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ANALYSIS OF STUDENTS' MATHEMATICAL CRITICAL THINKING IN SOLVING FUNCTION DERIVATIVE PROBLEMS BASED ON GENDER DIFFERENCES

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ABSTRACT

Critical thinking is a vital skill in solving mathematical problems, particularly in calculus where understanding derivative functions is essential. Previous research indicates that gender differences may influence students' cognitive strategies and performance in mathematical problem-solving. This study aims to analyze the critical thinking abilities of mathematics education students in solving derivative function problems, with a specific focus on gender differences. A qualitative descriptive method with a case study approach was employed. The participants were male and female students selected through purposive sampling from a mathematics education program. Data collection techniques included critical thinking tests, semi-structured interviews, and documentation. The analysis framework was based on Facione's critical thinking indicators: interpretation, analysis, evaluation, inference, and explanation. Thematic analysis was used to examine qualitative data, while descriptive statistics summarized students' performance on the tests. Results revealed that female students generally achieved higher critical thinking scores than their male counterparts. They showed a stronger tendency to employ analytical and reflective strategies, whereas male students typically adopted more procedural and direct approaches. Both groups encountered significant difficulties in the evaluation and explanation phases, which are crucial to advanced critical thinking. The study concludes that gender plays a role in shaping students' critical thinking strategies in solving derivative problems. These findings underscore the importance of gender-responsive and adaptive instructional strategies in calculus learning to enhance students' logical reasoning and overall critical thinking development in higher education mathematics instruction.

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INTRODUCTION

The development of science and technology in the era of globalization requires students to have 21st-century skills, one of which is the ability to think critically and creatively (Siregar, 2022; Trapsilasiwi et al., 2023). Critical thinking and creative thinking are two essential abilities that are interrelated and are very much needed by students to face complex and unpredictable future challenges (Siregar, 2023; Aritonang, 2024). Critical thinking helps students analyze, evaluate, and make decisions logically, while creative thinking encourages them to generate new and innovative ideas in solving problems (Siregar et al., 2020; Ramdan & Anita, 2024). Both form the basis of higher-order thinking skills that are important in developing self-potential, both in academics and the world of work (Ida et al., 2021). By integrating critical and creative thinking skills, students not only become individuals who are able to understand problems in depth, but are also able to create visionary solutions that are relevant to current developments (Rahmawati et al., 2022). However, this study will focus on discussing students' critical thinking skills. Reports from UNESCO, the National Council of Teachers of Mathematics (NCTM), and the Programme for International Student Assessment (PISA) show that critical thinking skills are the main competencies that students must have in order to compete globally (Herman et al., 2024). This ability is not only needed for academic success, but also to solve complex problems in everyday life (Kusuma et al., 2024). However, the results of the PISA study show that the level of critical thinking skills of Indonesian students, especially in the context of mathematics learning, is still relatively low compared to other countries (Jediut et al., 2023).

According to Facione, critical thinking is an active and skilled intellectual discipline process in understanding, applying, analyzing, synthesizing, and evaluating information obtained from observation, experience, reflection, reasoning, or communication (Putri et al., 2024). In the world of education, especially in higher education, critical thinking is an important foundation in encouraging students to not only receive information passively, but also to ask questions, criticize ideas, and build a deeper understanding (Aimar & Azwar, 2024). Without critical thinking skills, the learning process will be shallow and unable to prepare students to face the world of work or real life challenges.

However, the reality in the field shows that students' critical thinking skills still need to be improved (Ariawan & Zetriuslita, 2021; Arbain, 2022; Clarisa et al., 2021; Luritawaty et al., 2022). Many of them are still trapped in a learning pattern that is oriented towards memorization and achieving grades alone, not on developing reflective and analytical thinking. In fact, many of the students, one of the things that influences them to choose a major in mathematics education is their dream of becoming a mathematics teacher, so that prospective mathematics teachers who are critical are needed in it (Siregar, 2024). Therefore, it is important for educators and educational institutions to create a learning environment that encourages exploration, open discussion, and the use of learning strategies that foster students' critical reasoning skills. Thus, they can become individuals who are not only intellectually intelligent, but also wise and resilient in facing various future challenges.

