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ANALYSIS OF STUDENTS' MATHEMATICAL PROBLEM-SOLVING ABILITY ON SENIOR HIGH SCHOOL – CASE ON FUNCTION DERIVATIVE MATERIAL

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ABSTRACT

Derivative functions are a fundamental concept in high school calculus and serve as a crucial indicator of students' mathematical problem-solving abilities. However, many students face challenges in applying derivative rules, especially when the complexity of problems increases. This study aims to analyze the problem-solving abilities of eleventh-grade students on the topic of function derivatives. The research employed a descriptive qualitative method involving students from class XI as participants. Data were collected through a problem-solving ability test consisting of 10 essay questions based on indicators of mathematical understanding, followed by interviews to gain deeper insights into students' reasoning processes. The analysis focused on students' ability to apply differentiation rules, including the power rule, product rule, quotient rule, and chain rule. The findings revealed that students performed well on low to moderate difficulty problems, mainly due to routine practice and familiarity with basic differentiation procedures. However, performance significantly declined on more complex problems involving root functions and fractional exponents. Errors were commonly observed in the simplification process and the application of advanced differentiation techniques. This suggests that while procedural knowledge is somewhat developed, conceptual understanding remains limited. The study concludes that innovative teaching approaches are needed to bridge this gap, particularly in fostering deeper conceptual comprehension and critical thinking skills related to calculus problem-solving.

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INTRODUCTION

Education plays a very vital role in producing a generation that is intelligent, creative, and ready to face global challenges. One of the main goals of education is to produce competent human resources in various fields, one of which is through improving critical thinking and problem-solving skills. In the context of mathematics education, the ability to solve mathematical problems is one of the important aspects that every student must have (Siregar et al., 2022).

This ability is not only to solve mathematical problems, but also to hone analytical and logical skills that are very much needed in everyday life (Siregar, 2024). Furthermore, 21st-century learning is a shift from a teacher-centered learning approach to a student-centered learning approach (Munazah et al., 2021). Nantara (2021) argues that education is also important for the progress of the nation. The progress of a country lies in the level of success of the education of the next generation. If the next generation of the nation has the appropriate skills in the current era of globalization, the progress of the country will increase. Likewise, if the next generation of the nation is less skilled in the era of globalization, then a country can be destroyed. If a country has low quality human resources, then other countries will easily conquer the country. Therefore, the next generation of the nation must be reliable Human Resources (HR) in their respective fields. To realize this, every student should have 21st century skills. Currently, 21st century skills must be friendly to everyone, by utilizing the abilities they have and also technology as a supporter, it is hoped that everyone can keep up with the times. 21st century skills that must be mastered by everyone, make education have a responsibility to prepare the next generation to master them. 21st century skills or termed 4C (Critical thinking, Creativity, Communication, and Collaboration) are the objectives of the 2013 curriculum, namely the skills that students want to achieve. These skills are important for students to solve various problems using logical reasoning and appropriate solutions (Makhrus et al., 2018). One of the 21st century skills is critical thinking. Critical thinking is a high-level thinking skill that can improve a person's analytical power. This skill is very necessary for students to review the information that has been given based on the experience they have had so that they can sort out the information they receive (Solikhin & Fauziah, 2021).

Furthermore, in this era of globalization, critical thinking and problem solving skills are very relevant skills (Siregar, 2023). This is in accordance with the demands of 21st century learning which emphasizes the development of high-level thinking skills or High Order Thinking Skills (HOTS). In HOTS, students are not only required to memorize and remember information, but also to be able to connect, analyze, and solve complex problems. Learning mathematics, especially in the material of function derivatives, requires students to be able to think analytically and critically in understanding concepts and their applications.

Critical thinking is part of High Order Thinking Skills (HOTS). According to Akhirmaini et al., (2021) HOTS is the ability of students to think, be creative, analyze, and be able to solve problems. Students are expected to be able to master concepts, create new ideas or concepts, and work together to solve problems in everyday life. In HOTS, there are activities that students can carry out, namely connecting, manipulating, changing knowledge and experience analytically to make decisions and solve problems in new ways (Akhirmaini et al., 2021). Meanwhile, according to Hartono et al., (2022) HOTS includes the ability to think logically, critically, systematically, analytically, creatively, productively, the ability to reason, connect, communicate, and solve mathematical problems.

