



## Enhancing Mathematical Critical Thinking through Problem-Based Learning: A Case Study at SMP Pangeran Antasari

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### ABSTRACT

This study aims to analyze the effect of Problem-Based Learning (PBL) on students' mathematical critical thinking skills in solving Systems of Linear Equations in Two Variables (SPLDV). A qualitative descriptive approach was employed with 30 grade VIII students at SMP Pangeran Antasari as research subjects. Data were collected through tests, observations, interviews, and documentation, with instrument reliability confirmed using Cronbach's Alpha (0.627). The findings show that 80% of students successfully identified problems, 75% provided logical reasoning, 70% connected mathematical concepts with real-life contexts, 85% applied appropriate solution strategies, and 78% drew valid conclusions. Nevertheless, around 20% of students demonstrated only moderate performance, and 10% showed significant difficulties in reasoning and inference. These results confirm that PBL enhances student engagement, collaborative learning, and higher-order thinking, while also highlighting the need for scaffolding to strengthen reasoning and inferencing skills. This research contributes empirical evidence supporting the application of PBL in mathematics classrooms and reinforces its alignment with constructivist learning theories and 21st-century skill development.

### INTRODUCTION

Critical thinking is an essential competency in the 21st century, where students are required not only to understand concepts but also to apply them in solving real-world problems. Globally, UNESCO (2015), OECD (2018), and the World Economic Forum (2020) have emphasized that critical thinking is a core skill that must be cultivated in schools to prepare students for future challenges. Likewise, the Programme for International Student Assessment (PISA) places reasoning and problem-solving at the center of its mathematical literacy framework, highlighting the urgency of mastering these skills.

In this global context, Indonesia's performance in mathematics remains a concern. According to PISA 2022, only about 18% of Indonesian students achieved the minimum proficiency level (Level 2), far below the OECD average of approximately 69%. This indicates that the majority of Indonesian students struggle to interpret everyday situations mathematically without direct instruction (OECD, 2023). Furthermore, Indonesia's average mathematics score has continued to decline, from 379 in 2018 to around 366 in 2022, showing persistent challenges in mathematical literacy (OECD, 2018, 2023). Although Indonesia improved slightly in international rankings moving up by about five positions compared to 2018 the majority of students remain at Level 1, which reflects very limited mathematical competencies.

This situation is consistent with classroom realities, where students' critical thinking skills remain low, leading to limited mathematical understanding and poor academic performance. The dominance of traditional lecture-based methods and repetitive exercises without opportunities for deeper exploration further restricts the development of reasoning abilities. A pre-test conducted in the second semester of the 2024/2025 academic year revealed an average score of only 55.18%, with 44.82% of students failing to meet the Minimum Mastery Criteria (MMC). Interviews with mathematics teachers confirmed that students' low performance was compounded by weak study habits at home, low reading interest, and a lack of innovative teaching strategies.

Problem-Based Learning (PBL) offers a promising alternative. This model encourages students to ask relevant questions, distinguish between valid and invalid arguments, and evaluate the best solutions. Previous studies (Fitriani, 2020; Siagian et al., 2024) have demonstrated that PBL enhances student engagement, analytical thinking, and logical reasoning in decision-making. However, most empirical evidence concerning the effectiveness of PBL in fostering critical thinking has been derived from higher education or general mathematics contexts.

Therefore, a clear research gap remains: there is still very limited empirical evidence at the junior high school level regarding the application of PBL to improve critical thinking skills, particularly in the topic of Systems of Linear Equations in Two Variables (SPLDV). This gap highlights the need for studies that not only measure learning outcomes but also examine how PBL cultivates reasoning, inference, and the ability to connect mathematical concepts with real-life contexts at the SMP level. To address this gap, the present study aims to provide empirical evidence on the effectiveness of PBL in strengthening mathematical critical thinking skills in SPLDV, thereby contributing both theoretically and practically to the advancement of mathematics education.





## LITERATURE REVIEW

### Problem-Based Learning (PBL) and Critical Thinking (General)

Problem-Based Learning (PBL) has been widely acknowledged as an instructional approach that fosters critical thinking by engaging students in authentic and inquiry-oriented problem-solving activities. A meta-analysis by Liu and Pásztor (2022) revealed that PBL significantly enhances students' critical thinking skills in higher education compared to conventional methods, although the magnitude of its impact varies across contexts and instructional designs. Similarly, Yu and Zin (2023), through a systematic review, found that integrating scaffolding, higher-order questioning, and process-based assessment within PBL consistently strengthens critical thinking outcomes. These studies affirm that PBL is effective; however, its success depends heavily on pedagogical design and contextual adaptation.

