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An Analysis of Students' Errors Based on Newman's Error Analysis in Solving Partial Derivative Problems in Calculus

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Abstract

Understanding student errors in calculus is crucial for improving the quality of mathematics learning. This study analyzes students' errors in solving partial derivative problems in a calculus course based on the Newman Error Analysis framework. A quantitative descriptive approach was employed. The participants were 20 students from the Mathematics Education Study Program at Universitas Timor enrolled in a calculus course. Data was collected through written tests and unstructured interviews, and then analyzed using error categorization and percentage distribution. The findings reveal that the most frequent errors occur at the comprehension, transformation, and process skills stages. Comprehension errors are indicated by students' difficulties in interpreting the meaning and structure of mathematical expressions. Transformation errors are characterized by students' inability to convert problems into appropriate mathematical forms or procedures, particularly in selecting suitable strategies. Process skills errors arise when students make computational mistakes despite correctly understanding the problem. In contrast, errors at the reading and encoding stages are relatively infrequent. These results suggest that students' main difficulties lie in the intermediate stages of problem-solving, where conceptual understanding and procedural fluency are required simultaneously. Therefore, calculus instruction should emphasize conceptual strengthening and incorporate non-routine, higher-order thinking skills-based problems to enhance students' problem-solving abilities.

Pemahaman mengenai kesalahan mahasiswa dalam kalkulus penting untuk meningkatkan kualitas pembelajaran matematika. Penelitian ini bertujuan menganalisis kesalahan mahasiswa dalam menyelesaikan soal turunan parsial pada mata kuliah kalkulus berdasarkan kerangka *Newman Error Analysis*. Penelitian ini menggunakan pendekatan kuantitatif dengan metode deskriptif. Subjek penelitian terdiri dari 20 mahasiswa Program Studi Pendidikan Matematika Universitas Timor yang mengikuti perkuliahan kalkulus. Data dikumpulkan melalui tes dan wawancara tidak terstruktur, kemudian dianalisis menggunakan kategorisasi kesalahan dan distribusi persentase. Hasil penelitian menunjukkan bahwa kesalahan mahasiswa paling dominan terjadi pada tahap *comprehension*, *transformation*, dan *process skills*. Kesalahan *comprehension* ditunjukkan oleh kesulitan dalam memahami makna dan struktur ekspresi matematika. Kesalahan *transformation* terlihat dari ketidakmampuan mengubah soal ke dalam bentuk atau prosedur matematika yang tepat, terutama dalam memilih strategi yang sesuai. Sementara itu, kesalahan *process skills* muncul ketika mahasiswa keliru dalam melakukan perhitungan meskipun telah memahami soal. Sebaliknya, kesalahan pada tahap *reading* dan *encoding* relatif rendah. Temuan ini menunjukkan bahwa kesulitan utama mahasiswa terletak pada tahap-tahap menengah dalam pemecahan masalah, yaitu ketika diperlukan pemahaman konseptual dan kelancaran prosedural secara bersamaan. Oleh karena itu, pembelajaran kalkulus perlu menekankan penguatan konsep serta pemberian soal non-rutin dan berbasis *higher order thinking skills* untuk meningkatkan kemampuan pemecahan masalah mahasiswa.

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Introduction

Mathematics plays a crucial role in Indonesia's education system, as it is included as a nationally assessed subject across various levels and fields of study. Therefore, mathematics is considered a fundamental competency that all students, regardless of their academic background, are expected to master. In line with this, at the higher education level, particularly in mathematics study programs, calculus is a compulsory subject due to its wide applications in various fields. However, the transition from school-level mathematics to advanced university mathematics presents significant challenges for students, especially in terms of prior mathematical knowledge and conceptual understanding, which are crucial for success in early university mathematics courses (Rach & Ufer, 2020).

According to Khasanah and Febriana (2024), one of the greatest contributions to the development of modern mathematics, science, and engineering is the discovery of calculus in the late 17th century. In line with this, Shamsuddin et al. (2024) state that calculus is one of the most important achievements in mathematics, developed to address various scientific needs. Calculus plays a significant role in supporting the advancement of science and technology. Many modern technological developments are rooted in calculus concepts; without calculus, technological progress would likely be slower and limited to simpler forms (Youvan, 2024).