In mathematics education, critical thinking is an important foundation for constructing logical arguments, evaluating information, and formulating solutions to problems (Istofany et al., 2024; Hakiki et al., 2025). According to Ennis, critical thinking is a rational and reflective thinking process that focuses on deciding what to believe or do (Sihaloho & Saragih, 2024). This ability is very important in solving mathematics problems, especially on the topic of function derivatives which is a fundamental part of calculus. Function derivatives are one of the fundamental concepts in calculus that play an important role in various fields of science, such as physics, economics, engineering, and computer science (Dongoran et al., 2024). A strong understanding of this concept is not only important theoretically, but also in its application to solving real problems involving change and growth rates. In the context of mathematics

education, students' ability to solve function derivative problems reflects conceptual understanding, analytical skills, and logical and systematic thinking abilities. However, in reality, many students still have difficulty in connecting the basic concept of derivatives with their application in problem solving. Therefore, this topic is often a challenge for students because it requires a strong conceptual understanding and the ability to apply concepts in the context of problem solving.

Mathematical problem solving itself, as stated by Polya, is a process that includes understanding the problem, planning strategies, implementing solutions, and evaluating results (Pebriyanti & Amelia, 2023). Problem solving is an important process in learning that involves the ability to understand, plan, and solve a problem systematically (Son et al., 2020). In the context of education, this ability is the main indicator in measuring the reasoning power and application of concepts possessed by students (Anugraheni, 2020; Setiawan et al., 2021). In the context of function derivatives, critical thinking is needed to understand basic concepts, formulate solution strategies, and evaluate the final results logically. Thus, low mastery of basic calculus concepts is one of the main causes of students' weak ability to solve function derivative problems critically.

In addition, several studies have shown that gender differences can affect students' thinking skills and problem-solving strategies. Male students are generally superior in logical-abstract thinking, while female students tend to be more skilled in reflective and detailed thinking (Wood, 2017). Furthermore, several studies have shown that gender differences can affect students' thinking skills and problem-solving strategies. A study by Cahyono (2017) showed that although there was no significant difference in how male and female students solved problems, students with high abilities could solve problems well according to the indicators of critical thinking in mathematics. Furthermore, the PISA 2022 report shows that nationally, female students in Indonesia scored higher than male students in creative thinking. However, internationally, male students tend to excel in mathematics and science compared to female students (Awalyah et al., 2022). Therefore, it is important to review students' critical thinking skills from a gender perspective in order to identify appropriate and adaptive learning approaches and strategies.

However, most previous studies are still limited to measuring learning outcomes and have not examined in depth the critical thinking process of students in solving mathematical problems based on gender. In fact, a comprehensive understanding of these differences can help educators design more inclusive and effective learning approaches.

Based on this background, this study aims to analyze the critical thinking skills of mathematics education students in solving function derivative problems by considering gender differences. This study will also explore the problem-solving strategies used by male and female students, as well as the difficulties they face in critical thinking aspects. With this research, it is expected to provide a real contribution in improving the quality of mathematics learning, especially in calculus courses. In addition, the results of this study are also expected to be a reference for lecturers in developing learning methods that are adaptive to the characteristics and needs of students based on gender differences.

METHOD

This study uses a qualitative descriptive design with a case study approach. This approach was chosen to describe students' critical thinking skills in depth in solving function derivative problems, as well as to analyze the influence of gender differences on these abilities. The subjects of the study were first-semester Mathematics Education Study Program students from Al Washliyah University, Labuhanbatu who had completed the Calculus course. The subjects of the study consisted of male and female students who were selected using a purposive

sampling technique to ensure variations in ability levels. The object of this study was students' critical thinking skills in solving function derivative problems reviewed based on gender differences.

