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EVALUATION OF STUDENTS' CRITICAL THINKING ABILITY IN SOLVING REAL ANALYSIS PROBLEMS

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ABSTRACT

Critical thinking skills are essential for students, particularly in solving complex problems in Real Analysis, as these skills foster academic growth and prepare them for professional challenges. However, many students still struggle to apply these skills effectively. Through a qualitative case study involving fifth-semester students from the Tadris Mathematics program, this research explores the students' critical thinking demonstrate in solving Real Analysis problems, alongside the factors that support or hinder this ability. Data were gathered through semi-structured interviews, observations, and assessments, focusing on students' problem-solving approaches. The results indicate that while most students (62%) exhibit moderate critical thinking skills, a significant portion (38%) face challenges in developing these abilities, with none achieving high-level proficiency. Supporting factors include cognitive ability, motivation, and a conducive learning environment, while barriers include limited understanding of basic concepts, time constraints, and psychological obstacles. Students predominantly relied on procedural methods to solve problems, hindering deeper analytical thinking. The findings highlight the need for more interactive and reflective teaching methods, such as problem-based learning and group discussions, to enhance students' critical thinking and problem-solving skills. These insights offer valuable recommendations for improving teaching strategies in Real Analysis and contribute to advancing mathematics education in Indonesia.

Keywords: Critical Thinking, Real Analysis, Problem-solving, Teaching Strategies, Cognitive Development, Qualitative Research.

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PRELIMINARY

Critical thinking skills are essential for students facing complex problems in real-analysis courses, mainly because this ability supports their academic development and helps prepare them to face challenges in the professional world (Ennis, 2018; Facione, 2023). By thinking critically, students can identify, analyze, and solve complex mathematical problems logically, which is the essence of in-depth understanding and application of mathematical concepts in real contexts (Draper, 2015; Paul & Elder, 2020). However, several studies have shown that the student's critical thinking skills in real-analysis still need to be improved. For example, Setiawan and Rahmadani found that students often have difficulty understanding

abstract concepts such as theorems and definitions, which then hinders the application of the concept in solving problems. more complex problems (Setiawan & Rahmadani, 2019).

This is mainly due to the learning approach, which is still centered on lecturers, where students tend to only receive information without much active involvement in the learning process (Brookhart, 2010; Wahyuni et al., 2023). In many universities in Indonesia, mathematics courses are often taught using a conventional method, which emphasizes memorization and practice questions without providing opportunities for students to develop critical thinking skills or deepen their understanding of the material (Suryana & Iskandar, 2021). Patmawati (2016) noted that the lack of interactive learning methods could hinder students' analytical skills, which are needed in real analysis courses (Patmawati, 2016; Suryana & Iskandar, 2021). Lecturers often experience limited time and resources, making it difficult to implement learning methods that are more interactive, which ultimately influences the development of skills and critical thinking of students (Wulandari, 2019).

These limitations have serious consequences, especially for prospective mathematics educators who are expected to teach the next generation to become critical and analytical thinkers in solving mathematical problems (Facione, 2023). Students who do not master critical thinking skills will face difficulties in solving complex problems in the professional world because they have difficulty formulating effective solutions (Brown & Harris, 2018). In addition, limitations in critical thinking also affect their ability to handle multidimensional problems, often only repeating information analysis without conducting in-depth analysis (Johnson, 2020; Pramasdyasari et al., 2024; Warsah et al., 2021).

This study evaluates students' critical thinking skills in solving problems in real analysis courses. Specifically, it aims to identify and understand the extent to which students are able to apply critical thinking skills in solving complex problems in the field of real analysis. In addition, it aims to reveal factors that support or hinder students' critical thinking skills and explore their perceptions of the basic concepts and analytical procedures in this course.

