Students' Mathematical Critical Thinking Skills and Self-Esteem as a Basis for PjBL–STEM

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Abstract

Mathematical critical thinking skills are essential 21st-century competencies that must be developed through mathematics learning. However, results from international and national assessments indicate that these skills remain low among junior high school students. This study aims to describe the mathematical critical thinking skills and self-esteem of eighth-grade students at SMP Negeri 10 Semarang as a basis for designing innovative learning using a Project-Based Learning (PjBL) model with a STEM approach assisted by flipbook-based media. This study employed a descriptive quantitative design involving 31 eighth-grade students. Data were collected through a mathematical critical thinking skills test and an interview with a mathematics teacher. The results showed that the average score of students' mathematical critical thinking skills was 31.77, with most students categorized at a low level. Interview findings indicated that students' self-esteem tended to be moderate to low, characterized by low confidence, passive participation, and reluctance to engage with non-routine problems. These findings highlight the need for learning designs that simultaneously address cognitive and affective aspects through flipbook-assisted PjBL–STEM learning.

Keywords: mathematical critical thinking skills, self-esteem, STEM, PjBL, flipbook.

Introduction

The rapid development of science and technology in the 21st century requires students to master higher-order thinking skills, one of which is critical thinking (Asri et al., 2023). In mathematics learning, critical thinking involves not only computational proficiency but also the ability to analyze information, evaluate arguments, and solve non-routine problems systematically (Elfiandi Rizaldi et al., 2023; Hidayatullah et al., 2020). Therefore, mathematical critical thinking skills are essential competencies that must be developed through effective learning processes.

However, evidence from international assessments such as the Programme for International Student Assessment (PISA) indicates that Indonesian students' mathematical thinking skills remain relatively low. Based on the PISA 2022 results, Indonesia ranked 65th out of 81 participating countries, with many students demonstrating proficiency primarily in procedural tasks while experiencing difficulties in reasoning, decision-making, and problem solving (OECD, 2023; Sani & Prayitno, 2020). This condition reflects prevailing learning practices that emphasize memorization and routine exercises rather than deep conceptual

understanding and the application of mathematics in real-life contexts (Wulandari & Warmi, 2022; Rahmawati et al., 2023).

In addition to cognitive factors, affective aspects such as self-esteem play an important role in students' success in mathematics learning (Fisher et al., 2022). Students with high self-esteem tend to be more confident, active in discussions, and persistent in solving problems, while students with low self-esteem are often passive and reluctant to take intellectual risks (Melyana & Pujiastuti, 2020). In the context of mathematical critical thinking, self-esteem is closely related to students' willingness to explore ideas, propose arguments, and evaluate solutions (Bitasmi'ah, 2025). Students with positive self-esteem are more open to exploring various solution strategies and are less inhibited by fear of failure, allowing their mathematical critical thinking skills to develop more optimally (Ginanjar & Fitriah, 2022). Therefore, efforts to enhance mathematical critical thinking skills should be accompanied by initiatives to foster positive self-esteem.

Project-Based Learning (PjBL) combined with a STEM approach has been widely recognized as an effective instructional model for fostering critical thinking and self-esteem student (Chimwayange, 2025; Fitriani et al., 2024; Lianti et al., 2023). PjBL encourages students to actively solve contextual problems through meaningful projects, while the STEM approach integrates multiple disciplines to strengthen reasoning and creativity (Undari et al., 2023; Setyawati et al., 2022). The effectiveness of this model can be further enhanced through the use of digital learning media, such as flipbooks, which provide interactive visualization, flexible access to learning materials, and structured presentation of contextual problems (Chairunnisa & Usodo, 2025; Purnomo et al., 2024).

This study focuses on eighth-grade students because Grade VIII represents a critical transitional stage in junior high school mathematics learning. At this level, students have mastered basic mathematical concepts and begin to encounter more complex, non-routine problems that require higher-order thinking. Identifying students' mathematical critical thinking skills and self-esteem at this stage is essential to support their readiness for more abstract mathematical content in the following grade. Therefore, this study aims to describe the mathematical critical thinking skills and self-esteem of eighth-grade students as a foundation for flipbook media assisted PjBL–STEM learning.