Based on the results of the PISA (Programme for International Student Assessment) survey in 2018, Indonesia was ranked 74th out of 79 countries with a science score of 396, a mathematics score of 379, and a reading score of 371. The questions used in PISA are questions in the High Order Thinking (HOTS) category which test students' critical thinking and creative thinking skills (OECD, 2019). The results of the TIMSS (Trends in International Mathematics and Science Study) survey in 2015, Indonesia was ranked 44th out of 49 countries with an average Indonesian score of 397, while the average international score was 500 (Nizam, 2016). This ranking position shows that the problem-solving and critical thinking skills of Indonesian students are still less than optimal. Based on these data, the efforts that need to be made by teachers are to practice problem-based questions so that students can examine and interpret the problem more enthusiastically because they use the knowledge they have to solve problems in everyday life.

One of the sciences in the world of education that is important to learn is mathematics. Mathematics plays a role as one way to solve various problems that occur in life. In addition, mathematics is one of the foundations of educational science, which has an important role in supporting Science and Technology. Unfortunately, students' interest in learning mathematics is still very low, this is due to the difficulty of understanding the material given and also the difficulty in mastering mathematics. Learning mathematics has a very important factor, namely having students' mathematical understanding abilities.

The ability to understand mathematics should indeed be possessed by every student because this is the main goal in learning mathematics. In learning, students are expected not only to memorize the material but also to understand the learning material. Because by understanding the material in learning, students understand the concepts being learned. Kurniadi and Purwaningrum (2018) stated that the most prominent problem faced in teaching mathematics is generally ineffective mathematics learning. One of the consequences of the development of learning on students' mathematical understanding abilities is that it is not implemented optimally.

Therefore, there needs to be a mathematical understanding ability to reduce problems in mathematics learning. Mathematical understanding ability is students' knowledge of concepts, principles, procedures and students' ability to use strategies in solving mathematical problems (Sulisworo & Permprayoon, 2018; Alan & Afriansyah, 2017). Mathematical understanding ability greatly supports the development of other mathematical abilities, namely communication, problem solving, reasoning, connections, representation, critical and creative thinking and other mathematical abilities. Therefore, mathematical understanding ability is very important for students to have (Fitriani & Maulana, 2016).

The Ministry of National Education (2004) details the understanding ability as follows: a) restating a concept; b) classifying objects according to certain properties according to their concepts; c) giving examples and non-examples of concepts; d) presenting the concept in various forms of mathematical representation; e) developing necessary or sufficient conditions for a concept. f) Using, utilizing, and selecting certain procedures or operations. g) Applying concepts or algorithms in problem solving. Several studies conducted by Padhila Angraini et al., (2018) concluded that students' mathematical understanding abilities in solving problems of exponents, roots, and logarithms are classified into 3 categories, namely: students who lack understanding of number operations in roots, students who lack understanding of exponents in fractions, and students who have not been able to solve logarithm problems because they do not understand the concept of logarithms and multiplication and addition of logarithms. According to research conducted by Malihatuddarojah and Prahmana (2019), it was concluded that the errors found in the study were errors in variables, negative signs, solving algebraic equations, operating algebraic forms, and solving fractional forms. Furthermore, according to Susiaty et al., (2019), it was concluded that students' mathematical understanding abilities were still low, as indicated by the presence of many errors in solving mathematical understanding problems, especially in the indicators of defining concepts in writing, representing a concept in the form of models, diagrams, and symbols, identifying examples and non-examples of a comparison, and changing one form of representation to another.

The difference with this study is that the researcher conducted an analysis of the mathematical problem-solving abilities of students in class XII. In this study, the material analyzed was derivatives, because according to the opinion of the mathematics teacher who taught at the research school, the derivative material was quite difficult to understand compared to other materials. So the researcher analyzed the understanding of the derivative function material.

Derivative function is one of the materials that is often considered difficult by some students. As basic material in calculus, derivative functions require a deep understanding of the concepts of limits, continuity, and basic rules in differentiation. This difficulty often causes students to be less motivated and have difficulty in applying the concept of derivatives to more complex problems. Based on observations, the derivative function material is often considered difficult by students, especially in terms of understanding the concept and applying the right method to solve problems related to derivative functions.

