

Enhancing Students' Mathematical Problem-Solving Skills through Problem-Based Learning



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ABSTRACT

This study aimed to explore the effectiveness of Problem-Based Learning (PBL) in enhancing students' mathematical problem-solving abilities in secondary schools. A quasi-experimental design employing Classroom Action Research (CAR) was conducted in several secondary schools in Indonesia and Rwanda. Data were collected through problem-solving tests, observation, and documentation. Results demonstrated that PBL implementation significantly increased average problem-solving scores from 47.11 to 88.57 after two cycles of intervention. Qualitative observations indicated enhanced student engagement, critical thinking, and collaborative skills. PBL also promoted learning motivation, concept mastery, and student autonomy in tackling mathematical problems. These findings provide practical implications for developing an active and participatory mathematics curriculum.

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Introduction

Mathematics education at the secondary school level plays an important role in shaping students' critical thinking and problem-solving abilities. These abilities are not only relevant to academic success but also necessary for facing complex real-world challenges (Kholisah, Anggraini, & Kartini, 2024; Shinta, Sakur, & Heleni, 2024). Previous studies have shown that many students experience difficulty in applying mathematical concepts to contextual problems, creating a gap between theoretical understanding and practical problem-solving ability (Subekti, Murni, & Siregar, 2024). This condition indicates the need for innovation in learning strategies that can develop students' higher-order thinking skills, particularly in mathematics learning.

One approach that has proven effective is Problem-Based Learning (PBL). PBL emphasizes learning based on real problems, in which students are actively involved in formulating problems, identifying solutions, and evaluating outcomes (Dorimana, Uworwabayeho, & Nizeyimana, 2022). This approach emphasizes group collaboration, active participation, and contextual application of concepts. Empirical studies indicate that PBL can improve students' mathematical problem-solving abilities and critical thinking skills in both Indonesia and Rwanda (Baiq, Prayitno, & Savitry, 2025; Dorimana, Uworwabayeho, & Nizeyimana, 2022).

The findings of Kholisah, Anggraini, and Kartini (2024) indicate that the implementation of PBL increased the average mathematical problem-solving score from 63.44 to 84.56 over two learning cycles. This finding is consistent with other studies showing that PBL improves concept mastery, learning motivation, and student independence (Wahyuni Alamra, Anggraini, & Solfitri, 2024; Fauzia, Suprayitno, & Susilawati, 2025). This confirms that PBL not only improves mathematics test results but also encourages active engagement and the development of soft skills, such as analytical and collaborative thinking.

Although many studies have demonstrated the effectiveness of PBL, several studies remain limited to a single location or a small sample, making it difficult to generalize the findings to broader contexts (Panjaitan & Sihalohe, 2024; Putri, Ihsanudin, & Santosa, 2025). Therefore, studies across schools and even across countries are needed to examine the consistency of findings and the adaptability of the PBL model. The implementation of PBL in various educational contexts can provide more comprehensive empirical evidence regarding the benefits of this method, including its contribution to improving critical thinking skills and mathematical problem-solving ability.

Other studies show that integrating PBL with a STEM-based approach can be more effective in developing students' critical thinking and collaborative skills (Hari & Nggaba, 2025; Kholisoh, Buchori, & Rochmah, 2024). This approach encourages students to apply mathematical concepts to real-world problems, analyze data, and develop solutions systematically. In addition, PBL provides opportunities for students to learn independently, manage time, and improve communication skills within groups.

Beyond cognitive aspects, PBL also has significant implications for students' motivation and engagement in the learning process. Baiq, Prayitno, and Savitry (2025) found that students who participated in PBL were more active in classroom discussions, more motivated to complete assignments, and showed higher knowledge retention than students taught through conventional methods. This finding aligns with international studies emphasizing that student engagement is a key factor in the success of problem-based learning (Dorimana, Uworwabayeho, & Nizeyimana, 2022).

The research gap is also evident in the limited number of studies examining PBL implementation in different classroom contexts and among students with heterogeneous ability levels. Several previous studies focused on classes with relatively homogeneous academic abilities, so further evaluation is needed for more diverse groups (Fauzia, Suprayitno, & Susilawati, 2025). This study attempts to address this gap by involving findings from various classes and ability levels, so that the results are more representative and broadly applicable.

The main objective of this study is to evaluate the effectiveness of PBL in improving secondary school students' mathematical problem-solving abilities, analyze changes in student engagement and motivation, and provide implications for teaching practices and curriculum development. This study is expected to serve as a reference for teachers, researchers, and education policymakers in implementing active learning strategies that improve students' higher-order thinking skills (Kholisah, Anggraini, & Kartini, 2024; Dorimana, Uworwabayeho, & Nizeyimana, 2022; Baiq, Prayitno, & Savitry, 2025).