Method

This study employed a descriptive quantitative research design. The participants consisted of 31 eighth-grade students from class VIII-E at SMP Negeri 10 Semarang in the 2025/2026 academic year. Class VIII-E was selected purposively based on the school's instructional plan to implement innovative learning designs, including PjBL–STEM assisted by digital media, in the upcoming semester.

The research instruments included a mathematical critical thinking skills test and a teacher interview guide. The critical thinking test was developed based on Ennis's indicators, covering basic clarification, the basis for a decision, inference, advanced clarification, and supposition and integration. The instrument was reviewed by two experts in mathematics education to ensure content validity and alignment with the research objectives. Teacher interviews were conducted using a semi-structured format to explore students' self-esteem characteristics, including confidence, participation, and persistence in mathematics learning. Internal validity was ensured through expert validation of instruments, consistent test administration procedures, and the use of clear scoring rubrics. Data validity was strengthened through triangulation between quantitative test results and qualitative data obtained from teacher interviews.

The data analysis techniques in this research primarily utilize students' written test results, which are processed descriptively by calculating the mean, minimum, and maximum scores, as well as determining the distribution of students' critical thinking skill categories. These categories are classified based on specific score thresholds: a score ≥ 80 is categorized as high, a score $60 < \text{score} < 80$ is categorized as moderate, and a score ≤ 60 is categorized as low. Furthermore, interview data are analyzed qualitatively to identify the specific characteristics of students' self-esteem in relation to their performance on the written tasks. This multi-method approach ensures that the relationship between the students' critical thinking levels and their self-esteem is thoroughly evaluated. These procedures ensure that the findings accurately reflect students' actual critical thinking skills and self-esteem conditions.

Results and Discussion

1) Mathematical Critical Thinking Skills

The results indicate that the average score of students' mathematical critical thinking skills in class VIII-E was 31.77, with a minimum value of 0 and a maximum value of 90.

The distribution of mathematical critical thinking skills categories is presented in Table 1 below:

Table 1. Distribution of Critical Mathematical Thinking Skills of Class VIII E Students

Category	Number of Students	Percentage (%)
High	2	6.5%
Moderate	1	3.2%
Low	28	90.3%

The distribution of critical thinking skills shows that the average student score is 31.77, which is still far from the expected minimum completion criteria (KKM), which is 75. In addition, the number of students who completed according to the KKM was only 3 out of 31, or only 9.7% of students who completed. This indicates that the participants' critical thinking skills are still relatively low. One of the questions and the results of the students' work on the preliminary study test are as follows

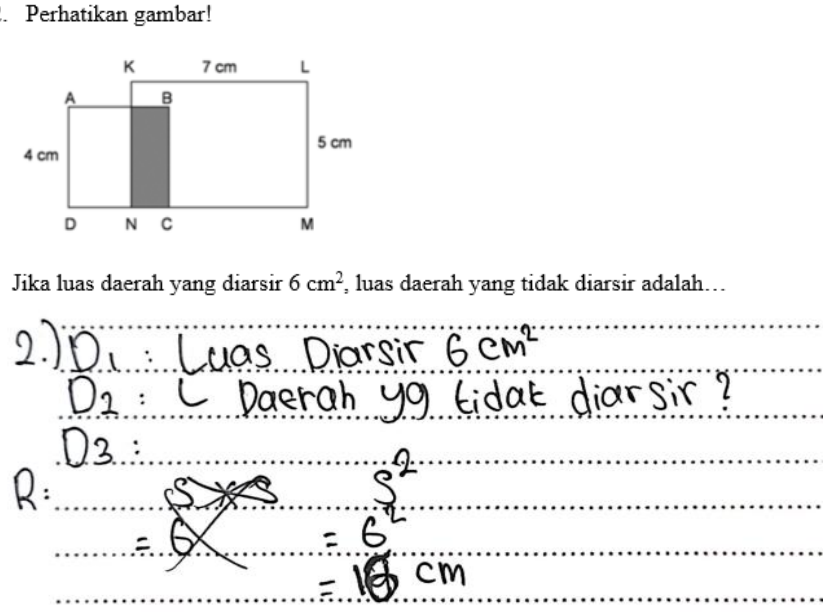

Figure 1. Questions and work results of one of the students
(Image Source: Researcher)

Picture 1 shows that students are unable to identify the known elements in the questions and cannot apply them appropriately to answer them. This condition indicates that students' critical thinking skills, particularly in the aspect of basic clarification, are still low. This low level of basic clarification leads to errors in applying known elements, which results in inaccurate answers.