Based on interviews with mathematics teachers of class XII, it shows that in the learning process the teacher has used a learning model, but the conventional learning model still uses the lecture method more often. Students are not fully involved in learning and are not trained to explore students' prior knowledge, process information, make decisions appropriately and solve problems (students are only recipients of information). This causes students to become bored, passive, less able to use the ideas they have and students' memory of learning materials is still classified as moderate, namely 70-75 because it does not reach the minimum completion criteria (KKM), this causes the daily test scores from the data shown not to reach the Minimum Completion Criteria (KKM) which is 77. Therefore, to overcome this problem, improvements are needed in the learning process so that students' ability to solve problems can increase. Based on this background, this study aims to analyze the ability of class XI students in solving mathematical problems on the material of function derivatives. By using a descriptive approach and problem-solving ability test instruments, it is expected to find a picture of students' ability to solve function derivative problems and the factors that influence their level of understanding of the material. The results of this study are expected to contribute to the development of more effective mathematics learning strategies that are in accordance with students' needs.

METHOD

This research is a descriptive research with a qualitative research method. Descriptive method is a statistic used to analyze data by describing or depicting the data that has been collected. This research is used to analyze the ability to solve mathematical problems on the material of function derivatives. The subjects of this research are students of class XI.

The data collection technique for this research in the initial stage is collecting information through interview techniques, interviews in this study are aimed at mathematics subject teachers which aim to find out information on how the teaching and learning process in the classroom takes place and what media and models are used. In the next stage of data collection through test techniques, the test technique in this study determines whether or not there is or is large or small understanding of students' abilities in solving mathematical problems on the material of function derivatives.

The research procedure was divided into three stages. The Initial Stage; a) Prepare a research schedule and make a letter of approval to the lecturer; b) Conduct observations to obtain initial data. And conduct interviews with teachers about the problems faced by students in learning; c) Prepare data collection instruments, namely essay questions with function derivative material; d) Conducting validity of the test/research instrument with a validator. The Planning Stage; a) Determining the class presented as a research sample; b) Conducting a posttest on the sample class to obtain information on problem-solving abilities. The Final Stage; a) Conducting statistical data analysis testing, namely normality tests and homogeneity tests; b) Conducting hypothesis testing, namely with an independent sample t-test to determine whether the given hypothesis can be accepted or rejected.

The instruments in this study were the material expert validation sheet, the learning expert validation sheet, mathematical problem-solving ability test questions on the function derivative material, and the problem-solving ability rubric. Next, the data analysis technique in this study was to determine the students' ability to solve problems as many as 10 questions with low question categories, medium question categories, and high question categories. The raw test score was worth 5 for each correct answer and 0 for the wrong answer. Furthermore, a total scoring was carried out for each test with a percentage formula. Furthermore, a hypothesis test was carried out using an independent t-test with the help of SPSS software and the Mann Whitney test.

RESULTS AND DISCUSSION

Results

This study aimed to analyze students' problem-solving abilities in calculus, specifically in the topic of derivatives, through a test consisting of 10 essay-based questions categorized by difficulty level. The analysis showed variation in student performance depending on the complexity of the derivative concepts being tested.

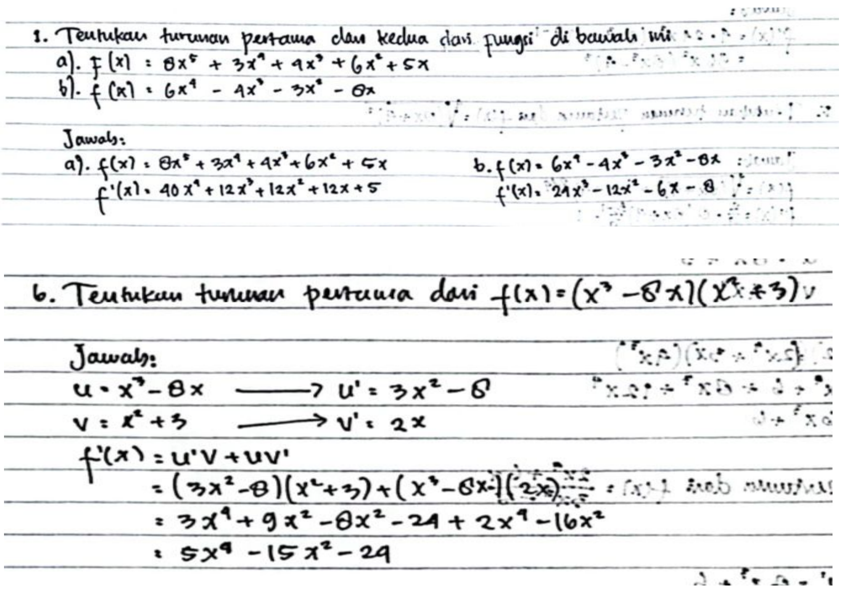
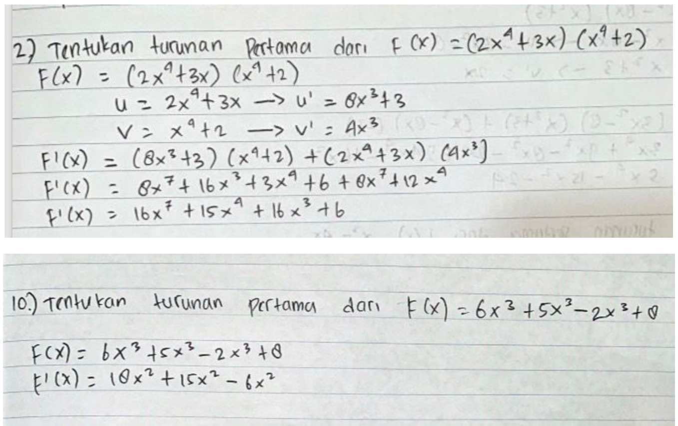


