Analysis of Differential Equation Misconceptions Among Pre-Service Mathematics Teachers

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ABSTRACT

Differential Equations (DE) is a fundamental course for pre-service mathematics teachers as it supports the development of advanced calculus understanding and mathematical modeling skills. Despite its importance, many studies report that students still experience misconceptions when understanding and solving DE problems. This study aims to analyze the types and causes of misconceptions among pre-service mathematics teachers in solving DE problems. A descriptive qualitative approach was employed involving 19 mathematics education students from two private universities in Banten. The research instruments consisted of misconception tests in the form of true–false and essay questions, in-depth interviews, and focus group discussions (FGDs). Data analysis was conducted through identifying errors, classifying misconception types, and triangulating data sources. The findings revealed that procedural misconceptions were the most dominant, with an average of 72.63%, followed by computational misconceptions at 67.37% and conceptual misconceptions at 54.74%. Procedural errors mainly occurred in applying separation of variables, performing integration, and checking exact conditions, while conceptual errors were related to understanding variable relationships and the meaning of DE solutions. These results indicate that students' understanding remains fragmented and not fully integrated. Therefore, instructional strategies are needed that balance conceptual understanding, procedural mastery, and computational accuracy in Differential Equations learning.

ABSTRAK

Mata kuliah Persamaan Diferensial (PD) merupakan mata kuliah penting bagi calon guru matematika karena berperan dalam mengembangkan pemahaman kalkulus lanjut serta keterampilan pemodelan matematika. Namun, berbagai penelitian menunjukkan bahwa mahasiswa masih mengalami miskonsepsi dalam memahami dan menyelesaikan masalah persamaan diferensial. Penelitian ini bertujuan untuk menganalisis bentuk dan penyebab miskonsepsi calon guru matematika dalam menyelesaikan soal persamaan diferensial. Penelitian ini menggunakan pendekatan kualitatif deskriptif dengan subjek sebanyak 19 mahasiswa pendidikan matematika dari dua perguruan tinggi swasta di Banten. Instrumen penelitian meliputi tes miskonsepsi berupa soal benar–salah dan esai, wawancara mendalam, serta diskusi kelompok terfokus (*Focus Group Discussion* / FGD). Data dianalisis melalui tahapan identifikasi kesalahan, pengelompokan jenis miskonsepsi, dan triangulasi data. Hasil penelitian menunjukkan bahwa miskonsepsi mahasiswa didominasi oleh kesalahan prosedural dengan rata-rata sebesar 72,63%, diikuti oleh kesalahan komputasi sebesar 67,37% dan kesalahan konseptual sebesar 54,74%. Kesalahan prosedural terutama muncul pada penerapan metode pemisahan variabel, proses integrasi, dan pemeriksaan syarat keeksakan, sedangkan kesalahan konseptual berkaitan dengan pemahaman hubungan antarvariabel dan makna solusi persamaan diferensial. Temuan ini menunjukkan bahwa pemahaman mahasiswa masih bersifat parsial dan belum terintegrasi. Oleh karena itu, diperlukan strategi pembelajaran yang menekankan keseimbangan antara pemahaman konseptual, ketepatan prosedural, dan ketelitian komputasi dalam pembelajaran persamaan diferensial.

INTRODUCTION

Differential Equations (DE) is an important course in the mathematics education study program because it is not only related to mastering the concepts of derivatives and integrals, but also has broad applications in modeling real phenomena (Lubis, 2025). The study of DE involves highly abstract ideas, such as existence and uniqueness of solutions and relationships between variables, which require strong conceptual understanding (Msomi et al, 2022; Delic, 2025). However, many pre-service mathematics teachers experience difficulties in understanding DE concepts and applying them appropriately in problem solving (Boyce et al, 2017). Previous studies have reported frequent misconceptions and procedural errors, particularly in the use of derivatives, integrals, and solution methods (Makamure & Jojo, 2022; Msomi et al, 2022). Students often struggle with fundamental DE concepts, including the meaning of derivatives, general and particular solutions, and solution techniques, leading them to rely heavily on procedural memorization rather than meaningful conceptual understanding (Yarman, 2025). Moreover, weak mastery of prerequisite knowledge in algebra and calculus has been identified as a major factor contributing to these conceptual difficulties (Noor, 2022). Students' errors in solving problems are varied (Muttaqi, et al, 2021), since mathematical problem-solving processes are sequential, errors at early stages may lead to subsequent errors in later steps (Budi, et al, 2020).