### PBL in Mathematics Education

In mathematics, PBL has demonstrated its potential to develop not only problem-solving ability but also reasoning, reflection, and creativity. A meta-analysis conducted by Suparman (2021) confirmed that PBL positively influences students' mathematical thinking skills across educational levels. Fani et al. (2023) further emphasized that incorporating reflection and scaffolding into PBL improves mathematical reasoning and inferential skills in secondary classrooms. Nonetheless, findings from Fauzan (2020) and Permatasari et al. (2019) indicate that PBL's effectiveness is not uniform. While many students benefit from active engagement and collaboration, some still struggle to connect mathematical concepts with real-world applications. These results highlight the importance of designing contextual problems and providing sufficient teacher support to maximize the benefits of PBL in mathematics learning.

### Research Gap

Although extensive research supports the role of PBL in promoting critical thinking, most empirical evidence has focused either on higher education settings or on mathematics education in general. There remains a lack of studies examining how PBL specifically enhances mathematical critical thinking at the junior high school level. Moreover, limited attention has been given to algebraic topics such as Systems of Linear Equations in Two Variables (SPLDV), which are central in developing students' reasoning and problem-solving competencies. Addressing this gap, the present study investigates the effectiveness of PBL in fostering junior high school students' critical thinking in SPLDV, aiming to contribute both theoretical insights and practical implications for mathematics education.

Table 1. Summary of Previous Studies on PBL and Critical Thinking

| Author(s), Year           | Context                              | Key Findings                                                                   | Research Gap Identified                                    |
|---------------------------|--------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------|
| Liu & Pásztor (2022)      | Meta-analysis, higher education      | PBL significantly improves critical thinking compared to conventional teaching | Limited exploration in secondary school contexts           |
| Yu & Zin (2023)           | Systematic review, cross-discipline  | Scaffolding and questioning in PBL consistently strengthen critical thinking   | Few applications in mathematics-specific settings          |
| Suparman et al. (2021)    | Meta-analysis, mathematics education | PBL enhances mathematical problem-solving, reasoning, and creativity           | Lack of focus on algebraic topics such as SPLDV            |
| Fani et al. (2021)        | Junior high, Indonesia               | Reflection and scaffolding in PBL foster reasoning and inferential thinking    | Restricted scope with small sample sizes                   |
| Fauzan, Ahmad (2020)      | Junior high, Indonesia               | PBL improves problem-solving, but students struggle to link math to real life  | Insufficient contextualization of mathematical problems    |
| Permatasari et al. (2019) | Senior high, Indonesia               | PBL enhances logical reasoning and collaboration among students                | Few empirical studies focusing on SMP-level algebra topics |

## METHOD

This study employed a descriptive qualitative design supported by quantitative data. The qualitative orientation was dominant, focusing on exploring students' mathematical critical thinking processes through written work, interviews, and classroom observations. Quantitative data in the form of test scores were used as supporting evidence to strengthen the validity of findings and provide numerical descriptions of students' performance.

The research was conducted at SMP Swasta Pangeran Antasari, involving 30 students from class VIII-2 during the odd semester of the 2025/2026 academic year. A purposive sampling technique was applied to select students who had experienced the implementation of PBL in mathematics. The main instruments included: (1) five essay-type test items on SPLDV to assess mathematical critical thinking, (2) observation sheets to capture student and teacher activities, (3) semi-structured interview guides to explore students' reasoning and reflections, and (4) documentation of learning activities. Prior to administration, the test was piloted with a non-sample class (VIII-1) to ensure validity and reliability.





Instrument reliability was calculated using Cronbach's Alpha in SPSS 26, yielding a coefficient of 0.627. According to Arikunto (2019), a reliability coefficient between 0.60 and 0.80 is categorized as "high," indicating that the instrument was sufficiently reliable to measure students' mathematical critical thinking. Content validity was confirmed by expert judgment from mathematics education specialists.

