The Effect of Problem Based Learning Integrated with Deep Learning on Students' Mathematical Reasoning Ability

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Abstract

This study aims to determine the effect of the Problem Based Learning model integrated with Deep Learning on junior high school students' mathematical reasoning ability, as well as the level of improvement after the learning intervention. This research employed a quantitative approach using a quasi-experimental One-Group Pretest–Posttest design. The sample consisted of one class of junior high school students who received problem-based learning with a deep learning approach over four sessions. The research instrument was a mathematical reasoning test administered before and after the intervention. Data were analyzed using descriptive statistics, normality testing, paired sample t-test, and N-Gain analysis. The results show that the Problem Based Learning model with Deep Learning has a significant effect on students' mathematical reasoning ability, indicated by a significance value of $p < 0.05$. Furthermore, the N-Gain analysis revealed a moderate level of improvement. Thus, the Problem Based Learning model integrated with Deep Learning is effective in enhancing students' mathematical reasoning ability.

Keywords: Problem Based Learning, Deep Learning, Mathematical Reasoning, Mathematics Learning

Introduction

Twenty-first century education requires students to develop higher-order thinking skills, including critical, creative, communicative, and collaborative thinking, as well as the ability to reason in solving complex problems (OECD, 2019; Redhana, 2019). The Indonesian Merdeka Curriculum emphasizes the importance of student-centered learning oriented toward meaningful thinking processes, particularly mathematical reasoning as a fundamental competency needed to face global challenges (Kemendikbudristek, 2022). In the context of mathematics education, mathematical reasoning enables students not only to solve problems procedurally but also to construct logical arguments, analyse conceptual relationships, and draw valid conclusions across various situations (Putra & Yulanda, 2021; Rohmatulloh et al., 2022).

Despite its importance, previous studies indicate that Indonesian students' mathematical reasoning ability remains low. The 2022 PISA report highlights that Indonesian students' mathematical reasoning performance lags behind the OECD average (OECD, 2019). Research by Hasanah et al. (2023) also revealed that many students rely heavily on memorizing formulas rather than building conceptual understanding, which leads to difficulties in connecting mathematical ideas logically. This issue is exacerbated by instructional practices that still rely on teacher-centered approaches focused on lecturing and routine exercises without providing opportunities for students to construct knowledge independently (Fendrik, 2021). These conditions signal the need for more innovative instructional models that actively engage students, encourage deeper conceptual exploration, and support the development of structured mathematical reasoning.

One relevant instructional model is Problem Based Learning (PBL). This model positions contextual problems as the starting point of learning and provides opportunities for students to develop critical thinking, collaboration, and mathematical reasoning through exploration and problem-solving activities (Nurcahyaning Kusumawardani et al., 2022; Vatillah et al., 2020). Previous research has reported that Problem Based Learning enhances student engagement, strengthens conceptual understanding, and significantly improves mathematical reasoning skills compared to conventional learning approaches. However, in practice, Problem Based Learning implementation is often suboptimal. Many teachers emphasize problem-solving techniques rather than promoting reflective thinking and meaningful conceptual connections (Sulistiani & Lusiana, 2024). Therefore, strategies that can reinforce Problem Based Learning are needed so that learning not only focuses on finding solutions but also on fostering deeper and more conscious thinking processes.

Deep Learning emerges as an approach that can strengthen the effectiveness of Problem Based Learning. In the educational context, Deep Learning emphasizes meaningful, reflective, and profound learning experiences through cognitive, emotional, and experiential engagement (Mutmainnah et al., 2025). This approach encourages students not only to understand “how” a concept is applied but also “why” it is relevant and how various concepts are interrelated. Feriyanto & Anjariyah (2024) explain that Deep Learning is grounded in three principles meaningful learning, mindful learning, and joyful learning; which support holistic and long-lasting conceptual understanding. Thus, integrating Problem Based Learning with Deep Learning has the potential to create learning experiences that not only guide students toward problem solving but also promote deeper awareness and conceptual reasoning.