The instruments used in this study included critical thinking tests, interview guidelines, and documentation. The critical thinking test was compiled based on critical thinking indicators according to Facione (1990), including interpretation, analysis, evaluation, inference, and explanation. The interview guidelines were compiled in a semi-structured manner to explore the subject's critical thinking process when solving problems. Documentation in the form of video or audio recordings during the test and interview, as well as field notes, were used to support the research data.

The research procedure was carried out in several stages. In the preparation stage, research instruments such as tests, interview guidelines, and analysis grids were compiled and tested for validity and reliability. In the implementation stage, critical thinking tests were given to the research subjects, followed by in-depth interviews to explore their critical thinking strategies. The data analysis stage included processing the test results and interviews to identify differences in critical thinking skills based on gender. The final stage was reporting, where the research results were summarized in a final report.

The data collected included the results of students' critical thinking tests related to function derivative problems, interview transcripts regarding the critical thinking process, and documentation during the implementation of the research. The data were collected through tests to assess critical thinking skills, interviews to explore students' thinking processes in more depth, and documentation to support further analysis.

The research data were analyzed using a critical thinking indicator-based assessment rubric for the test results. Interview data were analyzed thematically to identify critical thinking patterns based on gender. The combination of analysis results from tests and interviews provides a comprehensive picture of students' critical thinking skills. This research method is designed to provide holistic insight into students' critical thinking skills in solving mathematical problems, while exploring how gender differences affect these thinking processes.

RESULTS AND DISCUSSION

Results

This study aims to explore the critical thinking skills of mathematics education students in solving function derivative problems, by considering gender differences. The results of the study are presented in the form of statistical descriptions and in depth analysis based on data obtained from critical thinking tests and interviews. The data from the students' critical thinking test results include seven subjects with the following scores:

Table 1. Data from the results of the critical thinking test on students

No	Subject Initials	Value
1	SNH	60
2	AT	57
3	R	55
4	RM	80
5	PAR	53
6	NPYP	51
7	MAY	50
Average		**58**
Standard deviation		**10,29**

Mean value	**55**
Maximum value	**80**
Minimum value	**50**

Based on the data obtained, descriptive statistics show that the average value of students' critical thinking skills in solving function derivative problems is 58. This figure indicates that most students have moderate critical thinking skills. However, a fairly large variation in values is seen from the standard deviation of 10.29, which reflects a significant difference in ability among students. In addition, the median value of 55 indicates that half of the students have scores below or equal to 55, while the other half are above it. The range of values of 30, with a maximum value of 80 and a minimum value of 50, strengthens the indication that there is a fairly wide gap in critical thinking skills among students who are the subjects of the study. This finding confirms that although the average critical thinking skills of students are at a moderate level, there is a striking disparity in individual achievement. Students with high scores show good critical thinking potential, while those with lower scores still seem to have difficulty in several aspects of critical thinking, such as analyzing, evaluating, or explaining solutions logically. These differences in ability can be caused by various factors, such as academic background, learning style, self-confidence, and the influence of learning methods applied in class.

Thus, these results provide a strong signal that a more differential and personalized learning approach is needed. Lecturers and educators need to consider innovative ways to encourage the development of equitable critical thinking, including through problem-based learning, small group discussions, and systematic reflective feedback. These strategies are expected to be able to bridge the ability gap and improve the quality of students' critical thinking as a whole, especially in facing conceptual challenges such as in the topic of function derivatives.

For a more in-depth analysis, four subjects were selected based on gender categories, namely:

Table 2. Subject selection value data based on gender category

No	Research Subject	Category	Value
1	AT	Masculine	57
2	MAY	Masculine	50
3	SNH	Feminine	60
4	R	Feminine	55

The selection of research subjects was carried out purposively with the aim of exploring more deeply the critical thinking strategies applied by male and female students. This is important to understand how both gender groups approach and solve function derivative problems. By analyzing the approaches used by each group, this study seeks to identify fundamental differences in their critical thinking, including the ability to interpret problems, analyze information, evaluate solutions, draw conclusions, and explain the final results. The focus on gender differences also aims to provide deeper insight into the influence of gender factors on the development of critical thinking skills in the context of mathematics learning, especially in differential calculus material.