These learning difficulties are closely related to the presence of misconceptions, which can be defined as discrepancies between students' conceptual understanding and the scientifically accepted meanings of mathematical concepts (Meika et al., 2023; Meika, et al., 2025; Marcel et al., 2025). Such misconceptions not only hinder students' mastery of differential equations but also have serious implications for their competence as future mathematics teachers. Consistent with this perspective, previous studies have shown that pre-service mathematics teachers frequently experience misconceptions in understanding the general form of solutions, distinguishing between general and particular solutions, applying the method of separation of variables, and interpreting slope field graphs (Rasmussen & Keene, 2019;Afri & Reflina, 2024). These findings highlight the need for instructional approaches that explicitly address conceptual understanding and misconception remediation in differential equations learning.

Furthermore, Sari & Ekasatya (2020) reported that misconceptions may arise from weaknesses in prior knowledge, procedural errors, or the use of inappropriate learning strategies. Such misconceptions occur not only during calculation process but also at earlier stages, including understanding fundamental concepts, determining appropriate solution strategies, and interpreting results (Sumargiyani, 2025). Therefore, in the context of DE, students' errors are not merely the result of carelessness but rather reflect misunderstandings of the underlying concept (Msomi, et al, 2022). Consistent with this perspective, the present study categorizes students' errors into three main types: conceptual errors, which arise from inadequate understanding of basic DE concepts; procedural errors, which result from difficulties in selecting or applying appropriate solution methods; and computational errors, which are caused by inaccuracies in algebraic manipulation or integration processes.

These difficulties are not solely attributable to individual student limitations but are also influenced by the curriculum structure and the characteristics of the learning resources employed. Curricula and instructional materials that emphasize formalism and abstraction without sufficient conceptual grounding may fail to address the learning needs of pre-service mathematics teachers. Under such conditions, students tend to rely on mechanical procedures rather than developing meaningful conceptual understanding, which in turn fosters persistent misconceptions in interpreting differential equation concepts and connecting symbolic representations with their mathematical meanings. Accordingly, the central problem addressed in this study is the persistence of conceptual, procedural, and computational misconceptions among pre-service mathematics teachers, which are influenced not only by students' prior knowledge but also by curriculum misalignment and the nature of instructional resources used in differential equations courses. Therefore, this study seeks to identify the types of misconceptions experienced by students and analyze their underlying causes, with particular attention to curricular and instructional factors that contribute to these misunderstandings.

Meanwhile, pre-service teachers (students) require a more contextual and applied approach to master concepts and be able to teach them. This gap between the demands of the material and the needs of students has the potential to strengthen misconceptions. Therefore, this study aims to analyze the forms, patterns, and causes of student misconceptions in solving DE problems as a basis for formulating learning strategies that are more appropriate to the characteristics of pre-service mathematics teachers. Therefore, an in-depth analysis of student misconception patterns in this course is crucial. This study focuses on identifying the types of errors experienced by students and the factors that cause them, thus providing the basis for formulating more effective learning strategies.

METHOD

This study used a descriptive qualitative approach (Creswell, 2019) with the aim of analyzing student misconceptions in the DE course. The study subjects consisted of 19 mathematics education students from two private universities in Banten who had completed the DE course, namely 5 students from Universitas Mathla'ul Anwar and 14 students from Universitas La Tansa Mashiro. The study instruments included a misconception test consisting of five true–false questions and five essay questions, interview guidelines, and focus group discussion (FGD) sheets. The test instruments were validated by experts to ensure the suitability of the content and readability of the questions so that they were suitable for use in data collection.

