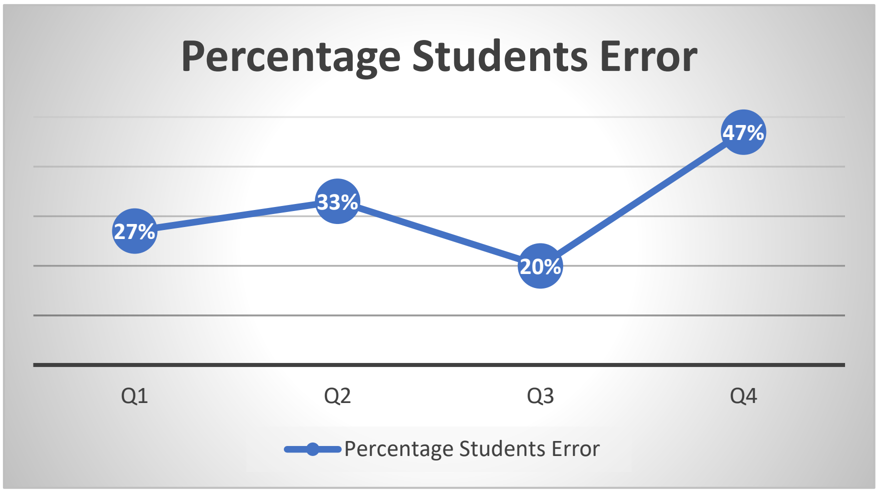

Figure 1. Percentage of Students Error based on Q1, Q2, Q3 and Q4

Figure 1 shows the chart of the percentage of student errors for Q1, Q2, Q3 and Q4 which includes errors involving concept, procedure and technique. It was found that 27% of students made mistakes for Q1, 33% of students made mistakes in Q2, 20% of students made mistakes in Q3 and 47% of students made mistakes in Q4. From this chart it can also be seen that the highest mistakes are in the integration question. This study also supports the study of Md. Isa et al. (2018) found that the level of student achievement on the integration topic's basic questions is low. Students make mistakes in integration on procedure and technical skills, Abdul Wahab et al. (2014). Students fail to select the mathematical process required to obtain the answer.

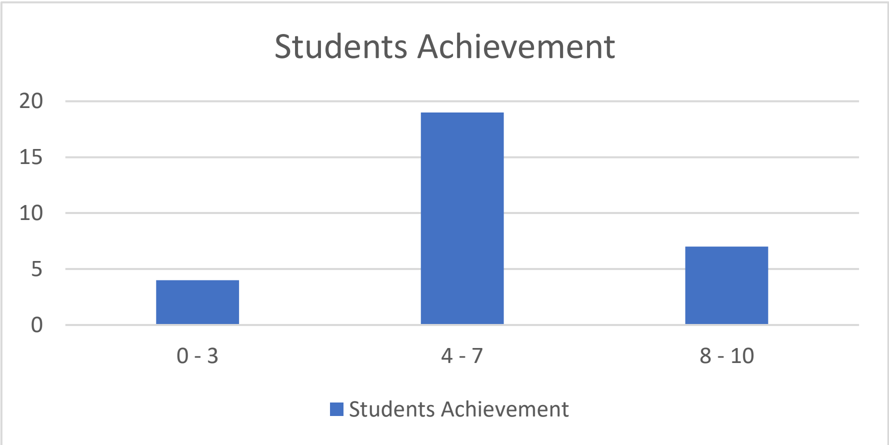

Figure 2. Students Achivement

Figure 2 shows the student's achievement from the test that has been given. It was found that four students got a score of 0 to 3 marks, nineteen students got a score of 4 to 7 marks and seven students got a score of 8 to 10 marks. Therefore, it can be said that the level of achievement of students in basic of differentiation and integration is still at a moderate level. From this chart, it can also be concluded that achievement for course learning outcome is also at a moderate level and needs to be improved. This is because students still do not really understand in describing concepts and theories in basic calculus which is related to further calculus. Students need to be emphasized in the basics of calculus so that they can solve the problems for further calculus easily. This is because students will face more difficulties in solving questions related to differentiation and integration and this affects the solution in other topics related to further calculus , namely integration by part, trigonometric substitution and partial fractions which contribute to high errors in these topics, Voon et al. (2016).

Conclusion

An analysis of student errors in calculus among engineering students partially involves collecting representative coursework, categorizing errors by type, and comparing errors to learning outcomes. Implementation of these strategies, ongoing assessment, and adaptation based on results contribute to refining teaching methods and enhancing students' mastery of calculus for practical engineering applications. Analyzing students' errors in the calculus subject holds significant importance as it provides valuable insights into their learning challenges and misconceptions. By understanding the specific types and frequencies of errors, educators can tailor their teaching strategies to address these issues effectively. This analysis enables instructors to identify common stumbling blocks, refine instructional methods, and design targeted interventions that foster a deeper understanding of calculus concepts. Ultimately, addressing students' errors enhances their grasp of fundamental mathematical principles, supports successful application in engineering contexts, and contributes to improved overall learning outcomes and academic success.

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