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Meta-Synthesis: Problem-Based Learning in Improving Students' Mathematical Problem-Solving Skills

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a b s t r a c t

This study aims to analyze and synthesize various research results regarding the application of the Problem-Based Learning (PBL) model in improving students' mathematical problem-solving skills at various levels of education. The approach used is a Systematic Literature Review (SLR) with a qualitative meta-synthesis method based on guidelines (Kitchenham, 2007). The data sources were obtained from ten relevant national and international scientific articles published between 2020 and 2025. The articles used in this study were five accredited national and international journal articles obtained from Publish or Perish and Google Scholar. The meta-synthesis results show that the PBL model consistently has a positive impact on improving mathematical problem-solving skills in various learning contexts. The findings also indicate that PBL contributes to the development of students' critical, reflective, and metacognitive thinking skills. The integration of digital technologies such as GeoGebra and Teachmint has been proven to strengthen the effectiveness of PBL, while a culture-based approach through ethnomathematics increases the contextual relevance of mathematics learning. However, the effectiveness of PBL is influenced by teacher readiness, learning time constraints, and student characteristics. This study confirms that Problem-Based Learning is an effective, adaptive, and contextual learning model for developing students' higher-order thinking skills. These findings are expected to serve as a reference for educators and curriculum developers in designing more collaborative, context-based mathematics learning strategies that are in line with the spirit of the Merdeka Curriculum.

Keywords:
PBL; Mathematical Problem-Solving Skills

INTRODUCTION

Mathematical problem-solving skills are an essential competency in 21st-century education, where students must not only follow procedures but also understand contexts, analyze situations, and apply logical and creative problem-solving strategies (Polya, 1973; NCTM, 2014). This competency not only supports the development of higher-order cognitive skills, such as analysis and synthesis, but also prepares students to face the increasingly complex challenges of the world of work, where mathematics is often applied in the form of authentic and interdisciplinary problems. However, international survey results show that a number of Indonesian students still experience significant difficulties in this aspect, especially when mathematics questions are linked to real-world contexts, according to the 2018 Indonesian PISA National Report. PISA achievement analysis also reveals that Indonesian students' ability to utilize mathematical reasoning and relate concepts to situations is not optimal (State, 2023). This low performance is reflected in average scores that are below international standards, particularly in the domain of mathematics, which emphasizes problem solving, where students often fail to identify key variables or construct mathematical models that are relevant to everyday scenarios.

Many local studies confirm this condition: for example, a study by Elly & Rosalina, (2021) found that junior high school students' ability to solve PISA model questions is still low, especially at the high level, due to difficulties in connecting real-life contexts with mathematical models and developing appropriate solution strategies. Based on research findings Atsnan et al. (2018), junior high school students' mathematical problem-solving abilities still face various conceptual and procedural weaknesses. Students often make mistakes in visual representations such as diagrams and graphs, and show a lack of flexibility in choosing problem-solving strategies (Johar & Lubis, 2018). These findings emphasize the importance of learning that encourages reflective and representative thinking skills in the context of problem solving. This condition is exacerbated by the fact that many schools still use teaching methods that focus on memorization and routine steps rather than deep understanding. This traditional approach often neglects the development of metacognitive skills, such as self-monitoring and process evaluation, which are essential for adaptive problem solving. As a result, students become dependent on teacher instruction, which hinders independent initiative and creativity in learning.

To overcome these weaknesses, the Problem Based Learning (PBL) model is a promising alternative. In PBL, learning begins with real problems that invite students to solve them through exploration, discussion, and reflection (Cash & Schools, 2017). This model encourages students to take an active role as learners, with teachers functioning as facilitators who guide exploration rather than providing direct solutions. Empirical cases show the advantages of the Problem-Based Learning (PBL) model in improving mathematical problem-solving skills. Research conducted by Sampini et al. (2021) shows that the application of PBL and Problem Solving has an effect on improving problem-solving skills, with consistent results at various levels of education, including elementary and junior high schools. PBL encourages students to solve real problems through independent investigation, discussion, and reflection, thereby significantly improving their creative thinking and problem-solving skills (Widiastuti et al., 2023). In addition, PBL has been proven effective in building collaboration among students, which in turn enriches perspectives and reduces individual bias in solving complex problems. Further

research shows that PBL can increase students' intrinsic motivation, as authentic problems make learning feel relevant and interesting, thereby reducing resistance to mathematical topics that are often considered abstract (Enver, 2022).