The determination of error types for the six interviewed students was based on established theoretical framework of mathematical error classification, which categorize error into conceptual, procedural, and computational types (Sari & Ekasatya, 2020; Lin et al, 2025). Six students were selected to participate in in-depth interviews using purposive sampling techniques based on variations in test result categories (low, medium, high) (Meika et al, 2022). Conceptual errors were identified when students demonstrated incorrect or incomplete understanding of fundamental concept, variable relationships, or the meaning of differential equations. Procedural errors were determined when students understood the underlying concepts but failed to apply solution steps systematically or selected inappropriate methods. Computational errors were classified when students made mistakes in arithmetic operations, algebraic manipulation, or integration despite using appropriate procedures.

Data analysis was conducted through a systematic multi-stage procedure to ensure a thorough examination of students' misconceptions in the Differential Equations course. In the first stage, students' written responses were carefully reviewed to identify errors occurring at each step of the problem-solving process. This analysis focused on how students interpreted the problem, selected solution strategies, and executed mathematical procedures, including algebraic manipulations and integration processes. By examining students' work step by step, the researchers were able to detect patterns of errors and pinpoint specific stages at which misunderstandings emerged. In the second stage, the identified errors were categorized into three main types of misconceptions: conceptual errors, procedural errors, and computational errors. This classification was guided by established theoretical perspectives on mathematical misconceptions and allowed the researchers to differentiate between misunderstandings related to core concepts, inappropriate application of solution methods, and inaccuracies in calculations.

In the third stage, the results of the error analysis were validated through a triangulation process by comparing data from multiple sources, namely written tests, individual interviews, and focus group discussions (FGDs). Interviews were used to explore students' reasoning, clarify their thought processes, and uncover the underlying causes of the errors identified in the written responses. FGDs further enriched the analysis by capturing students' shared perspectives and interactions when discussing problem-solving strategies. This triangulation enhanced the credibility and trustworthiness of the findings by ensuring consistency across data sources. Through this comprehensive analytical approach, the study aimed to provide an in-depth understanding of both the forms and underlying causes of students' misconceptions in learning differential equations, thereby offering valuable insights for improving instructional practices and curriculum design.

RESULTS AND DISCUSSION

This study was conducted on 19 mathematics education students from two private universities in Banten who had completed the DE course, namely 5 students from Universitas Mathla'ul Anwar and 14 students from Universitas La Tansa Mashiro. Six students were selected for interviews after completing a misconception test on DE. Data on misconceptions were obtained through the test results, which were then analyzed based on categories of error causes, namely conceptual errors, procedural errors, and computational errors. The results of the error data analysis on the students' DE misconception test are presented in Table 1.

Table 1. Data on the Results of the DE Misconception Test

Respondents	Question Number				
	1	2	3	4	5
R1	B	PO	KPO	PO	PO
R2	B	PO	KP	P	B
R3	B	PO	KP	P	B

Respondents	Question Number				
	1	2	3	4	5
R4	B	PO	KPO	KP	B
R5	B	B	KPO	KPO	KPO
R6	B	PO	KPO	KPO	KPO
R7	B	B	KPO	KPO	KPO
R8	B	PO	KPO	KPO	KPO
R9	B	KPO	KP	KPO	KPO
R10	B	KPO	KPO	KPO	KPO
R11	B	KPO	KPO	KPO	KPO
R12	B	O	KPO	KPO	KPO
R13	B	KPO	KPO	KPO	KPO
R14	B	PO	KPO	KPO	KPO
R15	B	PO	PO	KPO	KPO
R16	B	B	KP	KPO	KPO
R17	B	KPO	KPO	KPO	KPO
R18	K	KPO	KPO	KPO	KPO
R19	B	PO	KPO	KPO	KPO

Information
B = No error
K = Conceptual Error
P = Procedural Error
O = Computational/Operation Error

Next, the results in Table 1 were converted into percentages of error types in the students' DE misconception test, as presented in Table 2.