Details of students' critical thinking skills per indicator are as shown in Table 2 below:

Table 2. Details of students' critical thinking skills per-indicator

Critical thinking ability indicators Ennis (2011)	Many students meet the indicators					Average Percentage (%)
	Question 1	Question 2	Question 3	Question 4	Question 5	
Basic clarification	27	21	16	5	22	53%
The bases for a decision	21	16	5	22	19	39%
Inference	16	5	22	19	14	28%
Advanced Clarification	5	22	19	14	0	8%
Supposition and Integration	0	0	19	14	0	5%

A detailed analysis of students' mathematical critical thinking skills indicates that only about 53% of students met the first indicator, namely basic clarification, while achievement in higher-level indicators declined considerably. This finding suggests that the mathematical critical thinking skills of eighth-grade students at SMP Negeri 10 Semarang remain at a low level, particularly in indicators requiring deeper reasoning. These results are consistent with findings from previous national studies reporting similar conditions among junior high school students (Hutagalung & Meiliasari, 2025; Agoestanto et al., 2017). Rather than indicating a lack of novelty, this consistency reflects persistent instructional issues in current classroom implementation. Based on classroom observations and teacher interviews, mathematics learning is still largely dominated by teacher-centered instruction and routine exercises, which provide limited opportunities for students to engage in non-routine problem solving and higher-order thinking (Kartika & Rakhmawati, 2022). Therefore, this study positions its findings as an empirical basis for identifying instructional gaps and justifying the development of flipbook-assisted PjBL–STEM learning as a more effective alternative

In addition to these findings, interviews with the eighth-grade mathematics teacher showed that the learning process had used the Problem-Based Learning (PBL) model, supported by PowerPoint presentations (PPT) and YouTube videos. However, the implementation of PBL in the classroom had not yet fully align with its basic principles. The teacher explained that students were still highly dependent on teacher guidance, resulting in suboptimal independent problem exploration and in-depth discussions among students. Group discussions were often dominated by a few students with higher abilities, while the majority of students tended to be passive and simply followed their peers' answers without understanding the process. PPT and videos were used more as explanatory aids, rather than as stimuli that encouraged students to analyze information or develop their own arguments. This situation contributed to the low achievement of critical thinking skills in more complex indicators, such as inference, advanced clarification, and strategy and tactics, as shown in Table 2. Thus, although PBL has been implemented, its implementation has not been able to consistently foster higher-order thinking activities because the aspects of student

involvement and independence in learning are still low. That is why innovative learning designs are needed as an effort to improve students' critical thinking skills, one of which is by using the PjBL model with a STEM approach assisted by flipbook media.

2) Student Self-Esteem

Low critical thinking skills are not only influenced by cognitive factors, but also by affective aspects. Self-esteem is one of the affective factors that influence students' mathematical critical thinking skills. This is because self-esteem plays a crucial role in shaping students' confidence in their ability to understand and solve mathematical problems (Fisher et al., 2022). Students with high self-esteem tend to be more confident in thinking, arguing, and making decisions, which are essential components of the critical thinking process (Melyana & Pujiastuti, 2020).

Research by Wibowo (2023) shows a significant positive correlation between self-esteem and mathematical critical thinking skills, namely 0.506 (Wibowo, 2023). Similar findings were also stated by Djam'an et al. (2019), who found that students with high self-esteem were better able to understand, solve, and apply concepts in mathematical problems compared to students with low self-esteem (Djam'an et al., 2019). Therefore, efforts to improve mathematical critical thinking skills need to pay attention to the development of students' affective aspects through learning that encourages self-confidence and self-esteem.