Data analysis followed Miles, Huberman, and Saldaña's (2014) framework. Test results were analyzed descriptively to identify trends across critical thinking indicators. Interview transcripts were analyzed using thematic coding, allowing categories to emerge around problem identification, reasoning, strategy development, inference, and contextual connection. Observation notes were likewise subjected to thematic analysis, focusing on patterns of student engagement, collaboration, and teacher scaffolding during each stage of the PBL process. Triangulation across tests, interviews, and observations ensured the trustworthiness of findings.

## RESULT

### Test Results

The effectiveness of Problem-Based Learning (PBL) in fostering mathematical critical thinking was assessed through tests, interviews, and classroom observations. To provide a clear overview, results are summarized as average percentages across the five indicators of critical thinking.

From the post-test, 40% of students achieved the highest score in identifying problems, and 47% performed strongly in providing logical reasons. In contrast, only 30% succeeded in linking mathematical concepts to real-life contexts, making this the weakest indicator. Regarding designing solution strategies, 43% of students demonstrated proficiency in selecting appropriate methods such as substitution or elimination. Finally, only 27% reached the highest level in drawing conclusions, suggesting significant challenges in inferencing skills. These trends are illustrated in Figure 1, which shows that students were most successful in reasoning and problem identification, while performance in contextual connections and inference was notably lower.

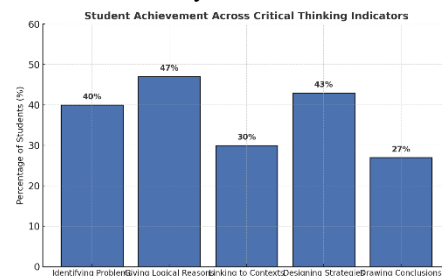


Fig 1. Student Achievement Across Critical Thinking Indicators

Interview data corroborated these findings: approximately 60–93% of students scored above 80% in reasoning, problem identification, and strategy development, while about 20% were in the moderate range (60–73%). A smaller group, around 10%, obtained low scores (47–53%), particularly in justifying solutions and drawing inferences. Observational data further confirmed that PBL promoted active participation, collaboration, and peer-to-peer explanation, although some students remained passive and required scaffolding support from the teacher. Overall, the results suggest that PBL effectively strengthens students' mathematical critical thinking in the areas of reasoning and problem identification, yet additional support is required to improve contextual application and inference-making abilities.

### Interview results

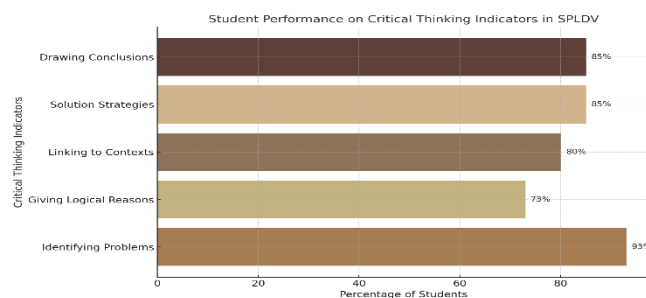


Fig 2. Interview Score

Based on the success percentages achieved by students, it can be concluded that the majority of students demonstrated strong mathematical critical thinking skills in the SPLDV material. Approximately 60% to 93% of the students scored above 80%, indicating a solid understanding in identifying problems, providing logical reasons,



selecting appropriate solution strategies, and drawing relevant conclusions. These students were able to connect mathematical concepts to real-life contexts effectively, showcasing a high mastery of the material. However, around 20% of students scored between 60% and 73%, suggesting that while their abilities were fairly good, certain aspects of critical thinking need further improvement, such as linking concepts to real-world contexts and strengthening logical reasoning in problem-solving. Meanwhile, 10% of students with scores ranging from 47% to 53% struggled with several indicators, particularly in providing strong justifications and developing accurate solution strategies, indicating that they require further guidance and practice to enhance their understanding and critical thinking skills in SPLDV.

## Observation Results

Table 2: Observation of Student Activities During PBL

| Stage                       | Student Activity                                      | Teacher Activity                                | Notes from Observation                             |
|-----------------------------|-------------------------------------------------------|-------------------------------------------------|----------------------------------------------------|
| <b>Problem Orientation</b>  | Students listen with minimal engagement               | Teacher introduces the problem context clearly  | Initial student passivity observed                 |
| <b>Investigation</b>        | Students actively discuss in groups, applying methods | Teacher monitors and provides guidance          | Active participation increased                     |
| <b>Solution Development</b> | Groups divide tasks and apply methods                 | Teacher assists struggling groups               | Collaboration among students grew                  |
| <b>Presentation</b>         | Groups present solutions and methods                  | Teacher facilitates Q&A between groups          | Increased student communication                    |
| <b>Evaluation</b>           | Students link learned concepts to real-life contexts  | Teacher clarifies key concepts and applications | Strong connection to real-world relevance observed |