Table 2. Percentage of Error Types in the DE Misconception Test

Type of Error	Question Number					AVG
	1	2	3	4	5	
Conceptual Error	5.26	31.58	73.68	84.21	78.95	54.74
Procedural Error	-	78.94	100	100	84.21	72.63
Operation Error	-	84.21	78.95	89.47	84.21	67.37

Based on Table 2, students' errors in solving DE problems were dominated by procedural errors, with percentages reaching 72.63%. This indicated that most students experienced difficulties in applying solution steps systematically, such as separating variables, performing integration, and checking exactness conditions. The dominance of procedural errors is consistent with the findings of Makamure and Jojo (2022) and Dorner et al (2025), who reported that students often rely on memorizing algorithms without understanding the underlying procedural reasoning.

In addition, computational errors were also relatively high (67,37%), particularly in algebraic manipulation and integration processes. This suggests that weaknesses in basic mathematical skills remain a significant obstacle in learning DE, as reported by Lin et al (2025) and Meika et al (2025). Meanwhile, conceptual errors with an average 54,74%, indicate that students have not yet fully understood the relationships between variables and the meaning of DE solution. This result supports the findings of Rasmussen and Keene (2019), who emphasized the importance of conceptual understanding and the integration of multiple representations in DE learning. These results are also consistent with Yarman (2025), who reported that students' errors in solving DE include misunderstanding the problem, incorrect transformation into mathematical models, procedural calculation errors, and mistakes in expressing final solutions, indicating weaknesses in both conceptual and procedural understanding. Furthermore, Figure 1 presents Question 1 along with students' responses.

Question 1:
Determine the order, independent variable, and dependent variable in the following DE:

a. $\frac{d^2y}{dx^2} + 3\frac{dy}{dx} - 2y = \sin x$

b. $\frac{dy}{dx} + y = 3x$

Students Answers:

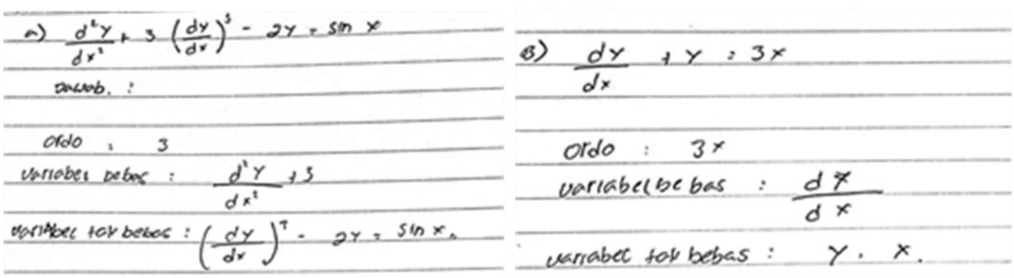


Figure 1. Low-category Student's Answer to Question Number 1

The analysis of Figure 1 indicates the presence of conceptual error. In question 1a, the students incorrectly identified the order of the differential equation: $\frac{d^2y}{dx^2} + 3\frac{dy}{dx} - 2y = sin\, sin\, x$ as three. However, the order of differential equation is determined by the highest-order derivate, which in this case is $\frac{d^2y}{dx^2}$. Therefore, the correct order of the equation is two, not three.

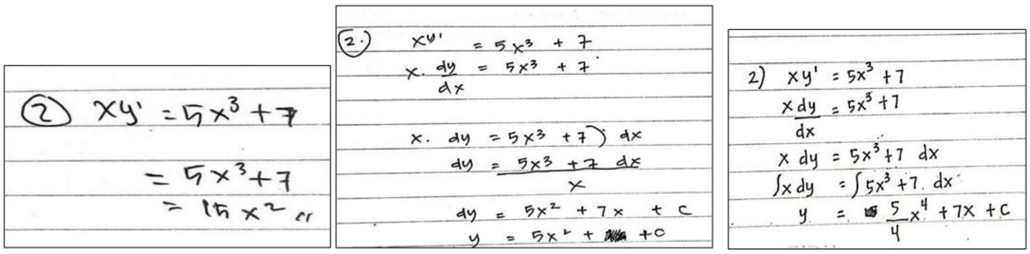
A similar conceptual error was observed in Question 1b. The student stated that the order of the equation $\frac{dy}{dx} + y = 3x$ was $3x$, whereas the correct order is one, since the highest derivate present in the equation is $\frac{dy}{dx}$.