In this context, previous studies are more general and less specific to real analysis courses. For example, Setiawan and Rahmadani (2019) only discussed obstacles in understanding abstract concepts without specifically highlighting critical thinking skills. Meanwhile, Patmawati (2016) examined the effectiveness of collaborative learning in basic mathematics without a specific focus on real analysis. Wulandari (2019) explored obstacles in developing critical thinking skills but more on general teaching obstacles and not on evaluating students' abilities in real analysis. Dewi et al.'s (2021) research, which highlighted

the influence of problem-based learning on critical thinking skills, also did not explore students' perceptions in real analysis. Meanwhile, Gunarti, Firdaus, and Budiawan (2023) discussed the realistic mathematics approach in teaching basic mathematics to improve critical thinking skills.

The novelty of this study lies in its specific focus on evaluating critical thinking skills in the context of real-world analysis and identifying factors that contribute to these abilities based on students' experiences. With a qualitative approach, this study can explore students' perspectives in depth that are not accessible through quantitative methods (Creswell & Cresswell, 2018; Yin, 2016). The results of this study hope to contribute to developing more relevant, collaborative, and adaptive teaching methods in higher education to improve students' critical thinking skills in Indonesia. This is also in line with the government's efforts to improve the quality of national education (Dewi et al., 2021; Kementerian Pendidikan dan Kebudayaan RI, 2021; Khusniddin, 2018).

METHODS

This study employs a descriptive qualitative approach using a case study design to investigate students' critical thinking skills in solving Real Analysis problems. Subjects were selected through purposive sampling, involving 5th-semester Mathematics Education students enrolled in the course. A total of 21 students were selected as research subjects because they were active in lectures and had studied real analysis material in depth. Selection was based on input from the course lecturer to ensure diverse levels of understanding (Creswell & Cresswell, 2018).

The instruments used in this study included semi-structured interviews, observations, and critical thinking skills tests. The semi-structured interviews aimed to explore in detail the strategies and obstacles students encountered when solving real-world analytical problems. Observations were conducted to observe students' thought processes and behaviors while taking the test, while a critical thinking skills test was used to quantitatively measure the development of students' critical thinking skills. These three instruments were applied sequentially and complement each other to provide a comprehensive picture of students' critical thinking skills in the context of solving real-world analytical problems. The validity of the instrument was tested using the content validity method through the involvement of mathematics and education experts, while the reliability of the instrument was tested using the inter-rater reliability method, which achieved a coefficient of 0.8 or more (Sugiyono, 2019; Yin, 2016).

The collected data were analyzed using thematic analysis techniques, including the process of data reduction, data presentation, and conclusion, to find patterns in students' critical thinking skills (Braun & Clarke, 2019). Data reduction involves selecting and filtering the most relevant information to the research focus to make the data more concise and manageable. The simplified data is then organized and presented in narrative or tabular form to facilitate the identification of key patterns and themes. The final stage is drawing conclusions based on the emerging themes to ensure a comprehensive understanding of the data. Table 1 illustrates the ability categories, providing a clear picture of the level of critical thinking skills among the research participants (Wulandari & Warmi, 2022).

Table 1. Students' Critical Thinking Skills Categories

Interval	Category
$X < (x - SD)$	Low
$(x - SD) \leq X \leq (x + SD)$	Medium
$X > (x + SD)$	High

This study uses four components of critical thinking indicators, namely interpretation, analysis, evaluation, and inference (Rosmalinda et al., 2021; Wulandari & Warmi, 2022). Interpretation is the process by which a person understands and conveys information from a problem. Analysis is the process of understanding the relationship between theorems, assumptions, and proof steps in a problem, by providing clear and precise explanations. Evaluation is the process of solving a problem using the appropriate strategy, completing the proof of a theorem with the correct steps, and providing appropriate explanations. Inference is the process of drawing accurate and complete conclusions based on proofs carried out with the correct steps.

