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SYSTEMATIC LITERATURE REVIEW: THE EFFECTIVENESS OF USING THE PROBLEM-BASED LEARNING MODEL IN IMPROVING PROBLEM-SOLVING SKILLS

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ABSTRACT

Amid challenges in mathematics education, students' low problem-solving skills have become a key concern. Studies have shown that many students struggle to understand problems, devise appropriate strategies, and validate their solutions, especially when faced with real-world mathematical tasks. Problem-Based Learning (PBL) has been identified in many studies as a promising approach to address this issue. This study aims to evaluate the effectiveness of PBL in enhancing students' mathematical problem-solving skills through a systematic review of recent literature. Using the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) method, this Systematic Literature Review (SLR) identified 20 relevant articles from 1,672 collected through databases like ERIC, ScienceDirect, IOP Science, and PubMed, using keywords "Problem-based Learning" and "problem-solving mathematics." The findings show that PBL consistently improves students' problem-solving skills and is more effective than traditional teaching methods. Thus, PBL is a valuable instructional model for educators to adopt. This review suggests that PBL should be integrated more systematically into mathematics instruction to support students in developing essential 21st-century skills.

Keywords: Problem-based Learning, Mathematical Problem-Solving Skills.

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PRELIMINARY

In mathematics education, problem-solving skills enable students to address new and complex challenges, often presented as non-routine problems, by applying foundational knowledge and reasoning patterns to navigate the problem-solving process (Ismiranda et al., 2024). These skills are essential in mathematics and are regarded as critical high-order skills for students in today's evolving education landscape (Adeoye & Jimoh, 2023; Bariyyah, 2021; Rahman, 2019). In today's workforce, problem-solving is indispensable, alongside other key skills such as creative thinking, communication, critical thinking, and teamwork (Thornhill-Miller et al., 2023). Furthermore, problem-solving abilities provide a strong foundation for individuals to adapt to changes, address complex issues, and transfer knowledge across various domains. As these skills are anticipated to remain essential for decades, understanding and enhancing students' problem-solving competencies is crucial to equip them for the increasingly dynamic and demanding future challenges.

At their core, problem-solving skills involve finding solutions to new problems or situations by leveraging prior knowledge. These skills include identifying problems, analyzing their causes, and implementing practical solutions (Choudhar et al., 2022; Sarma, 2021). They encompass various aspects, such as decision-making, understanding relationships, gathering information, communicating, and evaluating to arrive at solutions (Parwati, 2019). During problem-solving, the brain functions optimally, enabling individuals to think logically, systematically, and critically in addressing everyday challenges (Mauleto, 2019). These processes reflect the multifaceted nature of problem-solving, where cognitive, metacognitive, and affective elements are intricately interwoven. Educators thus need to recognize that problem-solving is not merely a procedural skill but an integrated competence that must be taught and nurtured deliberately through rich learning experiences

Developing problem-solving skills is integral to fostering higher-order thinking in students (Waluyo et al., 2020). Emphasizing these skills is particularly beneficial in learning mathematics, as it inspires students to apply critical thinking and creativity in tackling mathematical challenges (Sriwahyuni & Maryati, 2022). In mathematics education, developing problem-solving skills is often perceived as challenging (Khatimah & Sugiman, 2019). Students must utilize their cognitive abilities to find various approaches to solve real-world mathematical problems (Endah et al., 2019). Consequently, instructional strategies must be designed to explicitly support the development of higher-order thinking. Simply exposing students to mathematical problems is insufficient without guided inquiry, scaffolding, and opportunities for reflective learning. This highlights the need for pedagogical models that promote such engagement.

However, students' proficiency in solving mathematical problems is still low. Research by Andayani & Lathifah (2019) revealed students experiencing challenges when dealing with math problems is common. Similar findings have been reported by Anggraeni & Kadarisma (2020), Azzahra & Pujiastuti (2020), Bernard et al. (2018), Rambe & Afri (2020), and Utami & Wutsqa (2017), indicating that only a few students exhibit good problem-solving skills. These findings indicate a mismatch between the expectations of the curriculum and the skills demonstrated by students in practice. This may be due to instructional approaches that have not fully supported the development of deep conceptual understanding, as they still tend to emphasize procedural aspects.