Considering all empirical evidence, this study emphasizes the importance of PBL as a learning strategy that not only improves academic ability but also fosters students' social, collaborative, and critical thinking skills. Systematic implementation of PBL can provide a strong foundation for improving the quality of mathematics learning in secondary schools and can serve as an adaptable model in various educational contexts. This study is expected to become a theoretical and practical basis for more effective and participatory mathematics learning innovations in line with the demands of twenty-first-century education, which emphasizes critical, creative, and collaborative thinking skills.

Method

Type and Research Design

This study used a simple systematic literature review approach with a descriptive-qualitative method. This approach was selected because the article focuses on reviewing previous research findings regarding the implementation of the Problem-Based Learning model in improving students' mathematical problem-solving abilities. This design does not aim to test a new classroom treatment, but to analyze, compare, and synthesize empirical findings from various published journal articles. Therefore, this study does not add new experimental data but uses research data that are already available in the referenced articles.

Research Data Sources

The data sources in this study were scientific journal articles discussing the implementation of Problem-Based Learning or problem-based instruction in mathematics

learning. The articles used were references listed in the bibliography, including studies by Kholisah, Anggraini, and Kartini (2024), Shinta, Sakur, and Heleni (2024), Subekti, Murni, and Siregar (2024), Dorimana, Uworwabayeho, and Nizeyimana (2022), and other relevant studies. All articles were selected because they explicitly discussed mathematical problem-solving ability, mathematics learning outcomes, student activities, or the effectiveness of problem-based learning models at the secondary school level.

Article Selection Criteria

The analyzed articles were selected based on several criteria. First, the article had to discuss the Problem-Based Learning model or a problem-based learning approach in the context of mathematics learning. Second, the article had to contain empirical results, such as improvements in average scores, learning mastery, N-gain, student activity, or comparisons of learning outcomes before and after the implementation of the model. Third, the article had to be published in a scientific journal and have a clear publication identity, including author names, year of publication, journal name, and DOI. Fourth, the article had to be directly related to secondary school students, including junior high school, senior high school, or vocational high school students. Articles that only discussed general theory without empirical results were not used as main sources in the analysis.

Data Collection Techniques

Data collection was carried out through documentation of the selected articles. The collected data included researcher names, publication year, education level, research design, number of subjects when available, research outcome indicators, and key findings. The main focus of data collection was directed toward changes in students' mathematical problem-solving abilities after the implementation of Problem-Based Learning. Supporting data, such as improvements in learning activity, motivation, student engagement, and learning effectiveness, were also recorded when available in the referenced articles.

Data Analysis Techniques

The data were analyzed using content analysis and narrative synthesis. Content analysis was used to identify patterns of findings from each article, particularly those related to the improvement of mathematical problem-solving ability. Meanwhile, narrative synthesis was used to compare findings across studies and explain the general tendencies of Problem-Based Learning implementation. Each finding was grouped based on the examined aspects, namely improvement in problem-solving scores, learning mastery, student activity, and the contribution of problem-based learning to higher-order thinking skills.

Data Validity

Data validity was maintained through a strict source selection process and consistent use of references. Each article used in this study had to be directly relevant to the research focus and listed in the bibliography. The researcher also compared findings from several articles to examine consistency across results. When several studies showed a similar pattern of findings, the finding was considered to have stronger empirical support. Through this procedure, the study is expected to provide an objective overview of the effectiveness of Problem-Based Learning in improving students' mathematical problem-solving abilities.

Results and Discussion

Improvement in Mathematical Problem-Solving Scores

Data from several studies show a significant increase in students' problem-solving scores after the implementation of Problem-Based Learning (PBL). Table 1 summarizes empirical data from previous studies.

Table 1. Average Mathematical Problem-Solving Scores Before and After PBL

Researcher	Class / School	Number of Students	Average Score Before PBL	Average Score After PBL	N-Gain
Kholisah, Anggraini, & Kartini (2024)	IX B / SMP Negeri 2 Bangkinang	30	63.44	84.56	0.72
Shinta, Sakur, & Heleni (2024)	VIII / MTs PP Nurul Islam Kampung Baru	30	26.50	65.50	0.63
Subekti, Murni, & Siregar (2024)	VIII2 / SMP Negeri 17 Pekanbaru	41	55.97	81.09	0.61
Baiq, Prayitno, & Savitry (2025)	X.2 / SMAN 5 Mataram	36	5.5%	80.5%	0.74
Ananda & Amry (2024)	VIII-A / SMP Negeri 1 Stabat	30	47.11	84.11	0.69

The data in Table 1 show that PBL consistently improves students' problem-solving abilities, with N-Gain scores ranging from 0.61 to 0.74, indicating a high level of effectiveness. The increase is visible not only in average scores but also in the improvement of student participation, learning mastery, and confidence in solving mathematical problems.