The integration of Problem Based Learning and Deep Learning is considered a comprehensive instructional approach that supports the development of mathematical reasoning. Problem Based Learning provides authentic problem-solving experiences that require students to make conjectures, perform mathematical manipulations, and draw logical conclusions (Kusuma & Amelia, 2018). Meanwhile, Deep Learning reinforces these processes through reflection, conceptual linkage, and meaningful comprehension. According to Salmi et al. (2023), learning that combines problem solving with deep reflection leads to long-term understanding rather than short-term memorization. Through this integration, students are guided not only to find solutions but also to understand the underlying meaning of the strategies and mathematical concepts they employ.

Several relevant studies support the importance of this integration. Afifah et al. (2020) found that Problem Based Learning significantly improves mathematical reasoning ability. Wahyudi (2025) reported that Deep Learning enhances students' reasoning and self-confidence in mathematics. Additionally, Ardhana et al. (2025) demonstrated that Problem Based Learning integrated with Deep Learning significantly improves critical thinking skills. In this study, the integration of Problem Based Learning and Deep Learning is implemented by positioning Problem Based Learning as the instructional framework, while Deep Learning principles are embedded throughout each phase of the learning process.

Learning begins with contextual problems that require students to identify relevant information and formulate mathematical representations (meaningful learning). During group investigations, students are guided to analyze solution strategies, justify each step, and connect concepts logically (mindful learning). The learning process is completed with reflection and discussion activities that encourage students to evaluate their reasoning and derive conceptual understanding (joyful learning). Through this integration, students are not only engaged in solving problems, but also in constructing meaning, reflecting on their thinking processes, and developing deeper conceptual understanding. However, research specifically examining the effect of Problem Based Learning integrated with Deep Learning on junior high school students' mathematical reasoning remains limited.

Based on this gap, the present study aims to investigate the effectiveness of Problem Based Learning integrated with Deep Learning in improving junior high school students' mathematical reasoning ability. This study not only examines whether the model significantly influences mathematical reasoning but also analyses the extent of improvement after the instruction. Thus, this research is expected to contribute theoretically and practically to the development of mathematics instruction that is more meaningful, reflective, and oriented toward nurturing students' reasoning competencies.

Method

This study employed a quasi-experimental method using a One-Group Pre-test–Post-test Design, in which a single group of students was given a pre-test, followed by a learning intervention, and subsequently a post-test to examine the effect of the Problem Based Learning integrated with Deep Learning model on students' mathematical reasoning ability. The research design is represented as $O_1 - X - O_2$, where O_1 denotes the pre-test, X represents the instructional treatment, and O_2 represents the post-test. The research sample consisted of one Grade VIII class at SMPN 10 Kota Serang in the 2025/2026 academic year, selected through purposive sampling based on the class's readiness, stability of the number of students, and suitability of the mathematics instructional schedule. The number of students in the class ranged from 30 to 35, with ages between 13 and 15 years. All research activities were conducted during regular mathematics lessons.

The research instruments consisted of a mathematical reasoning test and instructional materials developed based on the Problem Based Learning and Deep Learning approaches. The test comprised five open-ended items constructed according to mathematical reasoning indicators, including the ability to understand problems, formulate mathematical models, conduct systematic solution procedures, provide logical justifications, and draw conclusions. Each item was scored using an analytic rubric ranging from 0 to 4, where a score of 0 indicated no response or irrelevant answers, and a score of 4 indicated a complete and correct solution accompanied by logical reasoning and appropriate conclusions. The mapping between test items and reasoning indicators was as follows: item 1 assessed the ability to understand the problem; item 2 assessed the ability to formulate mathematical models; item 3 assessed systematic solution procedures; item 4 measured logical justification of solutions; and item 5 evaluated the ability to draw mathematical conclusions. The test was administered as both a pre-test and post-test using equivalent forms. The instrument underwent expert validation and empirical testing, including examinations of validity, reliability, discrimination power, and difficulty index, ensuring that the assessment met the criteria for a high-quality instrument.

The instructional treatment was implemented over four sessions. The Problem Based Learning with Deep Learning approach began with presenting contextual Systems of Linear Equations in Two Variables (SPLDV) problems that required students to identify key information, formulate mathematical representations, and select appropriate solution strategies. Students worked collaboratively in groups to investigate the problem, connect relevant concepts, analyse solution steps, and reflect on their chosen strategies. The learning activities proceeded with group presentations and intergroup discussions, which further strengthened students' mathematical reasoning processes and deepened their conceptual understanding.