Furthermore, Ho (2025) states that calculus is widely used in mathematical modeling to represent various real-world phenomena. Calculus is studied progressively, beginning with fundamental concepts and advancing to more complex topics. As science continues to develop, calculus is no longer limited to single-variable functions but has expanded to include multivariable functions. In this context, partial derivatives represent a fundamental concept used to analyze how one variable changes with respect to another while other variables are held constant. This concept has wide applications in various fields, such as economics, physics, and mathematical modeling. Therefore, a solid understanding of partial derivatives is essential, as it forms the foundation for more advanced topics, including differential equations and mathematical modeling.

The Calculus course is a compulsory subject that must be undertaken by students of the Mathematics Education program at the Faculty of Teacher Training and Education, Universitas Timor. However, calculus material, particularly topics related to partial derivatives, still often poses difficulties for students. These difficulties can be observed from the various errors made in solving problems, indicating that conceptual understanding has not yet been optimal. As stated by Yang et al. (2021), mathematics learning is hierarchical in nature, where higher-level concepts are constructed based on the understanding of preceding concepts. Therefore, mastery of partial derivative concepts is essential in supporting students' success in understanding more complex mathematical material.

According to Ahmad et al. (2024), learning difficulties experienced by students can lead to errors in problem-solving. In the context of mathematics learning, these errors indicate weaknesses in both conceptual understanding and procedural skills. Ekasari & Putra (2024) categorize errors in calculus learning into several types, including errors due to inattention, process skill errors, errors in problem comprehension, transformation errors, and errors in the use of notation. This suggests that students' errors are not merely technical but are also closely related to fundamental conceptual understanding. Furthermore, students' errors may also reflect the influence of social interaction within collaborative learning environments (Diana et al., 2026).

Several studies have shown that students frequently experience difficulties in understanding mathematical concepts, which often lead to errors in problem-solving. In the context of calculus learning, many students still struggle to grasp fundamental concepts, as reflected in the high number of errors made when solving problems (Lisa et al., 2024; Ningsi et al., 2022). Based on the use of Newman's Error Analysis, common errors include transformation, processing, and answer-writing errors. These errors are often associated with students' difficulties in structuring solution steps and reformulating problems into appropriate mathematical models. Similar findings were also reported by Anggara & Solahudin (2022) who emphasized that students' errors are largely caused by comprehension difficulties, which hinder their ability to connect mathematical concepts with problem situations. In addition, Putri et al. (2023) highlighted that error analysis using Newman's framework can assist teachers in identifying students' difficulties and providing appropriate instructional support. Their study found that transformation, processing, and encoding errors are the most dominant types of errors, and these can be reduced through scaffolding strategies tailored to the type of error made by students.

In line with this, based on preliminary interviews and classroom observations, it was found that derivative topics, particularly partial derivatives, remain among the most challenging materials for students to understand. This difficulty arises because the topic requires a deep conceptual understanding as well as a solid mastery of prerequisite knowledge acquired at the secondary school level.

Therefore, calculus lecturers need to identify the types of errors made by students in solving problems, especially those related to partial derivatives. Analyzing these errors is essential to uncover students' conceptual weaknesses and to provide a foundation for designing more effective instructional strategies. Accordingly, this study focuses on analyzing students' errors in solving partial derivative problems in a Calculus course using Newman's Error Analysis. This study is expected to identify the types of errors made by students, which can serve as an evaluative basis for improving the quality of instruction and students' learning outcomes.

Methods

This study employs a qualitative approach within a descriptive research paradigm. The participants were 20 undergraduate students enrolled in a calculus course, selected using purposive sampling based on criteria relevant to the research objectives (Sugiyono, 2013). The instruments used in this study were tests and unstructured interviews. The test consisted of essay-type questions related to partial derivatives, with indicators developed based on the intended learning outcomes of the topic. Data collection in this study was conducted using Midterm Examination questions related to the topic of partial derivatives. The midterm exam questions are in Table 1.