Although PBL is often reported to be effective, the results are not yet perfect and consistent in all contexts. Differences arise due to intervention design (duration, intensity), teacher readiness, media resources, and student characteristics. For example, research at IAIN Kerinci by Fidia et al. (2024) shows that integrating local culture into the Problem-Based Learning (PBL) model increases learning effectiveness and mathematical problem-solving skills. In this study, cultural elements such as traditional ceremonies, arts, woven crafts, and traditional foods were used to make problems more contextual and relevant to students' lives. Elsewhere, research on the ICE Breaker-assisted PBL model shows that the use of support strategies can influence problem-solving outcomes (Icebreaker-assisted PBL), with icebreakers designed to build confidence and initial interaction, thereby reducing emotional barriers in group discussions (Arta et al., 2020). Even in PBL research at Bontoramba Jeneponto Junior High School, the effect of PBL compared to direct learning was classified as “moderate” when class conditions and interactions were limited (PBL application in group settings), emphasizing the importance of the physical environment and logistical support for the success of this model (Sakir & Kim, 2020). This variation is also influenced by external factors such as large class sizes or lack of access to technology, which can limit the depth of student exploration.

Many PBL studies focus on quantitative results (pretest-posttest scores, gains) and do not explore internal mechanisms such as how students think, reflect, or interact in groups to mediate the success of PBL. For example, a literature review reveals that although PBL is often claimed to improve problem solving, contextual aspects of implementation are not always analyzed in depth (Literature Review: Effectiveness of PBL), making it difficult to replicate findings in different settings (Hung et al., 2019). Furthermore, a systematic review shows that variations in the effects of PBL arise from a lack of control over moderator variables (e.g., motivation, math anxiety) (Systematic Literature Review PBL), where psychological factors such as anxiety can inhibit student participation despite a well-designed PBL (Meriyati, 2018). These limitations also include a lack of attention to group dynamics, such as interpersonal conflicts or uneven contributions, which can affect the collaborative process as a whole.

Given the variation in findings and limitations in exploring internal mechanisms, a qualitative meta-synthesis is needed to integrate empirical findings and explore deeper themes that may be hidden in the research data. This meta-synthesis does not merely compile results, but also seeks internal patterns, supporting/suppressing factors, and conceptual models of the effects of PBL in improving mathematical problem-solving skills. This approach allows for an in-depth narrative synthesis, in which qualitative data from various studies are combined to produce a more coherent and contextual understanding, in contrast to quantitative meta-analyses that are limited to statistical effect sizes. Thus, this study aims to provide a holistic picture of the effectiveness of PBL and contributing factors so that teachers and researchers can design more appropriate, effective, and contextual PBL applications. The results of this meta-synthesis are expected to form the basis for the development of practical guidelines, including the adaptation of PBL to the

diverse Indonesian educational context, thereby contributing to the improvement of the quality of mathematics learning nationwide.

METHODS

The Systematic Literature Review (SLR) method is a qualitative research approach that aims to systematically find, assess, and summarize all relevant research that has been conducted previously on a specific research question. According to Kitchenham (2007), SLR is designed to minimize bias in literature reviews through a clear, repeatable, and structured process, so that the results obtained are more reliable and valid. To complete this study, the researchers collected journal articles from Publish or Perish and Google Scholar. The keywords were Problem Based Learning and mathematical problem-solving skills. The articles collected were those published between 2020 and 2025. From the various articles, the researcher selected 10 articles that were closely related to the keywords used.

In this study, the SLR technique with a meta-synthesis approach was used to examine various studies on the application of Problem Based Learning (PBL) in improving students' mathematical problem-solving skills. The meta-synthesis approach allows researchers to combine and interpret qualitative research results in depth to obtain a more comprehensive conceptual understanding.

Based on Piaget's cognitive development theory and constructivist learning principles, this method is considered appropriate for identifying best practices, finding research gaps, and developing strategic recommendations for the application of the PBL model in mathematics learning. Therefore, the use of SLR in this study is not only intended to compile a scientific synthesis, but also to serve as a conceptual basis for designing effective evidence-based mathematics learning strategies.