Furthermore, the answers to the misconception test results for Question No. 2 is presented in Figure 2.

The analysis of Figure 2(a) reveals a conceptual error. The student misunderstood the meaning of the DE: $xy' = 5x^3 + 7,$ treating it as an expression to be differentiated the right-hand side to obtain $15a^2,$ even though the task required finding the solution of the DE what was asked was to solve the DE. This misconception at the conceptual level led to inappropriate solution steps and consequently, an incorrect final answer. Because they experienced conceptual problems, the solution steps were also incorrect, resulting in a wrong final answer. This is in line with Wardhani & Argaswari (2022), that low-category student are often wrong in determining the strategy used in solving problems.

Question 2:
Determine the solution to the following DE: $xy' = 5x^3 + 7$

Student Answer



(a) Low–category student (b) medium-category student (c) high-category student

Figure 2. Student's Answer to Question Number 2

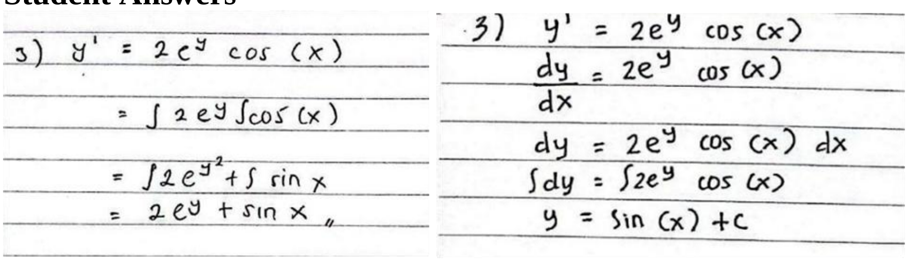
The analysis of Figure 2(b) indicates the presence of both procedural and computational errors. Procedurally, Respondent 1 (R1) applied the correct steps up to the fifth line by appropriately dividing both sides of the equation by x to facilitate variable separation. However, an error occurred during the integration process do to the incorrect application of integral rules. In terms of computational errors, although the student correctly simplified $\frac{5x^3}{x}$ as $5x^2$, the term $\frac{7}{x}$ was incorrectly rewritten as $7x$, which should have remained $\frac{7}{x}$.

Furthermore, the analysis of Figure 2(c) also shows procedural and computational errors. Procedurally, the student directly wrote $x\,dy = 5x^3 + 7$ without first dividing by x to properly separate the variables. Computationally, the student incorrectly transformed the integral $\int x\,dy$, the student immediately changed it into $y = \frac{5}{4}x^4 + 7x + C$ without recognizing that the left-hand side have been ∫dy resulting in y, not an expression involving x. These errors stemmed from incorrect initial procedures, which ultimately led to an invalid final solution.

Then, the answers to the misconception test results for Question number 3 is presented in Figure 3.

Question 3:
Determine the solution to the following DE: $y' = 2e^y \cos(x)$

Student Answers



(a) Medium-category students (b) High-category students

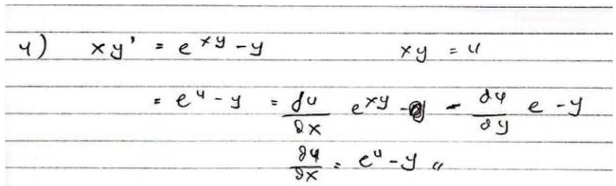
Figure 3. Student's Answer to Question Number 3