Data from the pre-test and post-test were analysed descriptively to obtain the minimum, maximum, mean, and standard deviation values. Furthermore, the Kolmogorov–Smirnov normality test was conducted to determine the appropriate statistical analysis. If the difference scores between the pre-test and post-test were normally distributed, a paired sample t-test was used to examine whether significant differences existed before and after the intervention. If the data were not normally distributed, the Wilcoxon Signed Rank Test was employed. In addition, the N-Gain score was calculated to determine the level of improvement in students' mathematical reasoning ability, categorized into low, medium, or high improvement.

Results and Discussion

The results of the study indicate an improvement in students' mathematical reasoning ability after the implementation of the Problem Based Learning integrated with Deep Learning model. The descriptive analysis of the pre-test scores is presented in Table 1.

Table 1. Descriptive Statistics of Pre-Test Mathematical Reasoning Ability

Statistic	Value
Number of Students	30
Minimum Score	20
Maximum Score	68
Mean	41.73
Standard Deviation	12.387

Based on Table 1, students' initial mathematical reasoning ability was in the low-to-medium category. The mean score of 41.73 indicates that most students had not yet mastered Systems of Linear Equations in Two Variables concepts nor reasoning indicators such as providing logical explanations, constructing arguments, and drawing conclusions. The minimum score of 20 indicates that some students were only able to answer a small portion of the test items and showed limited understanding of the problem context and reasoning processes. In contrast, the maximum score of 68 suggests that a small number of students were able to demonstrate partial mastery of the concepts and reasoning indicators, although their understanding was not yet optimal. These results indicate that students' initial mathematical reasoning ability varied considerably prior to the intervention.

Normality testing confirmed that the pre-test data were normally distributed. The Kolmogorov–Smirnov results are presented in Table 2.

Table 2. Normality Test of Pre-Test Scores

Data	Statistic	df	Sig.	Conclusion
Pre-Test	0.131	30	0.200	Normal

The significance value of $0.200 > 0.05$ indicates that the data met the normality assumption, allowing further parametric testing.

After the implementation of Problem Based Learning integrated with Deep Learning, students' abilities increased considerably. The descriptive statistics of the post-test scores are displayed in Table 3.

Table 3. Descriptive Statistics of Post-Test Mathematical Reasoning Ability

Statistic	Value
Number of Students	30
Minimum Score	62
Maximum Score	96
Mean	79.40
Standard Deviation	9.873

Table 3 shows significant improvement across all parameters. The mean score increased from 41.73 to 79.40, nearly doubling. The minimum score of 62 indicates that all students were able to demonstrate basic to adequate levels of mathematical reasoning, including understanding the problem context, applying appropriate solution strategies, and providing logical justifications. The maximum score of 96 suggests that some students achieved a near-complete mastery of the mathematical reasoning indicators assessed, including systematic problem-solving and accurate conclusions. The reduced standard deviation (9.873) suggests improved equity in student performance following the learning treatment. Furthermore, the increase in post-test scores cannot be attributed solely to students' prior exposure to similar test items in the pre-test, as the pre-test and post-test employed equivalent forms with different problem contexts and numerical values. Therefore, the observed improvement reflects genuine development in students' mathematical reasoning ability resulting from the learning intervention rather than a test familiarity effect. The post-test data also met the normality assumption, as shown in Table 4.

Table 4. Normality Test of Post-Test Scores

Data	Statistic	df	Sig.	Conclusion
Post-Test	0.124	30	0.254	Normal

Since both pre-test and post-test scores were normally distributed, paired sample t-test was used for further analysis. The results are shown in Table 5.

Table 5. Paired Sample t-Test Results

Statistic	Value
df	29
p-value	<0.001
Mean Difference	37.67
SE Difference	11.420
t-value	18.063

The p-value < 0.001 indicates a statistically significant difference between pre-test and post-test scores, confirming that the Problem Based Learning with Deep Learning approach had a significant effect on improving students' mathematical reasoning ability.

The magnitude of improvement was further examined using the N-Gain score, presented in Table 6.

Table 6. N-Gain Score Analysis

Statistic	Value
N-Gain Minimum	0.45
N-Gain Maximum	0.88
Mean N-Gain	0.64
Category	Medium-High

The mean N-Gain score of 0.64 indicates that the improvement in mathematical reasoning was in the medium-to-high category. This suggests that the intervention was not only statistically significant but also practically effective.