In addition, a qualitative approach through in-depth interviews allows researchers to explore students' thinking processes more personally, which cannot be fully revealed through written tests alone. Based on the interview results, it is known that female subjects (SNH and R) tend to use more reflective strategies, with a tendency to associate derivative concepts with real contexts and build logical arguments at each step they take. In contrast, male subjects (AT and MAY) focus more on direct procedural application, such as remembering formulas and

performing calculations without evaluating intermediate results or explaining the reasons for using certain strategies.

To explore more deeply the critical thinking strategies of students in solving function derivative problems, four research subjects were purposively selected based on gender categories: two male students (AT and MAY) and two female students (SNH and R). This selection aimed to gain a deeper understanding of how gender can influence the way students approach, process, and reflect on mathematical problems, especially in the context of differential calculus.

Based on the results of the written test, AT (score: 57) showed fairly good procedural fluency. He was able to correctly identify and apply the rules of derivation, but skipped the step of explaining the reasons for using certain rules. In the interview, AT admitted, "I just use the formula because it's the fastest way. If I'm sure, I don't think too much about why the formula is used." This shows that his approach is result-oriented and emphasizes speed and accuracy more than reflection on the process.

MAY (score: 50), another male subject, also relied heavily on procedural methods. His written answers showed a mechanical application of the formula, but some steps were skipped or incomplete. In the interview, she stated, "I remember my teacher said that this kind of problem uses the usual derivative formula. I just followed it like that." This reinforces the shallow understanding, where conceptual reasoning and evaluation are less visible.

In contrast, SNH (score: 60) presented a well-structured solution in her written test, accompanied by annotations explaining the reasons for using each derivative rule. She related the problem to previous examples and provided logical justification for her approach. Her interview reflected this analytical tendency: "I wanted to know why the answer was like that, so I tried to relate it to the function graph and the meaning of the derivative itself." SNH's response demonstrated reflective critical thinking, with strong interpretation, inference, and explanation skills.

R (score: 55), the second female subject, also demonstrated an analytical approach. Although there were some minor errors in her calculations, her solution process was thorough and provided justification for each step. In the interview, she stated, "I tried to imagine this problem in the form of a graph, then I saw how the values changed so I could better understand what was being asked." R's strategy highlights an attempt to construct meaning and explore the problem beyond just procedural calculations.

These findings indicate a clear difference in cognitive strategies between male and female students. Male students (AT and MAY) prioritized procedural execution, often missing the rationale behind the methods used, while female students (SNH and R) showed deeper engagement through reflective reasoning and contextual interpretation. This analysis supports the idea that critical thinking in mathematics is not solely dependent on mastery of the material, but is also influenced by cognitive style, which in turn may be related to gender-influenced tendencies. Female students in this study tended to internalize mathematical meaning and showed greater metacognitive awareness.

Statistical analysis based on gender categories produces the following information:

Table 3. Statistical Description of Differential Calculus Task Achievement

		Male	Female
N	Valid	2	5
	Missing	1	1
Mean		53,5	59,8
Median		53,5	55

Std. Deviation	4,95	11,78
Range	7	29
Minimum	50	51
Maximum	57	80

The results of the study showed several significant differences in the achievement of critical thinking skills between feminine and masculine students. The average score of feminine students was recorded higher, which was 59.8, compared to masculine students who had an average score of 53.5. This shows that in general, female students tend to have better critical thinking skills in solving function derivative problems.

In addition, the standard deviation for the feminine category of 11.78 reflects the presence of higher diversity or heterogeneity in the group. This means that female students have very varied levels of performance, ranging from low to very high. In contrast, the standard deviation of 4.95 in the masculine category shows that the critical thinking skills of male students are relatively more homogeneous, although in the lower range of values.