RESULT AND DISCUSSION

This study involved 21 fifth-semester Mathematics Education students taking Real Analysis. The focus of the study was on students' critical thinking skills in solving problems in the Real Analysis course. This course requires students to not only memorize theory but also analyze, evaluate, and draw logical conclusions from complex mathematical arguments. However, in reality, many students still experience difficulties in honing these critical thinking skills, which ultimately affects their understanding and ability to solve more complex problems.

This problem falls within the realm of critical thinking because problem-solving in Real Analysis requires students to break down complex issues into simpler components,

assess the validity and accuracy of arguments, and draw conclusions based on sound reasoning. The difficulties students experience in these areas indicate challenges in developing critical thinking skills, making evaluation of these abilities crucial in the context of college-level mathematics learning. The purpose of this study was to evaluate students' critical thinking skills in solving problems in Real Analysis and to identify factors that support and hinder the development of their critical thinking skills. The study also aimed to understand students' perceptions of the basic concepts and analytical procedures taught in this course.

1. Students' Critical Thinking Skills in Solving Real Analysis Problems

The critical thinking ability test assessed how students could apply these skills to solving complex Real-Analysis problems. The analysis showed that of the 21 students involved, most had intermediate critical thinking skills, while some showed low critical thinking skills. The high category reflects students who can demonstrate excellent critical thinking skills in solving real analysis problems. They can usually identify problems, conduct in-depth analyses, and provide precise and detailed solutions.

The moderate category describes students who have intermediate critical thinking skills. They have shown the ability to solve most real analysis problems, but they may still have difficulty dealing with some complex aspects or explaining the solution in detail. Figure 2 shows an example of a moderate student's answer that shows logical and coherent steps in solving the problem but tends to follow a procedural pattern without in-depth reflective analysis.

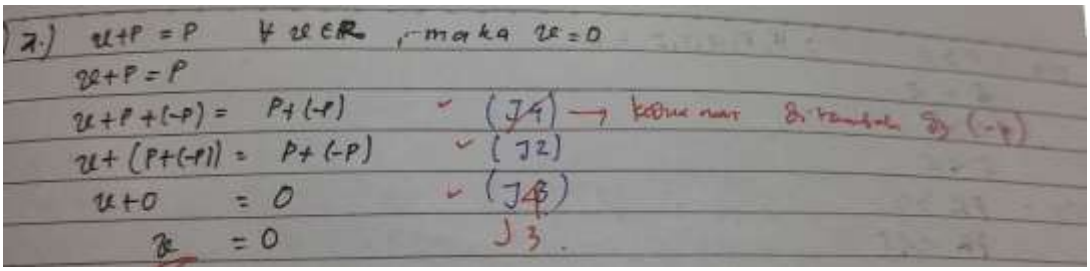

Figure 1. Medium Category Student Answers to Question $x + p = p$

Students in the medium category in answering the question $x + p = p$ for all $x \in \boldsymbol{R}$, then $x = 0$, showed a reasonably good understanding with coherent and logical steps. Students started with the correct initial step, namely $x + p + (-p) = p + (-p)$, and simplified it to $x + 0 = 0$, then concluded $x = 0$ correctly. This reflects an understanding of inverse and identity elements in real number operations. Compared to students in the low category, who were often confused in arranging steps or misapplying operations, the answers

in the medium category were more structured and closer to perfect completion. However, even though they were correct, students in the medium category tended to only follow procedural steps without providing in-depth analysis, thus indicating that there is room for further development in reflective thinking skills. The information provided on the right side of the answer, namely J2, J3, and J4, are the algebraic properties of real numbers, which are, in sequence, associative, identity, and inverse properties.

Students who get a total score <30 are included in the Low category. This describes students who have inadequate critical thinking skills in solving real analysis problems. They often have difficulty in identifying and understanding problems, as well as difficulty in providing appropriate or in-depth solutions. Figure 2 shows an example of an answer from a low-category student, which shows errors in understanding and solving real analysis problems.