Figure 3(a) shows that the response of a medium-category student contains three types of errors: procedural, computational, and conceptual errors. In a procedural error, the student directly performed integration without first separating the variable y and x, as observed in the solution to Question No.3. for the differential equation $y' = 2e^y \cos \cos x$, the error occurred because the student attempted to integrate the right-hand side directly by incorrectly splitting the integral into$\int 2e^y \int \cos(x)$. This indicates an improper application of the separation of variable method. In computational error, the student wrote$\int 2e^{y^2} + \int \sin(x)$, which demonstrates an incorrect manipulation of the exponential expression. There was no justification for the appearance of e^{y^2}, as a original equation only involved e^y, not the square of y. Consequently, the final answer $2e^y + \sin x$ lacked a valid computational basis, reflecting errors in algebraic and integral operations. In conceptual error, the student assumed that the integral of the product $\int 2e^y \cos x \, dx$ could be separated into $\int 2e^y$ and$\int \cos x$.. This misconception indicates a misunderstanding of the dependence between variables and the fundamental principle of variable separation in solving DE.

The analysis of students' responses in Figure 3(b) reveals three types of errors, namely procedural, computational, and conceptual errors. In procedural error, the student directly wrote $\int dy = \int 2e^y \cos x \, dx$ without first separating the variables. In solving DE using the separation of variables method, term involving y and x must be placed on opposite sides of the equation before integration. Failure to do so indicates an incorrect application of the solution procedure. In computational error, the student integrated the right-hand side as $\sin x$, ignoring the factor $2e^y$, which is not a constant with respect to the variable y. This error reflects incorrect manipulation during the integration process. In conceptual error, the student treated e^y as a constant with respect to x, leading to the assumption that $\int 2e^y \cos x \, dx$ is equivalent to $\int \cos x \, dx$. This indicates a misunderstanding of the dependency between variables and the role of functions of y in the integration process when applying the separation of variables method.

The low-category student's answer was not displayed because the student did not write the answer to Question No. 3 on the answer sheet. Question No. 4 and the answer is presented in Figure 4.

Question 4:
Determine the solution to the following DE: $xy' = e^{xy} - y\ (x)$
(Direction: use similes $xy = u$)
Student Answers



(a) Medium-category student

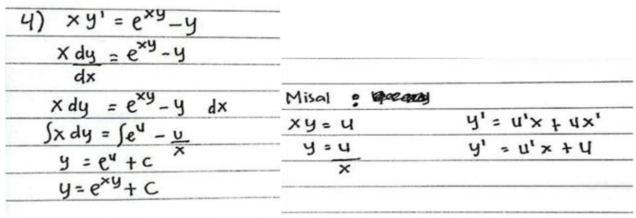


Figure4. Student's Answer to Question Number 4

Figure 4(a) shows that the response of a medium-category student contains three types of errors: procedural, computational, and conceptual errors. In procedural error, errors were also seen when the student wrote $\frac{dy}{dx} = e^u - y$, where y' still depended on variables u and$x$, and the relationship between the derivatives $\frac{du}{dx}$ with $\frac{dy}{dx}$ was not explained. In computational error, the error made by the student during substitution was replacing e^{xy} with e^u but not replacing all occurrences of y with $\frac{u}{x}$, creating mixed equations between u and y. In conceptual error, the error made by the student in solving Question No. 4 was an error in understanding the application of variable substitution in DE. The student substituted $u = xy$ into the form $xy' = e^{xy} - y$ but did not reduce the variables completely and correctly. In the process of solving the problem, R3 did not differentiate $u = xy$ using the derivative rule; therefore, the form $\frac{du}{dx} = x\frac{dy}{dx} + y$ which should have been the key to continuing the solution, was not obtained.

The analysis of high-category students' responses in Figure 4(b) reveals three types of errors, namely procedural, computational, and conceptual errors. In procedural error, at the variable integration step u, x and$y$ were mixed in one equation without proper separation. In computational error, the student incorrectly assumed the integration $\int e^u dx = e^u$ directly without replacing dx with the inner form du using the substitution relationship. In conceptual error, there was incorrect substitution in the integrals; the student attempted to substitute $u = xy$ into the integral $e^{xy} - y\, dx$, but did not make complete changes to the variables, including not replacing dx in the form of du.

The low-category student's answer was not displayed because the student did not write the answer to Question No. 4 on the answer sheet. Then, the answers to the misconception test results for Question number 5 is presented in Figure 5.