Table 1. Midterm exam questions for calculus course for partial derivatives.

No	Questions
1.	Given the function $f(x) = 3x^2 - 5x + 2$. Determine $f'(x)$. Find the slope of the tangent line at $x = 1$.
2.	Given the function a. $f(x,y) = \ln(x^2 + NPM\,y^2)$. b. $f(x,y) = x^2 - y^3 + 2x + 3y$ Determine f_x, f_y, f_{xy}, and f_{yx}.
3.	Given the following functions: a. $f(x,y,z) = e^{xy} \sin z$, b. $f(x,y,z) = x^2 e^{yz} + \sin(xy)$. Determine f_x, f_y, and f_z.
Note: *NPM* represents the last digit of the student identification number, excluding 0.	

The interviews were conducted to obtain deeper insights into the errors made by students. The data analysis technique followed the qualitative data analysis model proposed by (Sugiyono, 2013), which includes data reduction, data display, and conclusion drawing. In addition, Newman's Error Analysis (NEA) was employed to identify and classify the types of errors made by students at each stage of the problem-solving process. The indicators of NEA used in this study are presented in Table 2.

Table 2. Newman's Error Analysis (NEA) Indicators

Newman Procedure Error	Indicator
Reading error	Reading errors refer to mistakes made by students in recognizing or accurately reading the words and mathematical symbols presented in the problem.
Comprehension error	Comprehension errors occur when students are able to read the information in the problem correctly but fail to understand the meaning of the words, symbols, or what is being asked.

Transformation error	Transformation errors occur when students understand the problem correctly but are unable to determine the appropriate formula, properties, or steps needed to solve it.
Process skills error	Process skills errors occur when students are able to determine the correct formulas, properties, or steps, but fail to carry out the procedures accurately.
Encoding error	Encoding errors occur when students are able to carry out the procedures correctly but fail to express or conclude the final answer accurately.

Data validity in this study was established through method triangulation by comparing data obtained from tests and interviews. The interview technique used was a semi-structured interview, in which questions were asked flexibly while still adhering to the interview guidelines (Arikunto, 2013). Furthermore, the percentage of each type of student error was calculated to describe the distribution of errors across the NEA indicators.

Results and Discussion

This study aims to analyze students' errors in solving partial derivative problems based on the indicators of *Newman's Error Analysis* (NEA). The subjects of this study were 20 students who completed the test administered by the researcher. Table 3 presents the results of the students' answer corrections based on the NEA indicators.

Table 3. Percentage of Student Errors Based on Newman's Error Analysis Indicators.

Newman Procedure Error	**Percentage of Student Errors (%)**					**Mean**
	Question 1	**Question 2a**	**Question 2b**	**Question 3a**	**Question 3b**	
Reading error	10	5	0	0	5	4
Comprehension error	10	20	30	25	10	19
Transformation error	10	55	10	30	15	24
Process skills error	15	5	35	15	20	18
Encoding error	0	0	0	0	0	0
Number of students with correct answers	60	15	25	30	55	37

Table 3 presents the percentage of student errors based on the Newman Procedure across five questions (Question 1, Question 2a, Question 2b, Question 3a, and Question 3b), along with the mean percentage for each type of error. Overall, the results indicate that transformation errors and comprehension errors are among the most prominent difficulties experienced by students.

Transformation errors show a relatively high mean percentage (24%), with the highest occurrence in Question 2a (55%). This indicates that many students experience difficulties in selecting and applying appropriate mathematical procedures. In particular, students often fail to correctly transform the problem into a suitable mathematical form, such as misapplying fundamental rules (e.g., differentiation rules), which leads to incorrect solution strategies.

This result is consistent with the findings of Suherman et al. (2023), who reported that transformation errors were the most dominant type of error. This similarity indicates that students commonly experience difficulties in converting problems into appropriate mathematical forms, particularly in calculus contexts. Similarly, Rusyda et al. (2022) also found that transformation errors, along with encoding and process skills errors, were among the most frequently occurring errors in solving derivative problems. These similarities suggest that transformation errors represent a critical difficulty in students' problem-solving processes, particularly in calculus topics such as derivatives. According to Newman's Error Analysis, transformation is the stage where students must convert problem information into an appropriate mathematical form. Difficulties at this stage indicate that students struggle to connect conceptual understanding with procedural application. However, differences in the proportion of other error types may be influenced by variations in instructional approaches, student characteristics, or the types of problems used in each study.