The much larger range of values in the feminine group (29 points) compared to the masculine group (7 points) also reinforces the existence of significant internal disparities. This difference is important to note because it shows that uniform learning strategies or approaches may be less effective, especially for female students who show more diverse learning needs.

These findings underscore the importance of learning approaches that not only consider average achievement levels but also take into account the diversity of abilities within a particular gender group. Thus, more flexible pedagogical strategies are needed, for example through providing challenging but adaptable tasks to individual abilities, providing gender-based learning support, or integrating collaborative learning techniques that encourage interaction between different thinking styles. By considering these dynamics, educational institutions and teachers can design more targeted interventions to improve students' critical thinking skills, as well as reduce achievement gaps that may arise due to differences in gender and learning styles inherent in each individual.

Based on the results of the study, it can be concluded that the critical thinking skills of mathematics education students in solving function derivative problems are generally still in the moderate category, with an average score of 58. This shows that although students have received calculus learning, their understanding of the concepts and critical thinking processes in solving function derivative problems is not yet fully optimal. There is still a gap between the understanding of basic calculus concepts and students' ability to integrate them into logical and in-depth problem-solving strategies.

Furthermore, this study revealed significant differences in critical thinking skills based on gender. Female students performed better than male students in solving function derivative problems. They tended to use a more analytical, systematic, and reflective thinking approach. This can be seen from their tendency to read questions carefully, consider various alternative solution strategies, and evaluate the resulting solutions. In contrast, male students relied more on a procedural approach, namely directly applying formulas or technical steps without conducting an in-depth analysis of the context or accuracy of the answers obtained.

One interesting finding in this study is the greater variation in scores in the female student group, indicating that critical thinking skills in this group are more diverse. There were students who performed very well, but there were also those who still had difficulties, especially in the evaluation and explanation stages, two important aspects of critical thinking according to the Facione indicator. Meanwhile, male students showed scores that tended to be more stable, but overall were below the female group.

This finding has important implications for the development of learning strategies in higher education environments. Differences in approaches and results based on gender are indicators that the learning strategies used so far have not been fully responsive to the different characteristics and learning needs of male and female students. Therefore, it is important for lecturers to design more adaptive learning, for example by integrating collaborative approaches, problem-based learning, and formative evaluations that encourage students to not only work on problems, but also explain and evaluate the solutions they create. By considering these differences in thinking styles, it is hoped that mathematics learning, especially in differential calculus materials such as function derivatives, can be more effective in developing critical thinking skills for all students without exception. This study also serves as a basis for broader follow-up studies in the context of mathematics education, with a richer population coverage and variety of indicators.

Discussions

This study explores the critical thinking abilities of mathematics education students in solving derivative function problems, with a specific focus on gender differences. The results reveal a notable distinction between the approaches used by male and female students, suggesting that gender can significantly influence critical thinking strategies in mathematical contexts.

The most prominent scientific finding of this research is that female students tend to demonstrate higher levels of critical thinking in problem solving compared to male students. This result is consistent with the findings of Wood (2017), who noted that female students are generally more reflective and detail-oriented in their cognitive processing. Similarly, Nugroho et al. (2021) found that female high school students in Indonesia outperformed their male peers in mathematical reasoning tasks, particularly in identifying and evaluating multiple solution pathways. These similarities indicate a recurring pattern across educational levels and cultures.

In contrast, male students in the present study showed a stronger preference for procedural approaches, often skipping critical evaluation and alternative strategy exploration. This supports the findings of Sa'dijah & Fitriani (2020), who reported that male students are often more result-driven and quick to apply formulas without deeply analyzing the problem's context. While this approach may lead to faster responses, it may also overlook important nuances that are crucial in derivative problems, where understanding change rates and interpretations is key.