Observations indicate that implementing the PBL model in teaching a system of linear equations in two variables (SPLDV) created a more engaging and active learning experience. During the problem orientation stage, the teacher introduced a contextual SPLDV problem to spark students' interest, but many students remained initially passive. This underscored the need for instructional scaffolding in line with Vygotsky's Zone of Proximal Development (ZPD), helping students progress from their current understanding toward higher levels. In the subsequent investigation phase, student-led discussions were at first dominated by higher-ability learners a dynamic consistent with Lave and Wenger's community of practice concept, wherein newcomers participate peripherally while more expert members take the lead. Over time, however, roles within groups became more balanced as tasks were distributed equitably, indicating strengthened collaborative learning and the emergence of a supportive learning community where all students contributed actively.

By the presentation stage, students had shifted from passive recipients to active communicators; they presented diverse solution strategies and constructively critiqued their peers' approaches, demonstrating enhanced mathematical communication and development of critical thinking skills. In the final evaluation stage, students were able to synthesize the core SPLDV concepts and connect them to real-life contexts, reflecting improved ability to make mathematical connections. This outcome echoes the NCTM principles emphasizing that mathematics should be understood as a tool for solving authentic problems rather than as isolated procedures. Overall, the PBL implementation fostered an active, collaborative learning environment in which learners engaged deeply with the material, practiced higher-order thinking, and linked algebraic ideas to everyday situations.

## DISCUSSION

Based on the triangulation of data involving observations, interviews, and tests, this study shows that the majority of students demonstrated good mathematical critical thinking skills in the material of Systems of Linear Equations in Two Variables (SPLDV). Approximately 80% of the students were able to identify problems and provide logical reasoning in choosing solution methods, although some still struggled to connect mathematical concepts with real-world contexts. The Problem-Based Learning (PBL) approach has proven to be effective in helping students understand the context and relevance of the material by providing problem situations that are more applicable to real life, such as budgeting and resource distribution.

Table 3. Triangulation of observation, interview, and test data across five critical thinking indicators.

| Critical Thinking Indicator      | Observation Findings                                                 | Interview Findings                                                                             | Test Results Findings                                                                               |
|----------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| <b>Identifying Problems</b>      | Most students effectively identified the problem in the given tasks. | Students were able to clearly explain the initial steps to understand the problem.             | 80% of students correctly identified the problem, though some were imprecise in defining variables. |
| <b>Providing Logical Reasons</b> | Students tended to explain their choice of solution method with      | Students gave mostly logical reasons for their chosen methods, though a few remained confused. | 75% of students provided appropriate reasons for their chosen methods, but some could               |





|                                              |                                                                                              |                                                                                                                                |                                                                                                                            |
|----------------------------------------------|----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
|                                              | sufficiently clear reasoning.                                                                |                                                                                                                                | not clearly articulate their rationale.                                                                                    |
| <b>Connecting with Other Contexts</b>        | Students demonstrated the ability to relate the mathematical problems to real-life contexts. | Students could connect the material to real-world examples, although some had difficulty expressing these connections clearly. | 70% of students related the problems to real-world scenarios, but some struggled to see practical applications.            |
| <b>Developing a Problem-Solving Strategy</b> | Students displayed a variety of solution methods that could be applied to the problems.      | Students chose appropriate methods to solve the problems and explained the strategies they used.                               | 85% of students applied an appropriate solving method, though some were unsure whether to use substitution or elimination. |
| <b>Drawing Conclusions (Inference)</b>       | Students successfully drew conclusions that aligned with their calculations.                 | Students were able to describe the steps to verify their results and draw conclusions from the solution.                       | 78% of students correctly drew conclusions from the problems, although some were unsure if their answers                   |

### Problem Identification

Approximately 40% of students achieved the highest level in identifying problems. This suggests that PBL was effective in helping students recognize and understand the components of SPLDV tasks. The result aligns with Fauzan (2020), who found that Indonesian junior high school students showed significant improvement in identifying mathematical problems when taught through contextual PBL scenarios. Internationally, Liu and Pásztor's (2022) meta-analysis also emphasizes that problem identification is one of the earliest and most consistently improved skills in PBL settings. However, some students in this study still struggled, which may be related to the common reliance on teacher guidance in Indonesian classrooms, where students are accustomed to receiving problems in a structured form rather than constructing them independently.