Figure 1. Student Ability Answers for Questions 1 and 6

So it can be seen that the analysis of questions 1 and 6 is in the Easy category, where in Difficulty: These questions are included in the easy category, because they only require direct application of the basic rules of derivatives and product rules. It is expected that students already have a good understanding of this concept. Next in Application: This question is designed to test how well students can calculate the derivatives of polynomial functions and apply the product rules correctly. And in Required Skills: Students must understand the basic rules of derivatives, including derivatives of constants, variables, and polynomial functions. A strong understanding of the product rule is also very important, especially for question number six. So it can be concluded that this question is a good opportunity to practice basic skills in calculus, especially related to derivatives. This is very useful for building a solid foundation before students move on to more complex concepts.

Questions 1 and 6 were categorized as Easy. These questions involved basic applications of derivative rules, such as the power rule and product rule. Students were expected to directly apply foundational calculus concepts, which most of them managed with relative ease. These questions served as essential practice for strengthening fundamental derivative skills.

Compared to previous studies that showed students struggled even at the basic level (Bakri et al., 2021), this finding suggests a slight improvement in students' grasp of foundational calculus.

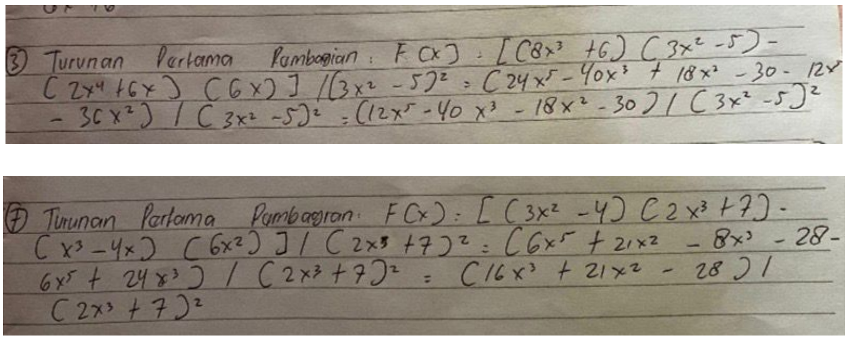

2) Tentukan turunan pertama dari $F(x) = (2x^4+3x)(x^4+2)$
$F(x) = (2x^4+3x)(x^4+2)$
$u = 2x^4+3x \rightarrow u' = 8x^3+3$
$v = x^4+2 \rightarrow v' = 4x^3$
$F'(x) = (8x^3+3)(x^4+2) + (2x^4+3x)(4x^3)$
$F'(x) = 8x^7+16x^3+3x^4+6+8x^7+12x^4$
$F'(x) = 16x^7+15x^4+16x^3+6$

10) Tentukan turunan pertama dari $F(x) = 6x^3+5x^3-2x^3+8$
$F(x) = 6x^3+5x^3-2x^3+8$
$F'(x) = 18x^2+15x^2-6x^2$

Figure 2. Figure of Student Ability in Questions Number 2 and 10

Next, in questions 2 and 10, there is an easy category level, where the questions in this category are relatively easy because they involve direct application of the basic rules of derivatives and product rules, which are crucial concepts in calculus. In this context, students are tested on their understanding of polynomial derivatives and their ability to apply the product rule correctly. Practicing these questions is very important, because it can help students build a strong foundation in calculus before they move on to more complex topics. Through this, it is hoped that students will better understand the process of calculating derivatives and can improve their skills in calculus.