Moreover, this study found that both male and female students struggled with the evaluation and explanation stages of critical thinking. This observation aligns with Hiebert & Wearne (1996), Hiebert (2007), and Chappell (2006) assertion that many students lack deep conceptual understanding in calculus, making it difficult for them to justify their solutions beyond procedural accuracy. Similarly, Darmawan & Siswono (2022) reported that students often fail to articulate reasoning during mathematical problem-solving, especially when confronted with abstract calculus concepts like derivatives.

Another important point of comparison is the variation in critical thinking abilities within gender groups. The standard deviation for female students was significantly higher than that of male students, indicating a broader range of abilities among female participants. This echoes findings by Muhtarom & Masrukan (2022), who emphasized the importance of individual differences in learning, suggesting that instructional strategies should not only consider gender but also variations within gender groups.

The qualitative data collected through interviews also reinforce earlier studies by Ennis (1987), who defined critical thinking as rational and reflective thinking focused on decision-making. Female students in this study exhibited precisely these traits carefully analyzing, cross-

checking, and justifying their answers whereas male students were more direct and formulaic, often omitting justification steps.

Collectively, these comparisons highlight the consistency of the current findings with existing literature, while also offering nuanced insights specific to function derivative problems in calculus. The implications of this study extend beyond gender-based observations; they suggest a broader need to strengthen conceptual understanding and evaluative reasoning in mathematics education.

The findings of this study have several important educational implications. First, instructional differentiation is crucial educators should design learning experiences that not only focus on finding correct answers but also emphasize process-based evaluation and reflective explanation. Applying gender responsive teaching approaches can help accommodate the diverse cognitive strategies employed by students. Collaborative problem solving can also be effective; forming mixed gender and mixed-ability groups may foster peer learning, allowing students to share and adopt both analytical and procedural problem solving strengths. In terms of curriculum development, there is a clear need to restructure the calculus curriculum to balance between conceptual understanding and procedural fluency. Incorporating real-world problems related to derivatives can make learning more meaningful and promote deeper critical thinking. Additionally, targeted interventions should be considered male students might benefit from support that enhances their reflective thinking, while female students may need reinforcement in building decision-making confidence to improve the efficiency of their problem-solving processes. Finally, teacher training must address the importance of recognizing and nurturing diverse thinking styles; by understanding these cognitive tendencies, educators can provide more personalized and effective feedback to support students' development of critical thinking skills.

In conclusion, understanding gender differences in critical thinking enriches our perspective on how students learn and approach mathematical challenges. This awareness is essential for designing more inclusive and effective mathematics instruction. By integrating reflective practices and strategic evaluation into calculus education, educators can help all students regardless of gender become more confident, thoughtful, and capable mathematical thinkers.

CONCLUSION

This study concludes that critical thinking abilities among mathematics education students in solving derivative function problems vary significantly based on gender. Female students generally demonstrated stronger interpretative and analytical skills, while male students tended to rely on procedural strategies with less emphasis on reflective evaluation. These findings contribute to a deeper understanding of cognitive and strategic differences in critical thinking based on gender, particularly within the context of differential calculus. The results emphasize the importance of developing inclusive and differentiated instructional strategies that go beyond assessing correct answers and instead focus on the reasoning processes influenced by gender-specific cognitive tendencies.

From a scientific perspective, this research supports the integration of reflective and evaluative thinking components into mathematics instruction, especially in subjects like calculus that demand higher-order reasoning. The study serves as a bridge between gender studies and mathematics education, offering valuable insights for educators and curriculum developers to design more responsive teaching practices. Practical applications of this research include the development of gender-sensitive learning modules, the use of collaborative problem-solving formats that promote strategic exchange among students, and the design of assessment models that prioritize process-oriented thinking alongside outcomes.

To extend this research, future studies should investigate additional variables that may influence these gender-based differences, such as learning motivation, cognitive styles, self-efficacy, and classroom dynamics. Moreover, conducting experimental research to evaluate the effectiveness of targeted instructional interventions aimed at enhancing critical thinking across genders could provide further validation and practical direction for mathematics education reform.

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