Comprehension errors (mean = 19%) and process skills errors (mean = 18%) show relatively similar proportions. Both types of errors also reach their highest percentage in Question 2b, with comprehension errors at 30% and process skills errors at 35%. Comprehension errors indicate that students experience difficulties in interpreting the structure and meaning of the given mathematical expressions, even when they are able to read the symbols correctly. This suggests that students may misinterpret how variables and operations are related within a function, leading to incorrect representations of the problem. Process skills errors indicate that students encounter difficulties in accurately executing mathematical procedures, even when they have understood the problem and selected an appropriate strategy. These errors are related to weaknesses in procedural fluency, particularly in applying fundamental rules such as differentiation.

In contrast, reading errors are relatively low, with a mean of only 4%, and are absent in several questions. This suggests that most students are able to read and recognize the problem statements correctly. Furthermore, encoding errors are not observed at all (0% across all questions), indicating that students who successfully reach the final stage are generally able to express their answers appropriately. Additionally, the percentage of students who answered correctly varies across questions, with the highest proportion in Question 1 (60%) and Question 3b (55%), and the lowest in Question 2a (15%). The overall mean of correct answers is 37%, which reflects that less than half of the students were able to solve the problems correctly on average. In summary, the findings suggest that the main challenges faced by students lie in understanding the structure of mathematical problems, transforming them into appropriate mathematical forms, and accurately executing solution procedures. These difficulties are reflected in the relatively high percentages of comprehension, transformation, and process skills errors, while reading and encoding errors are minimal.

Furthermore, examples of students' responses are presented in the following figures, categorized according to the types of errors based on the Newman Error Analysis indicators.

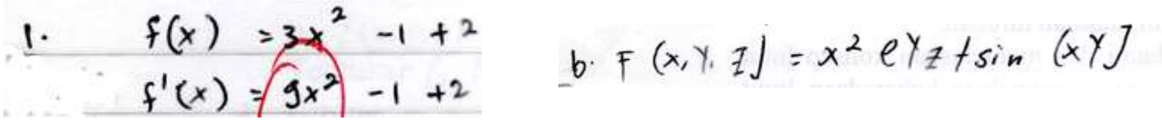

Figure 1. Reading errors in Questions 1 and 3a, respectively.

Reading errors occur when students are unable to accurately read or interpret mathematical symbols or notations, resulting in incorrect initial information. This type of error affects subsequent solution processes, as the problem is already misrepresented from the beginning. Based on Figure 1, the error made by the student is categorized as a reading error according to the Newman Error Analysis framework. This is evident when the student rewrote the function $f(x) = 3x^2 - x + 2$ as $f(x) = 3x^2 - 1 + 2$. The change from -x to -1 indicates a mistake in reading or transcribing the mathematical symbol, resulting in incorrect initial information. The same issue is also shown in Question 3a, where it should be $f(x, y, z) = e^{xy} \sin\ z$. Consequently, the entire solution process is based on an incorrect form of the function, leading to inaccurate results.

Reading errors are caused by students' inability to accurately read and interpret mathematical symbols, which leads to errors in subsequent stages of problem-solving. This finding is consistent with research by Winarso et al. (2022), which reported a reading error rate of 1%, and Suherman et al. (2023), which found a reading error rate of 60% in calculus. The variation in these percentages suggests differences in the level of task difficulty, learning contexts, and characteristics of the research subjects. Therefore, it is important to strengthen students' understanding of mathematical symbols and terminology as a foundation for effective problem-solving.

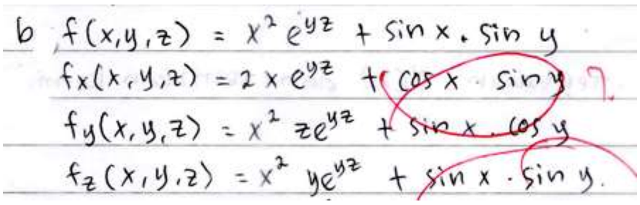

Figure 2. Comprehension error in Question 3b.