Questions 2 and 10, also categorized as Easy, similarly assessed the application of basic differentiation rules. Despite the similarity in difficulty level with questions 1 and 6, performance here varied slightly due to students' inconsistent understanding of how to apply the product rule in combination with polynomial functions. These results confirm findings by Masitoh & Herman (2024), which stated that conceptual understanding remains a challenge despite procedural familiarity.


3) Turunan Pertama Pembagian: $F(x) = [(8x^3+6)(3x^2-5) - (2x^4+6x)(6x)]/(3x^2-5)^2 = (24x^5-40x^3+18x^2-30-12x^5-36x^2)/(3x^2-5)^2 = (12x^5-40x^3-18x^2-30)/(3x^2-5)^2$

7) Turunan Pertama Pembagian: $F(x) = [(3x^2-4)(2x^3+7) - (x^3-4x)(6x^2)]/(2x^3+7)^2 = (6x^5+21x^2-8x^3-28-6x^5+24x^3)/(2x^3+7)^2 = (16x^3+21x^2-28)/(2x^3+7)^2$

Figure 3. Student Ability Answers for Questions 3 and 7

Next, in questions 3 and 7, there is a Medium category level, Medium Categorization: These questions are classified as medium because they require the use of more complicated derivative rules, such as the quotient and product rules, and require more careful simplification steps. Skills Tested: In these questions, students will be tested on their understanding of the derivatives of rational functions and their ability to apply several rules simultaneously. And the Importance of Practice: Working on these questions is essential to developing skills in handling more complex functions and preparing students for advanced material in calculus. With this, it is hoped that students can better understand more complex calculation processes and improve their calculus skills.

Questions 3 and 7 fell into the Medium difficulty category. These items required the application of more complex differentiation techniques, such as the quotient rule, and demanded a higher level of simplification skills. Student responses indicated difficulty in maintaining accuracy throughout multiple steps, reflecting challenges reported in previous studies (Lalu et al., 2022), particularly in handling algebraic manipulation within derivative contexts.

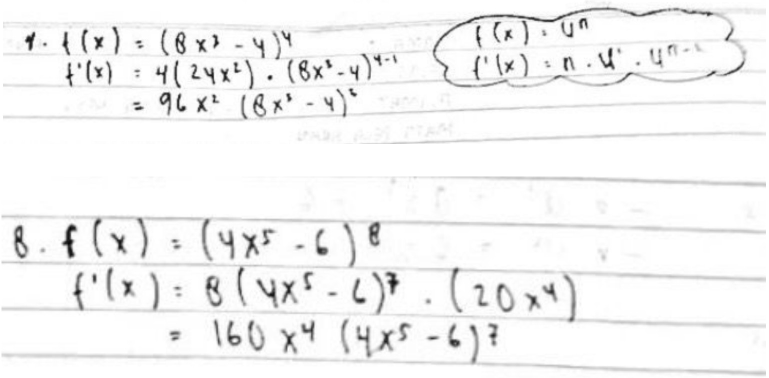
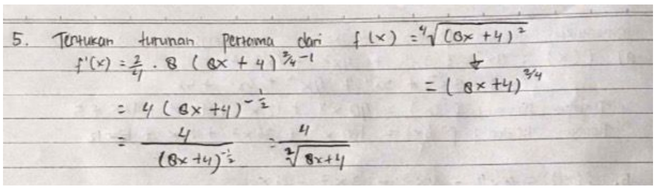


Figure 4. Student Ability Answers for Questions 4 and 8

Next, in questions 4 and 8, there is a Medium category level, where Medium Category: Questions in this category are considered medium because they involve the application of the chain rule, which requires a deep understanding of the derivative of a composition function. Skills Tested: Students are tested on their ability to apply the chain rule in calculating the derivative of a more complex function, as well as simplifying the results obtained. Importance of Practice: It is important for students to practice these questions in order to build their ability to understand and calculate the derivative of a polynomial function raised to the power. Through this, it is hoped that students can understand the steps required and strengthen their calculus skills.