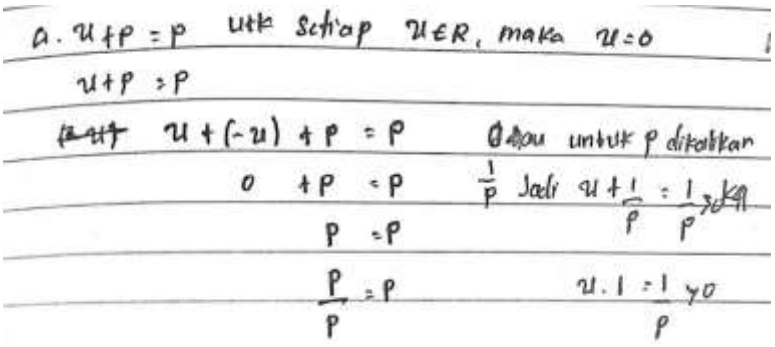

Figure 2. Low Category Student Answers to Question $x + p = p$

Students in the low category in answering the question $x + p = p$ for all $x \in \boldsymbol{R}$, then $x = 0$, showed a lack of understanding of the basic concept of real number operations. The student's initial step, which was using $x + (-x) + p = p$, was correct but was not followed up with proper algebraic manipulation. Students seemed confused with notation and symbols, such as the incorrect use of $x + \frac{1}{p} = \frac{1}{p}$, which indicated a conceptual error. At the end of the answer, the student concluded that $p = p$, but failed to show that $x = 0$, thus failing to achieve the question's objective. This answer reflected a more mechanical approach without in-depth reasoning, indicating difficulty in applying the basic concept of inverse operations to solve problems logically and precisely.

Table 2. Distribution of Students' Critical Thinking Ability Levels in Real Analysis Courses

Critical Thinking Skills Category	Number of Students
Low ($X < 30$)	8
Medium ($30 \leq X \leq 59$)	13
High ($X > 60$)	0

Based on data on students' critical thinking skills in solving problems in the Real Analysis course, most students (62%) are in the Medium category, which means they show adequate critical thinking skills. However, they still need development to solve problems in more depth. Around 38% of students are in the Low category, indicating that they have difficulty solving real analysis problems and need more attention to improve their critical thinking skills. No students are in the High category, which indicates that no students have reached an optimal level of understanding and skills in solving the problems. These findings indicate the need for a more effective teaching approach that provides more practice, significant challenges, and intensive guidance to help students improve their critical thinking skills in this course.

2. Supporting and Inhibiting Factors of Critical Thinking Skills

Student reflections revealed some factors that supported and hindered their critical thinking skills in the Real Analysis course. One of the main supporting factors was students' cognitive skills, which allowed them to analyze and evaluate the material well (Jaramillo et al., 2025). Motivation and interest in learning also played an important role, especially for students with an incredible drive to understand complex concepts (Borbon et al., 2025). In addition, a supportive learning environment, including a comfortable classroom atmosphere and the availability of learning materials such as books and sample questions, also contributed positively to the learning process (Eze et al., 2022).

On the other hand, the biggest obstacle experienced by students is the lack of understanding of basic concepts, such as mathematical proof and sequence properties. Limited time to study the material in depth during lectures or exams is also a challenge that is often felt (Jaramillo et al., 2025). Several students mentioned psychological obstacles, such as fear of asking questions or lack of self-confidence, which prevented them from being more active in exploring understanding. In addition, the lack of variation in learning resources was considered less supportive in helping students understand more abstract concepts. Figures 3 and 4 compare factors that support and inhibit students' critical thinking skills.