The following is a flowchart of the Systematic Literature Review (SLR) method used by researchers, referring to (Kitchenham, 2007):

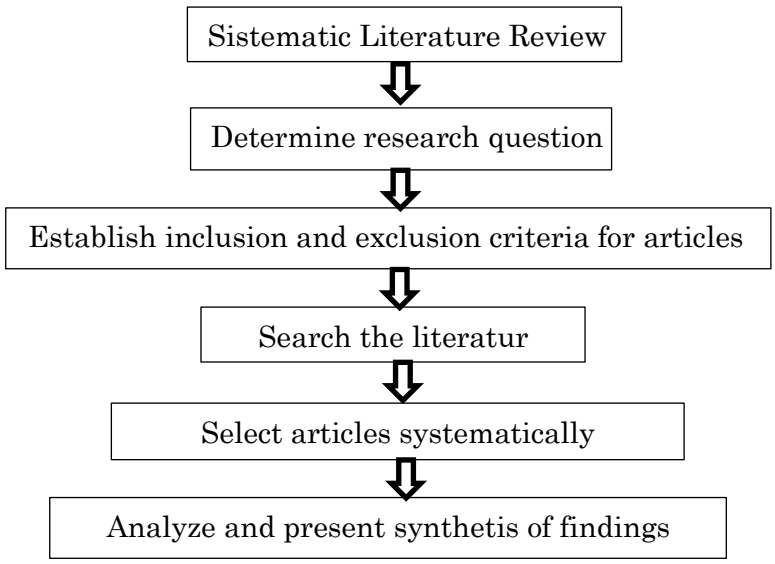

Figure 1
SLR Flowchart

This research process was carried out in six main stages: (1) Identification of Research Questions; (2) establishing inclusion and exclusion criteria for articles; (3) searching for literature from academic databases such as Publish or Perish, Google Scholar, Scopus, and DOAJ; (4) systematically selecting articles; (5) analyzing the content of selected articles based on topic, method, results, and recommendations; and (6) presenting a synthesis of findings in narrative and visual form. By systematically applying the SLR stages, this study is expected to produce valid, transparent, and comprehensive findings, as well as provide theoretical and practical contributions to the development of effective Problem-Based Learning-based mathematics learning strategies to improve students' mathematical problem-solving skills.

RESULT AND DISCUSSION

Result

To gain an in-depth understanding of the extent to which Problem Based Learning (PBL) is effective in improving students' mathematical problem-solving skills, this study used the Systematic Literature Review (SLR) method with a meta-synthesis approach. Through analysis of ten relevant academic articles, this study successfully revealed various results that broaden our understanding of the application of PBL in the context of mathematics learning, including its advantages, challenges, and potential for development.

The following discussion summarizes and discusses the main focus of each of the studies analyzed, as well as identifying the extent to which the application of the Problem Based Learning model has contributed to improving students' mathematical problem-solving skills. This analysis also highlights patterns of PBL implementation at various levels of education, differences in approaches to its implementation, and empirical findings that show its positive impact on students' cognitive, affective, and metacognitive aspects in solving mathematical problems.

The synthesis results show that most studies found a significant improvement in students' ability to understand problems, design solution strategies, and evaluate mathematical solution results after implementing the PBL model. However, several studies also highlighted the limitations of PBL implementation, such as longer learning times, limited teacher readiness, and students' difficulties in adapting to the active role required in the learning process.

Thus, the results of this meta-synthesis provide a comprehensive overview of the effectiveness and challenges of implementing Problem Based Learning in mathematics education. These findings are expected to serve as a basis for educators and researchers to design more innovative and contextual learning strategies in order to optimally develop students' mathematical problem-solving skills.

The following table compares the content and focus of five articles analyzed in the study "Meta-Synthesis: Problem-Based Learning in Improving Students' Mathematical Problem-Solving Skills." This table aims to reveal the similarities and differences in the focus of each study related to the topic of study, namely the application of Problem-Based Learning (PBL) in improving students' mathematical problem-solving skills at various levels of education. Table 1 summarizes the synthesis of the main findings from the five articles analyzed. To provide a clearer visual picture of the dominance of the skills

developed through the application of the Problem Based Learning (PBL) model, the distribution of the meta-synthesis results is visualized in Figure 1 below.