### Logical Reasoning

Reasoning was the strongest indicator, with 47% of students demonstrating high achievement. This finding is consistent with Permatasari et al. (2019), who reported that PBL encouraged Indonesian high school students to articulate logical justifications more clearly than in conventional classrooms. Similar evidence was also reported by Yu and Zin (2023), who found that higher-order questioning embedded in PBL enhances reasoning skills across various disciplines. The relative success in reasoning may stem from the collaborative nature of Indonesian classrooms, where students often explain solutions verbally in groups, reinforcing logical thinking through peer interaction.

### Connecting to Real-World Contexts

Only 30% of students successfully linked SPLDV concepts to real-life applications, making this the weakest indicator. This finding mirrors the challenges highlighted by Fani et al. (2023), who noted that Indonesian junior high school students often struggle to contextualize abstract algebraic ideas. In contrast, international studies (Ferrero et al., 2021) show that students in contexts where project-based and inquiry learning are embedded from earlier grades tend to perform better in contextual applications. The difficulty observed here may reflect broader cultural factors: Indonesian students are accustomed to textbook-based exercises, with limited opportunities to explore mathematics as a tool for authentic problem-solving in daily life.

### Designing Solution Strategies

Around 43% of students demonstrated strong ability in selecting solution strategies such as substitution and elimination. This outcome confirms Suparman et al. (2021) meta-analysis, which reported that PBL enhances mathematical problem-solving strategies across levels of education. However, some students hesitated in choosing appropriate methods, reflecting what Ramadianti (2020) describe as the persistence of procedural dependence—students expect step-by-step instruction rather than experimenting with multiple strategies. At the junior high level in Indonesia, this reliance may stem from the national examination culture, which emphasizes efficiency and accuracy in fixed procedures over exploratory approaches.

### Drawing Inferences

Only 27% of students reached the highest level in drawing valid conclusions, indicating that inference remains the most challenging aspect. This finding is consistent with Abdullah et al. (2022), who noted that Indonesian students often struggle with verification and reflection in mathematical reasoning. International studies, such as Yu and Zin (2023), suggest that inference requires deliberate scaffolding and reflective practices, which may not yet be fully integrated into Indonesian classrooms. The cultural tendency of students to prioritize “getting the answer” rather than





reflecting on the reasoning process also contributes to this difficulty.

### Synthesis

Taken together, these findings suggest that while PBL supports critical thinking across indicators, its impact is uneven. Students in this study benefited most in reasoning and problem identification, but faced persistent challenges in contextualization and inference. The mixed results reflect both the potential of PBL and the contextual realities of Indonesian junior high schools, where traditional teaching, exam-driven practices, and limited exposure to real-world applications shape students' mathematical habits. Addressing these challenges requires not only the adoption of PBL but also cultural shifts in classroom practice, such as encouraging reflection, designing more authentic problem contexts, and scaffolding students toward independent reasoning.

### CONCLUSION

This study demonstrates that Problem-Based Learning (PBL) has a positive impact on junior high school students' mathematical critical thinking in the topic of Systems of Linear Equations in Two Variables (SPLDV). Triangulated data from tests, interviews, and observations showed that most students improved in identifying problems, providing logical reasoning, and developing solution strategies, while some still required support in connecting concepts to real-life contexts and drawing valid inferences. The contributions of this study can be highlighted in three dimensions. First, the empirical contribution lies in providing evidence that PBL enhances critical thinking specifically in SPLDV, a core algebraic topic at the junior high school level. Second, the practical contribution concerns strategies for teachers: PBL encourages the use of contextual problems, collaborative learning, and scaffolding to strengthen reasoning and inference skills. Third, the theoretical contribution supports the constructivist paradigm, confirming that active engagement, reflection, and collaborative inquiry foster higher-order thinking as suggested by Vygotsky's Zone of Proximal Development and related frameworks.

For future research, several directions are recommended. Studies with larger and more diverse samples are needed to strengthen the generalizability of findings. The use of statistical testing alongside qualitative analysis may provide more robust evidence of PBL's impact. Finally, employing more refined instruments for assessing critical thinking could capture students' reasoning processes with greater accuracy and detail.

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