Question 5:
Check whether the following DE is exact?

a. $(e^x - 1)\, dx + (e^{2y})\, dy = 0$
b. $2xy\, dx + (4y + 3x^2)\, dy = 0$

Student Answers

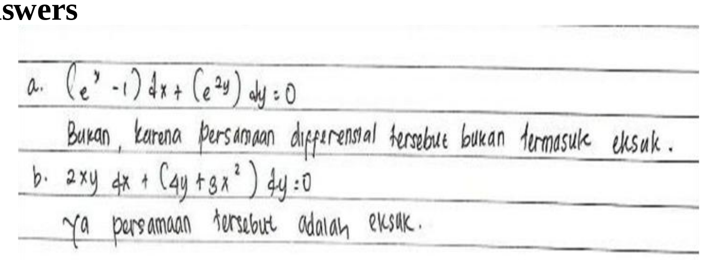


Figure 5. Medium-category Student's Answer to Question Number 5

Figure 5 shows that the response of a medium-category student contains three types of errors: procedural, computational, and conceptual errors. In procedural error, the student only wrote the conclusion about whether the DE was exact or not without showing the checking steps. In computational error, in Question (b), the student should have calculated

$\frac{\partial M}{\partial y}$ and $\frac{\partial N}{\partial x}$. The student wrote the conclusion directly without any calculation evidence. In conceptual error, the student had a misconception because they assumed the equation was automatically exact just by looking at its form, without actually checking the exactness conditions. The low-category student's answer was not displayed because the student did not write the answer to Question No. 5 on the answer sheet. Similarly, the high-category student's answer was not displayed because their answer was correct.

Based on the analysis of the students' answers to the DE misconception test, three characteristics of misconceptions were found: procedural errors, computational errors, and conceptual errors (Lin et al., 2025). Procedural errors occurred when students did not apply the solution steps correctly even though the concept used was correct. These errors were generally caused by inaccuracy, incomplete application of steps, or the selection of an incorrect solution strategy, resulting in an incorrect final answer. Jameson et al. (2024) state that procedural errors often arise from the habit of memorizing algorithms without understanding the reasoning behind the procedures. Computational errors arise from mistakes in arithmetic operations, algebra, or symbol manipulation, even though the concepts and procedures had been understood. These errors are often influenced by weak arithmetic skills and inaccuracy (Lin et al., 2025; Meika et al., 2025). Meanwhile, conceptual errors are misconceptions stemming from an incorrect or incomplete understanding of concepts, such as misinterpreting symbols, relationships between variables, or generalizing procedures incorrectly.

Next, interviews were conducted with three students to gain a deeper understanding of the difficulties experienced in completing the DE misconception test. One interview focused on Question No. 2, which required solving the DE problem through direct integration. The interview results showed that students did not experience difficulties in the initial steps, particularly in separating variables. Errors actually appeared at the integration step, where students forgot the correct integral rules and incorrectly applied the integral formula. Students assumed that certain integral forms could be solved directly like the general form, even though the function "ln(x)" had different specific rules. This finding indicated that the errors that occurred were more computational errors due to inaccuracy and weaknesses in remembering integral rules rather than conceptual errors in understanding the method of separating variables.

Interviews were also conducted with students regarding their answers to Question No. 3 to identify the reasons for the errors made by students in solving Question No. 3. Excerpts from the interview with R3 are presented as follows:

A	:	*How did you solve the given Question No. 3?*
R3	:	*I saw the equation* $y' = 2e^y \cos(x)$, *then changed it into the form* $dy = 2e^y \cos(x)$, *then directly integrated the two sides, so* $\int dy = \int 2e^y \cos(x)$ *resulted in* $y = \sin(x) + C$
A	:	*Why did you integrate directly without separating the variables?*
R3	:	*Because I thought that such a form could be directly integrated, so there was no need to separate the variables first.*
A	:	*What was your reason for writing the right-hand-side integral result as* $\sin \sin (x)$?
R3	:	*Initially, it was known* $\cos (x)$, *so I just integrated it directly. The integral of* $\cos \cos (x)$ *is* $\sin \sin (x)$.
A	:	*In your opinion, is* e^y *a constant with respect to the variable* x?