This deficiency negatively impacts students' cognitive and skill development (Suryani et al., 2020b). It results from scant chances given by instructors for learners to nurture such skills. Students often struggle to connect mathematical concepts with real-world applications, hindering their problem-solving skills (Wirandingsih et al., 2017). Low-achieving students face challenges in understanding problems, planning solutions, and verifying answers (Roswanti et al., 2020). To address this issue, implementing the Problem-based Learning (PBL) model shows promise in enhancing students' problem-solving skills (Ariandi, 2017; Suryani et al., 2020b). PBL fosters active student engagement, allowing them to construct knowledge through authentic problem-solving experiences. Furthermore, integrating structured tasks within PBL can enhance problem-solving skills by providing more opportunities for practice and skill development (Ariandi, 2017). The evidence strongly supports the notion that PBL serves as a pedagogical response to students' low problem-solving achievement. By situating problems within meaningful contexts, PBL encourages deeper engagement and motivates students to explore various solution strategies beyond memorized procedures.

Problem-based Learning (PBL) is a teaching model that requires students to engage in discovery-based learning through planned and principle-driven activities, also known as discovery learning. This model enhances students' problem-solving skills (Murniati & Hermawan, 2018). The primary goal of PBL is to foster students' creative thinking, active learning, logical reasoning, and the integration of various creative ideas (Saputro & Rahayu, 2020). In this context, PBL not only contributes to cognitive outcomes but also supports the development of student independence and learning motivation through active engagement in the learning process. The teacher's role shifts from being merely a transmitter of knowledge to a guide and facilitator, enabling students to gradually construct their understanding.

As cited in Hotimah (2020), PBL is categorized as a problem-driven learning model that fosters both individual and collaborative efforts among students. Furthermore, Apriani et al. (2021) presented an analysis stating that PBL focuses on learners' active participation in addressing real-world challenges to gain knowledge, enhance their independence and self-esteem, and develop complex thinking skills.

Several studies, including those by Oktaviana & Haryadi et al. (2022), Silvi et al. (2020), Suciyati & Hardiansyah (2020), and Widyastuti & Airlanda (2021), demonstrate that applying the PBL model can improve students' mathematical problem-solving skills. These empirical findings reinforce the theoretical promise of PBL, indicating its practical effectiveness across varied educational contexts. It also suggests that further synthesis of these findings can inform best practices for implementation.

Therefore, this study aims to investigate the extent to which the Problem-Based Learning (PBL) model is effective in enhancing students' mathematical problem-solving skills, based on a systematic analysis of recent literature.

METHODS

This study applied a Systematic Literature Review (SLR) method guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to ensure transparency and reproducibility in identifying and synthesizing relevant research (Haddaway et al., 2018). The identification stage involved searching four databases—ERIC, ScienceDirect, IOP Science, and PubMed—using the keywords "Problem-Based Learning" and "problem-solving mathematics," yielding 1,672 records. After removing 121 duplicate records, 1,551 articles remained for screening. During the screening stage, 1,433 articles were excluded based on title and abstract review due to irrelevance to the study focus. Subsequently, 118 full-text articles were assessed for eligibility. In the eligibility stage, 98 articles were excluded for not meeting the inclusion criteria.

The inclusion criteria were: (1) publication years between 2015 and 2024, (2) written in English, (3) indexed in reputable academic databases such as Scopus or Web of Science, (4) focused on the application of Problem-Based Learning (PBL) in mathematics education, and (5) presenting empirical evidence regarding the enhancement of mathematical problem-solving skills. As a result, 20 studies were included in the final qualitative synthesis. The entire review process is illustrated in the PRISMA flow diagram.

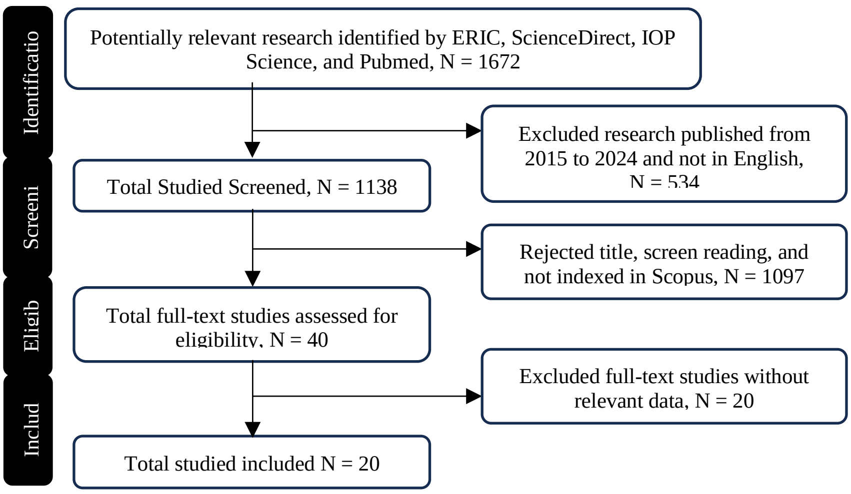

Figure 1. PRISMA Diagram

RESULT AND DISCUSSION

1. Classification of Journals Based on Various Criteria

This section describes the findings of the article selection process based on the systematic literature review (SLR) technique. The final total of selected articles is 20 that are pertinent to Problem-Based Learning and problem-solving in mathematics. The details of the journals are given below:

Table 1. Identity of 20 Journals

No	Author	Journal Name	Indexed
1	Boye & Agyei (2023)	Social Sciences and Humanities Open	Q1
2	Anduri et al. (2021)	Journal of Physics: Conference Series	Q4
3	Herdianto et al. (2021)	Journal of Physics: Conference Series	Q4
4	Isriani et al. (2021)	Journal of Physics: Conference Series	Q4
5	Jannah et al. (2021)	Journal of Physics: Conference Series	Q4
6	Priyatno et al. (2021)	Journal of Physics: Conference Series	Q4
7	Siagian et al. (2021)	Journal of Physics: Conference Series	Q4
8	Erawati & Permana (2020)	Journal of Physics: Conference Series	Q4
9	Hasrawati et al. (2020)	Journal of Physics: Conference Series	Q4
10	Hayati et al. (2020)	Journal of Physics: Conference Series	Q4
11	Pandu & Prabaningrum (2020)	Journal of Physics: Conference Series	Q4
12	Permatasari et al. (2020)	Journal of Physics: Conference Series	Q4
13	Santuthi et al. (2020)	Journal of Physics: Conference Series	Q4
14	Suryani et al. (2020a)	Journal of Physics: Conference Series	Q4
15	Siagian et al. (2019)	International Electronic Journal of Mathematics Education	Q3
16	Nay & Rudhito (2020)	Journal of Physics: Conference Series	Q4
17	Sagita et al. (2019)	Journal of Physics: Conference Series	Q4
18	Hendriana et al. (2018)	Journal on Mathematics Education	Q2
19	Surya and Syahputra (2017)	International Education Studies	Q3
20	Ahamad et al. (2017)	Journal of Physics: Conference Series	Q4

One criterion in the journal selection stage is that the chosen journals must be published within the last 10 years, specifically from 2015 to 2024. This reflects the most recent developments and innovations in the field of study, ensuring that researchers consider the most relevant and up-to-date information and data. This period allows for identifying research gaps that are still relevant and unresolved, as well as revealing new trends and findings that may not be present in older literature. Furthermore, methodologies and technologies in research are continuously evolving, meaning that recent studies often employ more advanced and efficient techniques. Reviewing literature from the past 10 years also helps researchers adhere to the latest standards and regulations, providing a more accurate and relevant context for current situations and issues. Therefore, researchers can produce a more comprehensive, relevant, and helpful literature review for advancing knowledge in the field.

Focusing on recent publications also enhances the alignment between literature and present-day educational practices. In the last decade, there has been a growing shift in curriculum frameworks across various countries that emphasize higher-order thinking skills, such as problem-solving, critical thinking, and collaboration—skills that are central to the implementation of PBL. Recent journals are more likely to report on the application of PBL in digital classrooms, hybrid learning contexts, and diverse cultural settings, which are increasingly relevant in today's education systems. In addition, current publications tend to provide more rigorous methodological designs and often adopt frameworks that reflect the latest pedagogical theories and assessment practices. Therefore, restricting the publication window to 10 years helps ensure that the review reflects not only academic relevance but also practical applicability. This focus supports a stronger foundation for making evidence-based decisions in classroom settings and future research directions.

Below is the classification of journals based on their publication years.

Table 2. Classification of Journals by Year of Publication

No	Year of Publication	Number of Journal	Percentage (%)
1	2024	0	0
2	2023	1	5
3	2022	0	0
4	2021	6	30
5	2020	7	35
6	2019	3	15
7	2018	1	5
8	2017	2	10
9	2016	0	0
10	2015	0	0
	N	20	100

Based on the table above, one journal was published in 2023, accounting for 5%; six journals were published in 2021, accounting for 30%; seven journals were published in 2020, accounting for 35%; three journals were published in 2019, accounting for 15%; one journal was published in 2018, accounting for 5%; and two journals were published in 2017, accounting for 10%. No journals were published in 2024, 2022, 2016, and 2015, each contributing 0%.

The table provides a clear overview of the publication timeline of journals relevant to the research topic. Most relevant journals were published between 2017 and 2020, with a significant number in 2020. This suggests a particular trend in the publication of journals related to the Problem-based Learning model in the context of enhancing mathematical problem-solving skills.