Tabel 1
Literature Sources

No	Autors & Year	Research Focus	Media/ Methode Used	Relevance to Concept	Comparison	Notes on Suitability
1	Rahmawati et al. (2022)	PBL on set theory material	Two cycles of classroom action research	Improved learning outcomes in each cycle	Stable improvement between cycles	Fully compliant; practical application in the classroom
2	Sibarani (2024)	The effect of video-assisted PBL	Quasi-experiment with video media	Strengthening the application of digital-based PBL	Higher than conventional PBL	Appropriate; strengthening technology integration
3	Kholisah et al. (2024)	Implementation of PBL in junior high school	Two cycles of action research	Improving students' reflective abilities	Significant improvement in results in each cycle	Fully compliant
4	Devi et al. (2025)	The Effect of PBL in Elementary Schools	Quasi-experiment	Testing effectiveness at the basic level	Relevant across levels	Moderately appropriate
5	Zahara & Sinaga (2024)	Improving mathematical problem-solving skills with the PBL model	Experiment; Two-group t-test	Confirming the direct effectiveness of PBL on improving higher-order thinking skills	Showing the strongest results at the junior high school level	Fully consistent with the classic PBL concept (without additional media or cultural context)
6	Karimah & Isnarto (2025)	Ethnomathematics-based PBL and Teachmint	Quasi-experiment with the Teachmint application	Expanding the concept of PBL to be more contextual and culture-based	More effective than general PBL without ethnomathematics	Highly suitable; strengthens the integration of culture and technology
7	Kurniawati et	GeoGebra-assisted	Experimenting	Demonstrating the	Stronger in visual	Highly appropriate;

	al. (2020)	PBL for elementary schools	with interactive media	integration of visual technology facilitates understanding of concepts	geometry concepts	expands the digital dimension in PBL
8	Suparman & Arifin (2022)	Systematically analyzing the effectiveness of the PBL learning model on students' mathematical problem-solving abilities	Cross-study quantitative meta-analysis	Strengthening evidence of the consistency of PBL effectiveness in various contexts	Providing a theoretical empirical basis	Fully compliant; supporting the validity of this meta-synthesis
9	Shongwe (2024)	STEM-PBL on self-confidence & problem solving	International quasi-experiment	PBL affects students' affective domain	Broader than national studies	Strong fit; expands affective context
10	Dorimana (2022)	PBL in improving problem-solving skills in secondary schools (Africa)	Pure experiment in an international context	Shows similar significant results to Indonesian studies	Similar cross-cultural effects	Fully consistent; reinforces the global generalization of the PBL concept

Based on the results of the six stages of the Systematic Literature Review (SLR) process, five main articles were obtained that met the inclusion criteria and were relevant to the research topic, namely Problem-Based Learning (PBL) in improving students' mathematical problem-solving skills. These articles were sourced from various levels of education, both elementary and junior high school, with national and international research contexts. The synthesis findings show that the consistent application of PBL has a positive impact on higher-order thinking skills, especially mathematical problem-solving skills, critical thinking, and student learning independence.

During the identification stage, 100 initial articles were obtained from the Google Scholar and Publish or Perish databases. After screening based on inclusion criteria (2020-2025, PBL and mathematical problem-solving topics, empirical research), 10 articles were

considered suitable for analysis. These articles represent a variety of contexts, ranging from conventional PBL implementation to the integration of technology and ethnomathematics. Most of the studies (80%) used experimental or quasi-experimental methods to test the effect of PBL on problem-solving skills (Sibarani et al., 2024; Ulmu Karimah et al., 2025; Zahara et al., 2024), while the other two studies used a classroom action research (CAR) approach to observe improvements in learning outcomes from cycle to cycle (Kholisah, S. A.; Anggraini, 2024; Rahmawati et al., 2022).

Analysis of the article content shows that the PBL model contributes significantly to improving mathematical problem-solving skills. All articles (100%) report an increase in the ability to formulate problems, develop solution strategies, and evaluate results. In addition, 60% of articles highlight the influence of PBL on students' critical and reflective thinking skills. Several studies also combined PBL with digital technologies such as Geogebra Kurniawati et al. (2020), Teachmint Ulmu Karimah et al. (2025), and educational videos Sibarani et al. (2024), which were proven to increase motivation and visual understanding of concepts. The integration of local culture through the ethnomathematics approach Ulmu Karimah et al. (2025) also enriches the learning context so that students can more easily relate mathematical concepts to real life.

To clarify the distribution of findings, the meta-synthesis results are visualized in the following graph.