Based on Figure 2, the student's error is categorized as a comprehension error according to the Newman Error Analysis framework. The given function is $f(x, y, z) = x^2 e^{yz} + \sin\ (xy)$;

however, the student rewrote it as $f(x,y,z) = x^2e^{yz} + \sin x \cdot \sin y$. This change indicates a misunderstanding of the structure of the function. Although the student correctly read the mathematical symbols, they failed to interpret that $\sin(xy)$ represents a sine function with the argument xy, rather than the product of two separate functions $\sin x$ and $\sin y$. This error shows that the student misinterpreted the relationship between variables within the function. Such a mistake reflects a lack of conceptual understanding of function notation and composition, particularly in distinguishing between operations within a function's argument and operations between function values. Therefore, this error occurs at the comprehension stage, before the student proceeds to transformation or process skills.

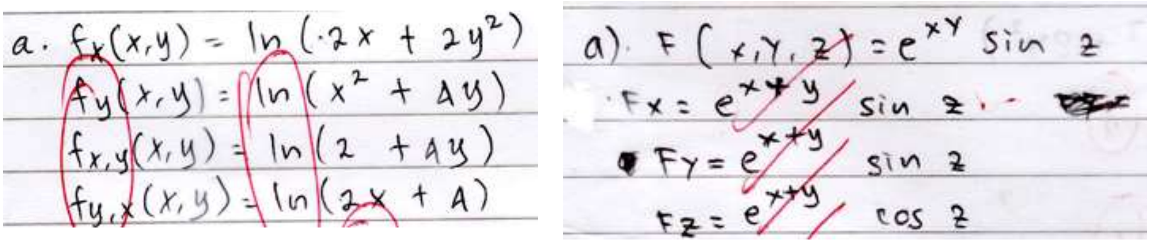

Figure 3. Transformation error in Question 2a and 3a, respectively.

Based on Figure 3, the student's error is categorized as a transformation error according to the Newman Error Analysis framework. The problem involves finding the partial derivative of the function $f(x,y) = \ln(x^2 + 2y^2)$ with respect to x (Question 2a). Although the students correctly understood what was being asked, they failed to select and apply the appropriate differentiation rules. This is evident from the student's response $f_x(x,y) = \ln(2x + 2y^2)$, which indicates an incorrect transformation of the problem into a mathematical procedure. The student appears to assume that the derivative of a logarithmic function is equal to the logarithm of the derivative of its argument, thereby neglecting the proper application of the logarithmic differentiation rule and the chain rule. This error reflects a difficulty at the transformation stage, where the student is unable to translate the given problem into an appropriate mathematical form or procedure. The same issue is also found in Question 3a. Based on the interview results, it was observed that the student incorrectly interpreted the partial derivative of e^{xy} as e^{x+y}.

Factors that contribute to errors in the transformation and process skills stages include insufficient mastery of prerequisite knowledge, weak conceptual understanding, and a lack of accuracy in problem-solving. These findings are consistent with Anggoro (2022), who argued that errors in mathematical problem-solving arise not only from procedural weaknesses but also from a limited understanding of underlying concepts. In the context of this study, such errors are evident when students fail to correctly apply differentiation rules, such as the chain rule in logarithmic functions. This suggests that students experience difficulty in transforming problems into appropriate mathematical procedures, even when they understand the intent of the problem.