Interviews with the eighth-grade E math teacher further supported this theory. The teacher observed that students' self-esteem in mathematics learning was moderate to low. She stated that most students:

a. Lack of confidence when asked to solve problems on the whiteboard,
b. Tends to be passive in group discussions,
c. Reluctant to ask questions or give opinions, especially when learning takes place in front of the class.

The teacher also mentioned that some students with low academic achievement often exhibited avoidance and lacked persistence when faced with non-routine problems. Conversely, students with high achievement demonstrated better self-esteem and were more active in discussions. Thus, self-esteem is not treated as a separate variable, but as an affective factor that directly influences students' critical thinking performance.

Based on the explanation above, the researcher plans to include an assessment of affective aspects (self-esteem) in the research. This is because the PjBL model is a learning model that can support the improvement of these affective abilities. The PjBL model can

naturally build self-esteem through real-life projects within the community that give students autonomy in decision-making, planning, and implementation (Chimwayange, 2025).

3) Implications for Learning Design

The results of this preliminary study show two main findings that students' critical mathematical thinking skills are still low and students' self-esteem in mathematics learning tends to be moderate to low. These two conditions indicate the need for contextual, collaborative, and technology-based learning designs to increase student engagement and confidence.

Research by Lianti et al. (2023) shows that the implementation of the PjBL-STEM model has an effect of 75.5% on improving critical thinking skills, while the meta-analysis by Fitriani et al. (2024) emphasized that PjBL-STEM has a positive impact on mathematical critical thinking skills at various levels of education. In addition to the learning model, the effectiveness of PjBL-STEM can be strengthened by the use of interactive digital media such as flipbooks. Various studies, such as those conducted by Purnomo et al. (2024), Setyorini & Sukarmin (2024), and Chairunnisa & Usodo (2025) show that flipbooks can improve students' learning motivation, learning outcomes, and critical and creative thinking skills. In the affective aspect, Fisher et al.'s (2022) study entitled "Mathematical Self-Esteem Ability of Junior High School Students in Project-Based Learning" shows that the achievement of mathematical self-esteem of students who received PjBL learning is better than students who received conventional learning. From the explanation above, it can be concluded that the relationship between self-esteem and mathematical critical thinking skills is an important basis in designing a comprehensive learning strategy, which not only focuses on material content, but also on students' mental readiness to think critically in depth. The novelty of this study lies in integrating students' mathematical critical thinking skills and self-esteem as a combined empirical foundation for designing flipbook-assisted PjBL–STEM learning.

Conclusion and Suggestion

This preliminary study provides a comprehensive description of the condition of mathematical critical thinking skills and self-esteem of class VIII-E students of SMP Negeri 10 Semarang as a basis for developing innovative learning designs. The test results show that students' mathematical critical thinking skills are still very low, marked by an average score of 31.77 and most students are in the low category. Analysis per indicator also shows

that students have not mastered high-level critical thinking skills, especially in the inference, advanced clarification, and strategy and tactics indicators.

Furthermore, teacher interviews indicated that students' self-esteem was moderate to low. Low self-confidence, a tendency to be passive in discussions, and a fear of being wrong when expressing opinions were factors that hampered the development of critical mathematical thinking skills. This condition was also influenced by the suboptimal implementation of problem-based learning, where students still relied on teacher direction and were not accustomed to exploring solutions independently.

These findings confirm that improving mathematical critical thinking skills cannot be separated from strengthening students' affective aspects, especially self-esteem. Therefore, a learning design is needed that can improve both simultaneously. One relevant and potential alternative is the implementation of the Project-Based Learning (PjBL) model with a STEM approach assisted by flipbook media. This model provides opportunities for students to actively engage in contextual projects, develop reasoning, and build self-confidence through collaborative processes and more meaningful learning experiences. Therefore, the findings of this preliminary study provide a strong empirical foundation for the development of flipbook-assisted PjBL–STEM learning designs aimed at simultaneously enhancing students' mathematical critical thinking skills and self-esteem.

This study has several limitations, including the involvement of only one class in a single school, the descriptive research design without a comparison group, the limited sample size, and the reliance on teacher interviews to describe self-esteem. Therefore, future studies are recommended to involve larger samples, multiple schools, experimental designs, and direct self-esteem measurement instruments

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