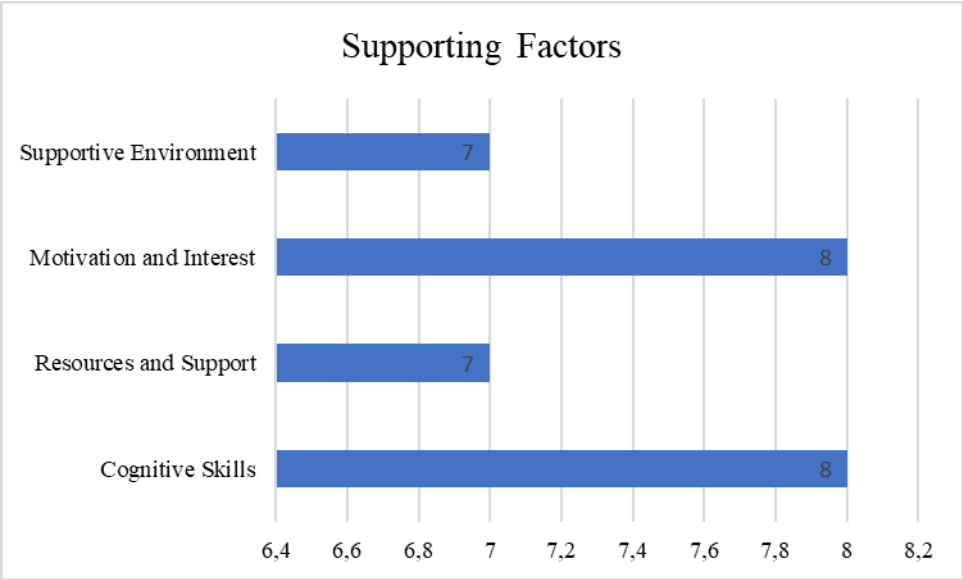

Figure 3. Supporting Factors Students' Critical Thinking Skills

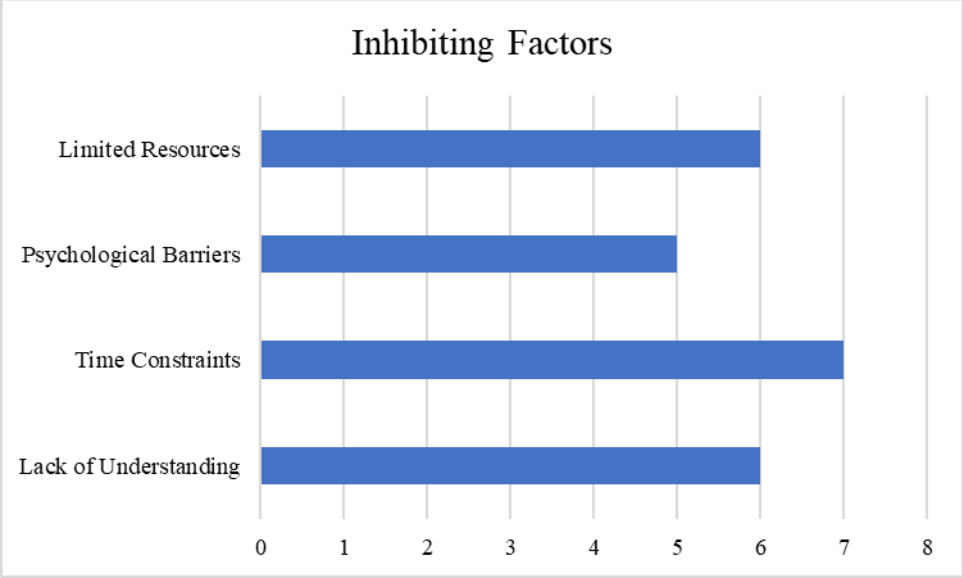

Figure 4. Inhibiting Factors Students' Critical Thinking Skills

Figures 3 and 4 show that although cognitive skills and motivation have high scores as supporting factors, lack of understanding and time constraints are significant barriers that must be overcome. Therefore, a planned effort needs to be made to increase the utilization of supporting factors and reduce the influence of these barriers in order to optimize students' critical thinking skills.