Questions 4 and 8, also rated as Medium, tested students' understanding of the chain rule, specifically involving composite functions. Students struggled with both recognizing function compositions and applying the chain rule correctly, indicating a need for more focused practice in this area. These results align with earlier findings by Zulmaulida et al. (2021), emphasizing students' limited mastery in multistep derivative problems involving composition.



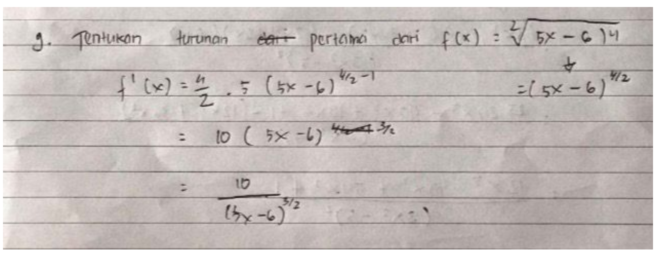


Figure 5. Student Ability Answers for Questions 5 and 9

Finally, on questions 5 and 10 with the High category level, where High Category: Questions in this category are considered high because they require a deep understanding of the chain rule and simplification of more complex functions. Skills Tested: Here, students are tested on their ability to apply the chain rule in calculating derivatives of functions involving roots and fractional exponents. Importance of Conceptual Understanding: Understanding how functions behave and interact with other variables is key in calculus. Therefore, students need to practice with various forms of functions in order to strengthen their skills. So this question aims to help students understand the steps needed to solve more complex derivative problems.

So, Questions 5 and 9 were identified as having High difficulty. These questions required deep conceptual understanding and the ability to differentiate complex expressions involving roots and fractional exponents. Many students failed to simplify expressions accurately or misapplied the chain rule, highlighting persistent weaknesses in higher-order calculus skills. This contrasts with the findings of some previous research where students showed moderate performance on similar items (Marwiyah, 2022), suggesting that the difficulty level of these particular items may have exceeded the standard classroom preparation.

In summary, the findings indicate that while students demonstrate satisfactory performance in solving basic derivative problems, they face significant challenges when addressing medium to high-level derivative tasks, especially those involving the quotient rule, chain rule, and function simplification. The significant challenges that students face when dealing with intermediate to advanced derivatives tasks, particularly those involving the quotient rule, chain rule, and simplifying functions, can be attributed to several interrelated factors: First, conceptual understanding of the rules of derivatives is often lacking. Although students can memorize formulas such as the quotient or chain rule, they often do not fully understand why or how these rules work. This limited understanding makes it difficult for them to identify which rule to apply in a given context, especially when multiple rules need to be combined in a single problem. Second, the ability to simplify algebraic expressions plays a critical role in solving complex derivatives. Many students struggle with basic algebraic manipulations such as factoring, expanding, or rationalizing expressions, which are essential skills in preparing and simplifying solutions to derivatives. When simplifications are required after applying a rule (as is often the case with the chain or quotient rule), students may feel overwhelmed and make avoidable errors. Third, procedural fluency does not necessarily translate into flexible thinking. Students may succeed on problems that are easy to understand and familiar but become confused when the format or structure of the question changes. Intermediate- to advanced-level assignments often require adaptive and strategic problem-solving skills, which students have little practice in. Fourth, the lack of scaffolding and guided practice in the classroom contributes to these difficulties. When instruction is largely lecture-based and focuses more on direct instruction than interactive or exploratory learning, students miss out on opportunities to deeply engage with the material and practice applying their knowledge to a variety of nonroutine problems. Finally, anxiety and low self-esteem also play a role. Derivatives can be abstract and intimidating, and students may doubt themselves or freeze when confronted with seemingly complex expressions. Without adequate support and reinforcement, these emotional barriers can significantly impede problem-solving performance. In short, these challenges are rooted not only in mathematical difficulty but also in pedagogical, cognitive, and emotional factors that influence how students engage with and internalize the material. These results suggest the need for instructional strategies that more explicitly address conceptual understanding and multistep problem-solving in calculus.

Discussions

The findings of this study highlight significant insights into the mathematical problem-solving abilities of students in relation to derivative functions, a foundational topic in calculus. The primary finding reveals that while students tend to perform well on basic derivative problems, their performance decreases considerably as the complexity of the problems increases. This highlights the critical gap between procedural fluency knowing how to perform rules and conceptual understanding, which involves understanding why and when those rules apply. These results address the core objective of the study: to analyze students' ability to solve problems in derivative functions by measuring their performance across various difficulty levels.