Comparison Diagram of Scores Before and After PBL

The following bar chart presents a comparison of average scores before and after PBL implementation across several studies.

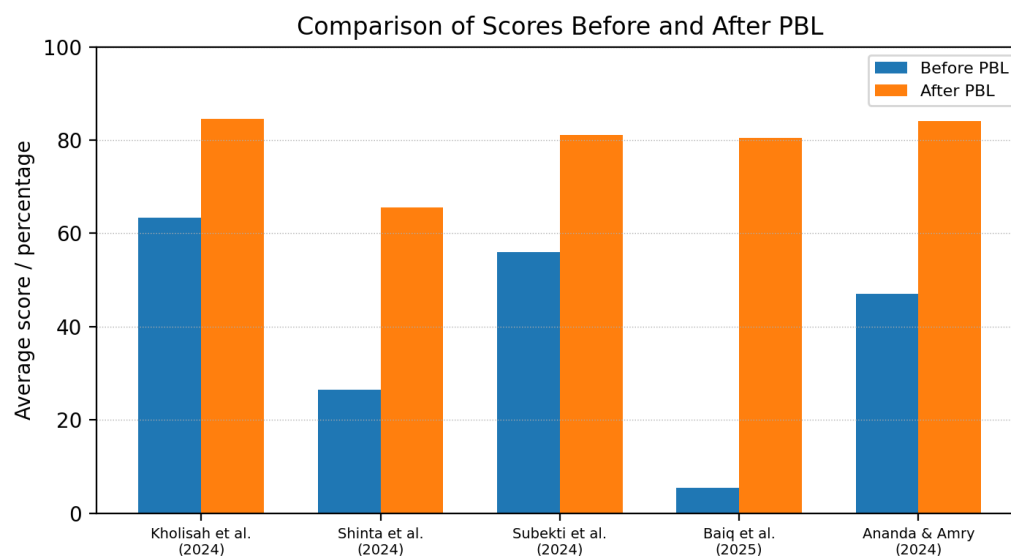


Figure 1. Comparison of average scores before and after Problem-Based Learning implementation.

Figure 1 shows a clear improvement across all studies. The highest post-implementation scores were reported by Kholisah, Anggraini, and Kartini (2024) and Ananda and Amry (2024), both of which reached scores above 84. The findings indicate that PBL provides structured opportunities for students to understand problems, discuss solution strategies, test mathematical reasoning, and evaluate answers collaboratively.

In addition, the findings from Baiq, Prayitno, and Savitry (2025) show a substantial increase in learning mastery from 5.5% to 80.5%. This result indicates that PBL can support not only students with stronger initial abilities but also students who previously had difficulties achieving learning mastery. Through problem orientation, group investigation, presentation, and reflection, students are encouraged to connect mathematical concepts with contextual situations.

Overall, the literature synthesis suggests that PBL contributes to three important aspects of mathematics learning. First, it strengthens cognitive ability by requiring students to analyze problems and construct solution strategies. Second, it improves affective aspects, such as motivation, engagement, and confidence. Third, it develops social skills through discussion, peer collaboration, and communication of mathematical ideas. These findings support the use of PBL as a relevant active-learning strategy for secondary mathematics instruction.

Conclusion

This bibliometric study successfully mapped research on numeracy and mathematical problem-solving skills in mathematics education in Indonesia for the period 2020–2026. Publication trends show a consistent increase, peaking in 2025, reflecting researchers' high interest in both topics. The most productive authors and most active collaborators are Fauziyah, Nur, and Wintarti, Atik, with contributions of 2 articles and the highest TLS score (4). The journal MATHEdunesa is the most productive publisher, while the Journal of Realistic Mathematics Education (JI-MR) has the greatest research impact based on total citations (355). Keyword cluster analysis identified 6 main thematic clusters, indicating that research in this field centers on ability testing, test instruments, and the AKM policy context. Topics that remain under-researched include error analysis, gender perspectives, and the application of Polya's theory presenting opportunities for future researchers to develop more diverse and novel studies. This study is limited to a single database (Google Scholar) with a restriction to the Indonesian language; therefore, further studies are recommended to expand data sources to Scopus, Web of Science, or SINTA for a more comprehensive overview.

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