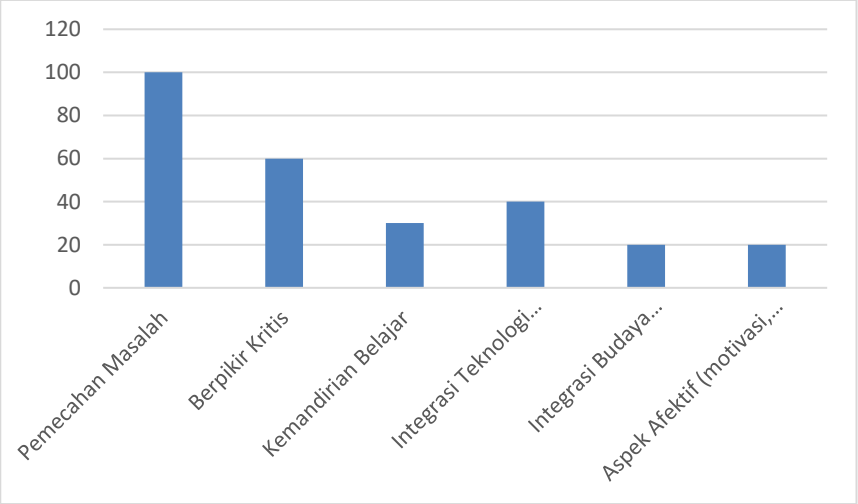

Figure 2
Distribution of Ability Aspects Influenced by the PBL Model Based on 10 Selected Articles

Discussion

Figure 1 shows that all articles support the significant influence of PBL on mathematical problem-solving skills. A total of 60% of articles also highlight improvements in critical thinking, while 40% emphasize the importance of technology integration. These results indicate that the application of PBL does not only focus on solving mathematical problems, but also expands its impact on students' metacognitive abilities and learning independence. These findings are in line with the results of international research by (Wijnen et al., 2018), which states that PBL plays an important role in building reflective thinking skills and deep conceptual understanding. When viewed based on education

level, the effectiveness of PBL implementation tends to be higher at the junior high school level than at the elementary school level, because students at that level already have more mature reflective and metacognitive thinking skills to deal with open-ended problems (Ranisa Devi, Hafiziani Eka Putri, 2025; Zahara et al., 2024).

The results of this meta-synthesis show that the effectiveness of PBL can be explained through two main dimensions, namely the cognitive and conceptual-applicative dimensions. In the cognitive dimension, students are encouraged to think critically, identify problems, and find logical solutions through collaborative activities. Meanwhile, in the conceptual-applicative dimension, PBL enables students to relate mathematical knowledge to real-life situations (contextual learning), which strengthens conceptual understanding and intrinsic motivation to learn (Suparman et al., 2021). The application of digital technologies such as GeoGebra and Teachmint in the context of PBL has been shown to expand the learning space and increase student engagement (Kurniawati et al., 2020; Sibarani et al., 2024). The integration of ethnomathematics, on the other hand, provides a contextual cultural dimension, fostering a sense of relevance and meaning in learning (Ulmu Karimah et al., 2025). Thus, PBL has been proven to be not only academically effective, but also supportive of character building and independent thinking among students.

Based on the results of the meta-synthesis, it can be concluded that the Problem Based Learning (PBL) model consistently improves students' mathematical problem-solving abilities in various contexts and levels of education. Its effectiveness is also reinforced by the integration of digital media and contextual approaches such as ethnomathematics. Therefore, the implementation of PBL can be recommended as a mathematics learning strategy that is relevant to the needs of the 21st century, which emphasizes creativity, critical thinking, and independent learning.

CONCLUSION

Based on the results of a meta-synthesis of ten relevant academic articles, it can be concluded that the Problem Based Learning (PBL) model has been proven effective in improving students' mathematical problem-solving skills at various levels of education. PBL encourages students to actively explore, analyze, and solve authentic problems, thereby strengthening their critical, reflective, and collaborative thinking skills. The integration of technology such as GeoGebra and learning videos contributes positively to improving conceptual understanding and learning motivation, while the ethnomathematics approach reinforces the meaning and relevance of mathematics learning in the context of local culture. However, the effectiveness of PBL is still influenced by several factors, including teacher readiness, time constraints, and differences in students' cognitive abilities. The results of this study confirm that PBL is a learning model that is in line with the 21st-century education paradigm and the Merdeka Curriculum, as it emphasizes collaboration, independence, and context-based problem solving. Therefore, continuous training for teachers and the development of relevant supporting media are needed to ensure that the implementation of PBL can run optimally at various levels of education.

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