3. Student Perceptions of Real Analysis Learning

Based on student reflection, perceptions of Real Analysis learning show that the main difficulties experienced are understanding the proof (35%) and limited exam time (20%), often hindering optimal problem-solving. Students often find it difficult to prove theorems, especially when they have to connect definitions and basic concepts that need to be

understood well, which is one of the biggest challenges in learning mathematical analysis (Chand, 2021). Lack of sample questions (15%) is also an obstacle, although many students feel helped by group discussions (18%) and effective lecturer explanations (25%). The existence of supporting materials such as example questions and group discussions has been proven to be very helpful for students in understanding more complex material (Sari et al., 2021). However, psychological obstacles such as fear of asking questions (12%) also affect students' active participation in learning. Patterson (2021) notes that psychological barriers, such as anxiety about asking questions or feeling embarrassed, often prevent students from being more actively involved in learning and overcoming the difficulties they face (Patterson, 2021). This curve illustrates that although there is support from teaching methods and discussions, there is still a need to improve reflection time and provide more varied supporting materials.

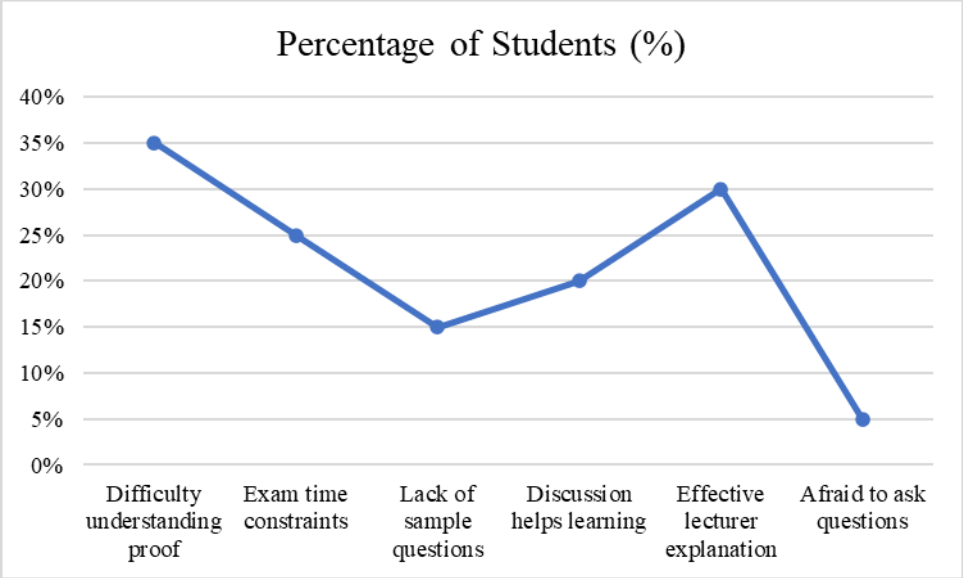

Figure 5. Student Perceptions of Real Analysis Learning Aspects

4. Students' Problem-Solving Strategies in Critical Thinking Ability Tests

The reflection results showed that most students (13 out of 21) used a procedural approach, following the steps taught without exploring alternative solutions. This approach is practical for structured questions but does not support in-depth analysis. A total of 5 students applied a reflective approach, which involves in-depth analysis and consideration of various alternative solutions, usually supported by discussion or direct interaction with the lecturer. Meanwhile, 3 students showed inconsistent strategies, where they could solve simple questions but had difficulty with complex ones. To support the development of

reflective strategies, gradual questions, interactive discussions, and variations of questions are needed to strengthen students' critical thinking skills.

Table 2. Students' Problem-Solving Strategies in Thinking Ability Tests Kritis

Problem-Solving Strategy	Description	Number of Students
Procedural	Following structured steps without further exploration	13
Reflective	Conducting critical analysis and considering alternatives	5
Inconsistent	Understanding fluctuates between simple and complex problems	3

Table 2 summarizes the main findings of students' problem-solving strategies. Most students still rely on procedural approaches, so learning strategies that emphasize critical analysis are needed to help them develop reflective thinking skills optimally.