Students were generally successful in solving questions that required the direct application of basic differentiation rules, such as the power rule and product rule (e.g., questions 1, 2, 6, and 10). This outcome aligns with findings from Alan & Afriansyah (2017), who observed that students taught using repetition-based strategies often demonstrated procedural mastery, though this rarely translated into higher-order reasoning. Similarly, Fitriani & Maulana (2016) found that while students performed adequately in routine exercises, they struggled when asked to apply the same rules in unfamiliar or non-routine contexts.

However, when facing more complex problems particularly those involving the quotient rule, chain rule, and rational expressions (questions 3, 4, 7, and 8) students showed a marked decline in performance. This is consistent with Malihatuddarojah & Prahmana (2019), who reported that students often commit structural errors when working with algebraic manipulation and composition in calculus problems, indicating insufficient understanding of the function's structure and interrelations. Furthermore, this study also corroborates findings from Siregar et al. (2022), which emphasize that conceptual flexibility is necessary to handle complex derivative tasks, especially when multiple differentiation rules must be applied in combination.

The most challenging items in this study were questions 5 and 9, which involved fractional exponents and nested functions. These results resonate with Padhila & Rully (2018), who documented that students faced significant obstacles when dealing with root-based and logarithmic functions due to misinterpretation of function behavior. Likewise, Sari et al. (2020) noted that students frequently failed to simplify functions appropriately before differentiating, indicating a lack of algebraic readiness and conceptual clarity in higher-level derivative tasks.

A possible interpretation for the observed difficulties lies in the limited use of cognitive scaffolding during instruction. Students may lack the metacognitive tools needed to deconstruct complex problems into manageable parts. This interpretation is supported by Nantara (2021), who argued that students' critical thinking skills often underdeveloped in traditional lecture-based environments are essential for navigating multi step calculus problems. The classroom observations and teacher interviews in this study reinforce this view, showing that instruction still largely relies on teacher-centered methods, which tend to promote passive learning and memorization over conceptual engagement.

These findings offer valuable implications for instructional practices and curriculum development. There is an urgent need to transition toward student-centered, inquiry-based approaches such as Problem-Based Learning (PBL), which have been shown by Munazah et al. (2021) to enhance students' problem-solving abilities and conceptual understanding. Curriculum designers should also incorporate higher-level questions that demand synthesis and reasoning, as well as formative assessments that challenge students to justify and explain their thinking process.

In conclusion, while students demonstrate potential in solving basic derivative problems, their struggles with complex tasks involving multiple differentiation rules highlight the need for pedagogical reform. Compared with other research, this study both confirms existing findings on the conceptual challenges in calculus and extends them by showing the nuanced difference in student performance across different levels of question complexity. Future studies might focus on experimental approaches using active learning models to empirically measure improvements in conceptual understanding and problem-solving performance in calculus instruction.

CONCLUSION

Based on the results of the analysis of the ability of grade XI students in solving mathematical problems on the material of function derivatives, it can be concluded that students' abilities are generally still relatively low. This can be seen from the low level of student success in solving high-level questions, especially in questions 5 and 9 which involve the concept of roots and fractional exponents, where students do not show adequate conceptual understanding and make many mistakes in simplifying derivative forms and using differentiation rules. Although in low and medium category questions (such as questions 1, 2, 4, 6, and 8) most students are able to solve them correctly, this ability reflects more procedural mastery than strong conceptual understanding. This finding indicates a gap between students' procedural skills and conceptual understanding caused by conventional and teacher-centered learning approaches that still dominate in the classroom, thus limiting students' active involvement and not encouraging the development of critical thinking or problem-solving skills. Scientifically, this study contributes to the understanding of challenges in learning calculus, and emphasizes the need for a more interactive and student-centered approach such as Problem Based Learning (PBL) to help students build connections between concepts and their applications. The results of this study can be used as a basis for developing a curriculum that emphasizes contextual questions and high-level thinking skills, and can be a reference for teachers in designing more meaningful learning. Further research is recommended to explore the effectiveness of innovative learning models such as PBL, inquiry learning, and flipped classroom in improving students' problem-solving abilities, as well as conducting a quasi-experimental approach to directly measure their effects on improving students' mathematics learning outcomes.

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