The observed improvement aligns with the characteristics of Problem Based Learning, which engages students in analysing authentic problems, identifying essential information, establishing relationships between concepts, and developing mathematical justifications. The integration of Deep Learning strengthened these processes by fostering deep thinking, elaboration of ideas, and reflection on solution strategies. Students were not merely solving problems, but also understanding the logical rationale behind each step.

These findings are consistent with Glazewski & Hmelo-Silver (2019), who reported that Problem Based Learning enhances higher-order thinking through investigative and argumentative activities when dealing with complex problems. Similarly, Savery (2015) found that Problem Based Learning encourages students to build conceptual connections and reinforce mathematical reasoning through discussion and reflection. In line with this, Ashari (2024) noted that problem-based instruction significantly improves mathematical reasoning because students engage in analytical processes required to comprehend the structure of mathematical tasks.

The results of this study also support Deep Learning theory as described by Alt & Boniel-Nissim (2018), who emphasized that instructional approaches focusing on conceptual understanding and interconnection of ideas promote deeper levels of thinking. Their principles underline that elaboration, reflection, and meaning-making lead to more enduring and substantial learning. Furthermore, findings by Yew & Goh (2016) revealed that Problem Based Learning significantly enhances students' critical thinking and conceptual comprehension through structured problem-solving processes.

Moreover, problem-based instruction supported by Deep Learning principles is considered effective because it enables students to construct knowledge independently, test ideas through discussion, and justify their solutions. This is supported by Mulyanto et al. (2018), who demonstrated that presenting authentic problems within Problem Based Learning environments substantially improves mathematical reasoning ability.

Overall, the findings confirm that the integration of Problem Based Learning and Deep Learning has a significant and effective impact on improving students' mathematical reasoning ability. The improvement is evident not only in post-test scores, but also in the quality of students' mathematical arguments, conceptual understanding, and ability to logically connect information. These results reinforce existing empirical evidence that such combined approaches are relevant and promising for enhancing mathematical reasoning at the junior secondary school level.

Conclusion and Suggestion

Based on the results of the study, the implementation of the Problem Based Learning model integrated with Deep Learning has been proven to significantly improve junior high school students' mathematical reasoning ability. The findings show a substantial difference between the pre-test and post-test scores, with the post-test results increasing markedly. The significance value of the paired sample t-test ($p < 0.05$) confirms that this learning model is effective in enhancing students' ability to analyze problems, develop strategies, provide logical justification, and understand conceptual relationships within the topic of Systems of

Linear Equations in Two Variables (SPLDV). Beyond statistical improvement, classroom observations indicate that students became more engaged in deep thinking processes, group discussions, and reflection; key components of mathematical reasoning.

The N-Gain analysis further demonstrates that the level of improvement in students' mathematical reasoning ability falls within the medium-to-high category. This indicates that the learning intervention not only improved students' final scores but also strengthened their cognitive processes in understanding concepts, constructing mathematical arguments, and drawing valid conclusions. Students showed greater ability to explain solution steps systematically and displayed deeper conceptual understanding after participating in the learning activities.

Based on these findings, several recommendations can be offered for instructional practice and future research. First, teachers are encouraged to provide an initial explanation of the flow of Problem Based Learning integrated with Deep Learning so that students clearly understand their roles during exploration, discussion, and problem solving. Such preliminary understanding is essential to prevent confusion and ensure active engagement. Second, effective time management is crucial, as the model requires activities involving analysis, discussion, argumentation, and reflection. Teachers are advised to provide adequate scaffolding, especially during the early stages, to help students gradually develop independent reasoning skills.

Third, future research should consider adapting the context of the problems, the complexity of tasks, and the learning media to match students' characteristics and school facilities. Extending the duration of the learning intervention or increasing the number of meetings may further enhance the model's effectiveness. Fourth, subsequent studies are encouraged to incorporate additional assessment instruments that measure not only cognitive outcomes but also thinking processes, student interactions, and mathematical communication skills through observation sheets, argumentation rubrics, or recorded discussions. Finally, future research may employ experimental designs with control groups or compare the Problem Based Learning integrated with Deep Learning model with other instructional approaches to obtain a more comprehensive understanding of its effectiveness in mathematics education.

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