R3 : For that, I just considered it a constant because I focused on $cos\ (x)$ *only.*

Interviews with R3 revealed difficulties in solving DE problems involved procedural, computational, and conceptual errors simultaneously. Procedurally, the student failed to separate variables before integration. Computationally, the student integrated $cos\ (x)$ into $sin(x)$ without considering the multiplier factor $2y^e$ that should have been included. Conceptually, the student treated e^y as a constant with respect to the variable x indicating a lack of understanding of the relationship between independent and dependent variables.

These findings indicate that the student did not fully understand the fundamental concepts underlying the separation of variables method and the relationship between variables in DE. The result is consistent with the findings of Yarman et al (2025), who reported that misconceptions in DE persist across multiple stages of problem solving, including problem comprehension, mathematical modeling, procedural execution, and solution representation, reflecting the absence of coherent conceptual understanding among students.

Furthermore, interviews were also conducted with students regarding their answers to Question No. 5 to identify the reasons for the errors made by students in solving Question No. 5. Excerpts from the interview with R9 are presented as follows:

A : How do you determine whether a DE is exact or not?
R9 : I immediately look at the equation's form. If I think it looks exact, I write it as exact. If not, I write it as inexact.
A : Why did you not write down the steps for checking the exact condition, such as calculating $\frac{\partial M}{\partial y}$ *and* $\frac{\partial N}{\partial x}$*?*
R9 : I forgot how, ma'am. I only remembered that it had to be checked, but I did not remember the exact rules. So I just wrote the conclusion.

The student made three errors. First, procedurally, he failed to demonstrate the exact checking steps and only wrote a conclusion. Second, computationally, he failed to perform the calculations $\frac{\partial M}{\partial y}$ and $\frac{\partial N}{\partial x}$, so there was no computational evidence to support the answer. Third, conceptually, the student assumed that DE can be immediately considered exact just by looking at their form, without truly understanding and verifying the exact conditions.

Based on the DE misconception test and interviews in the DE course, several key findings were obtained. First, the most dominant errors were procedural errors, with a percentage of 72.63%. This indicated that students were not consistent in applying solution steps, such as variable separation, integration, and checking exact conditions. This finding aligned with the study of Dorner et al. (2025), which emphasized the importance of utilizing errors as a means of reflection to deepen procedural and conceptual understanding. Second, computational errors were also quite high, at 67.37%, reflected in errors in calculating integrals or partial derivatives, such as equating $\frac{7}{x}$ with $7x$. This error indicated weak mastery of basic algebra skills. Third, conceptual errors were found at 54.74%, such as the misconception that e^y is a constant with respect to x, or that an equation is automatically exact without verifying its conditions. This finding confirmed that students' basic understanding of DE still needed to be strengthened through collaborative discussion of errors (Shimizu & Kang, 2025).

CONCLUSION

Based on the results of the Differential Equations (DE) misconception test and interviews, it can be concluded that students still experienced significant difficulties in learning DE. The most dominant errors occurred in the procedural aspect, indicating that students were not yet consistent in applying the solution steps systematically. Furthermore, the high number of computational errors indicated that mastery of basic algebra and calculus skills was not yet fully established. The significant number of conceptual errors also reflected students' limited understanding of the relationships between variables and the meaning of differential concepts. Overall, these findings indicated that students' understanding was still unbalanced across the procedural, computational, and conceptual aspects.

Based on these findings, it is recommended that students be more active in practicing basic algebra and calculus skills and develop the habit of reviewing each step of the solution, not only focusing on the final result. Group discussions and collaborative learning can help students recognize and correct the errors that occurred. Lecturers are expected to design learning that emphasizes students' thinking processes, for example, through a productive error-based approach (productive failure) and by providing a variety of questions to strengthen integrated understanding. Further study is recommended to explore didactic interventions that can minimize student misconceptions, for example, through technology-based or collaborative learning designs, and to involve a wider variety of subjects to obtain a more comprehensive picture.

DAFTAR PUSTAKA

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