This study revealed that most students (62%) use a procedural approach when working on Real Analysis problems. This approach involves implementing structured steps without considering alternative solutions. Although the procedural approach can be practical for clearly structured problems, this approach does not support the development of critical thinking skills (Anggraini & Fauzan, 2020). This finding follows the results of previous studies, which show that a mechanical approach can limit students in exploring various alternative solutions (Wang & Abdullah, 2024). In the context of national education, Putri and Haryanto (2021) also found that reliance on procedures can hinder a deeper understanding of concepts.

On the other hand, technology-based learning models, such as those implemented through Schoology in mathematics learning, can improve students' critical thinking skills (Pradana & Noer, 2023). This more interactive learning model allows students to be more open in seeking alternative solutions, which supports the development of their problem-solving skills. Furthermore, research by Nashrullah et al. (2023) revealed that students' critical thinking skills are greatly influenced by learning that emphasizes self-regulation and mobile learning-based learning, which allows students to be more active in their learning process (Nashrullah et al., 2023).

As many as 24% of students implemented reflective strategies involving in-depth analysis and consideration of various alternative solutions. Students who use this strategy tend to have a better understanding of concepts and more developed critical-thinking skills (Nasution et al., 2021). Other studies have also shown that reflective approaches can improve analytical and problem-solving skills (Cacho & Abbas, 2022; Yuni et al., 2021). Kurniawan et al. (2020) found that group discussions and independent reflection can strengthen reflective strategies in Indonesia.

In contrast, 14% of students showed inconsistent strategies, characterized by fluctuations in understanding between simple and complex questions. This may be due to the lack of gradual practice and adequate guidance (Anggraini et al., 2022). Previous research has emphasized the importance of structured feedback to build consistency of understanding (Cuyacot & Cuyacot, 2022). In the national context, Wijaya and Prasetyo (2021) noted that intensive guidance can reduce inconsistencies in student understanding.

The first assumption is that procedural strategies are dominated by a learning approach that overemphasizes the application of steps without exploring alternatives. This follows the behaviorist theory, which emphasizes repetition and reinforcement (Schunk, 2020). However, constructivism theory suggests effective learning should allow students to build understanding through exploration and reflection (Piaget, dalam Schunk, 2020). Research by Anggraini et al. (2022) shows that a learning approach that integrates local culture can improve understanding of mathematical concepts.

The second assumption is that gaps in understanding basic concepts cause the lack of reflective strategies. According to Facione (2023), critical thinking skills depend on deep conceptual understanding (Facione, 2023). The revised Bloom's Taxonomy emphasizes mastering basic concepts before reaching the evaluation level (Wilson, 2016).

This study's recommendations include applying problem-based learning methods, structured group discussions, and step-by-step exercises to enhance the adoption of reflective strategies. This approach effectively improves students' analytical and critical thinking skills (Yuni et al., 2021). In Indonesia, it is recommended that ethnomathematics be integrated into learning to enhance student engagement and understanding (Anggraini et al., 2022).

CONCLUSION

This study shows that the majority of students have moderate critical thinking skills (62%), while 38% are at a low level, with none reaching a high level. The main supporting factors are learning motivation, cognitive ability, and a conducive learning environment, while obstacles include a lack of understanding of basic concepts, time constraints, and psychological obstacles such as fear of asking questions. These findings indicate the need for a problem-based learning approach, structured group discussions, and gradual exercises to improve students' critical thinking skills. The implication of this study is the need for innovation in real-analysis teaching strategies to support the development of students' critical thinking skills. However, the limitations of this study lie in the small sample size and focus on one particular study program, so the results may not be generalizable. Further research

should involve more respondents from various study programs and explore more varied innovative learning methods.

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