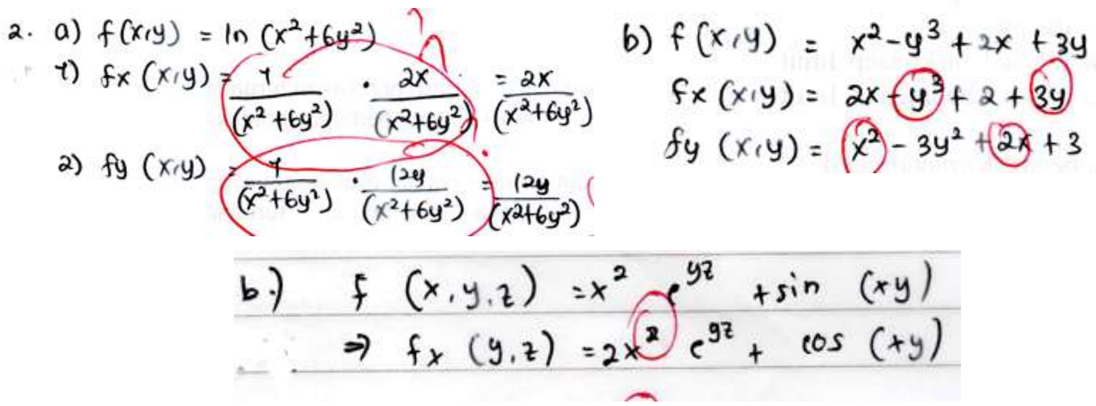

Figure 4. Process skills error in Question 2 and 3b, respectively.

Based on Figure 4, the student was asked to determine the partial derivatives of the function $f(x,y) = x^2 - y^3 + 2x + 3y$ with respect to x and y (Question 2b). However, the student provided the answers $f_x(x,y) = 2x - y^3 + 2 + 3y$ and $f_y(x,y) = x^2 - 3y + 2x + 3$, indicating errors in the differentiation process. The same issue is also observed in Question 2a "$f(x,y) = \ln{(x^2 + NPM\, y^2)}$" and 3b "$f(x,y,z) = x^2e^{yz} + \sin{(xy)}$". This error is categorized as a process skills error according to the Newman Error Analysis framework. The student correctly understood the task and identified that partial derivatives with respect to each variable were required. However, the mistake occurred at the procedural stage, specifically in applying the rules of partial differentiation. Mathematically, the correct partial derivatives are $f_x(x,y) = 2x + 2$ and $f_y(x,y) = -3y^2 + 3$, where terms involving the other variable should be treated as constants. In contrast, the student retained all terms in the function without eliminating those that are constant with respect to the variable of differentiation. This indicates that the student has not yet mastered the procedural rules of partial derivatives, particularly in treating non-differentiated variables as constants during the differentiation process.

Errors at the comprehension stage are primarily caused by students' limited understanding of the information presented in the problem. At the transformation stage, errors arise from a lack of accuracy in converting this information into an appropriate mathematical form. Meanwhile, errors in the process skills stage are associated with limited conceptual mastery, as well as the propagation of errors from previous stages. These findings are consistent with Sulistyoningrum et al. (2021), who demonstrated that errors at each stage are interrelated and can influence subsequent problem-solving processes.

Conclusion

Based on the findings of this study, it can be concluded that students' errors in solving calculus problems, as analyzed using the Newman Error Analysis (NEA) framework, are predominantly found in the comprehension, transformation, and process skills stages. Errors at the comprehension stage indicate that students still have difficulties in understanding the structure and meaning of mathematical expressions. Furthermore, transformation errors suggest that students are not yet able to convert problems into appropriate mathematical procedures. Meanwhile, process skills errors reveal that students lack accuracy in applying mathematical rules and procedures, even when they understand the problem. In contrast, errors at the reading and encoding stages are relatively minimal, indicating that most students are able to read the problems and express their final answers correctly.

Therefore, calculus instruction should place greater emphasis on strengthening students' conceptual understanding and procedural skills. Lecturers are encouraged to provide a variety of tasks, such as non-routine, open-ended, and higher order thinking skills-based problems, to develop deeper understanding and improve students' problem-solving abilities. Reinforcement of fundamental concepts, including function structure, differentiation rules, and the interpretation of mathematical notation, is also essential to reduce errors in the comprehension, transformation, and process skills stages.

This study has several limitations. First, the number of participants was limited to 20 students from a single study program, which may restrict the generalizability of the findings. Second, the data were collected only from one topic, namely partial derivatives in calculus, so the results may not represent students' error patterns in other calculus topics. Future research is recommended to involve a larger and more diverse sample, as well as to explore different mathematical topics to obtain more comprehensive insights into students' error patterns.

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