In addition to the year of publication, one of the criteria is that the journal must be indexed in Scopus. Scopus-indexed journals are important as they ensure research credibility and quality, enhance academic visibility and reputation, comply with international standards, and provide access to extensive bibliometric data. The following is the classification of journals based on their Scopus index level.

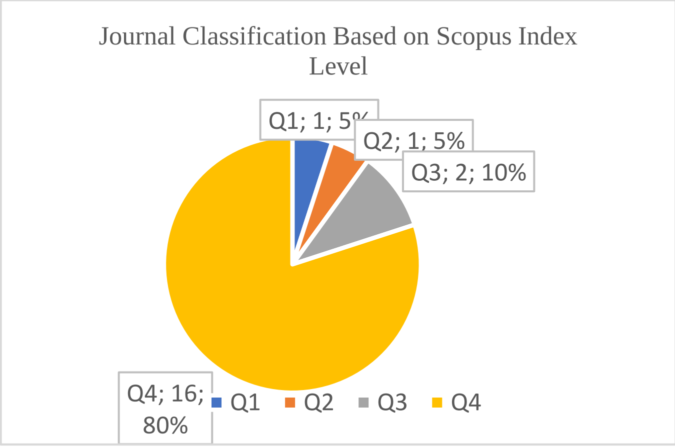

Figure 2. Diagram of Journal Classification Based on Scopus Index Level

Based on the figure above, 5% of the journals are indexed in Scopus Q1, 5% in Scopus Q2, 10% in Scopus Q3, and 80% in Scopus Q4. This analysis indicates that the distribution of journals relevant to the research topic varies regarding indexing quality, as reflected by the Scopus quartile rankings. These quartiles represent the categorization of journals based on citation performance and scholarly impact within specific disciplines.

The majority of the reviewed articles were published in Q4 journals. This reflects a broad interest in Problem-Based Learning (PBL) in mathematics education within academic communities, particularly in journals emphasizing classroom innovation, practical applications, and contextual studies across various regions. Meanwhile, the presence of journals in the Q1, Q2, and Q3 categories indicates that this topic also gains attention at the international level and is featured in journals with wider readership and higher visibility.

Overall, this distribution suggests that research on PBL is widely published across different types of journals, with strong international reputations, and those focusing on local educational issues. This demonstrates that the effectiveness of PBL in enhancing mathematical problem-solving skills is seen as relevant and worthy of investigation from various perspectives, approaches, and educational contexts.

In addition to the distribution by quartile index, differences in educational levels targeted by the reviewed studies were also identified. This classification is discussed in the following section.

Table 3. Classification of Journals Based on Educational Levels

No	Education Level	Class	Number of Journals per Class	Total Journals per Level	Percentage (%)
1	Elementary School	3rd	1	1	5
2	Middle School	7th	6	11	55
		8th	5		
3	High School	10th	4	7	35
		11th	3		
4	Higher Education		1	1	5
	N		20	20	100

The table above shows that one journal is at the elementary school (SD) level, accounting for 5%; 11 journals are at the middle school (SMP) level, accounting for 55%; seven journals are at the high school (SMA) level, accounting for 35%; and one journal is at the higher education level, accounting for 5%.

This analysis illustrates the distribution of journals based on the educational levels that are the focus of the research. The results show that most relevant journals are related to secondary education, with 55% focusing on the middle school level, followed by 35% at the high school level. This indicates a particular emphasis on applying the Problem-based Learning (PBL) model in the context of secondary education, especially during the developmental stage when students are beginning to engage with more abstract mathematical concepts.

The prominence of PBL studies at the middle and high school levels may be due to the increasing demand for instructional strategies that promote independent thinking, logical reasoning, and structured problem-solving during adolescence. At these stages, learners often face more complex mathematical content, such as algebra, geometry, or probability, where PBL can provide meaningful engagement and practical relevance.

However, it is also noteworthy that some journals discuss the application of this model at the elementary school level and in higher education, each accounting for 5%. At the elementary level, PBL is often used to introduce contextual learning and stimulate curiosity through real-world problems suitable for young learners. Meanwhile, in higher education, PBL is frequently implemented to promote reflective thinking and to prepare prospective teachers or professionals for complex decision-making in academic or work-related settings.

This distribution highlights the research community’s interest in implementing PBL across educational levels, reflecting its flexibility and adaptability to different cognitive and academic development stages. It also demonstrates that PBL can be contextualized and refined according to the characteristics and learning needs of students at various levels.

The identified journals can also be classified based on the type of research, as follows::

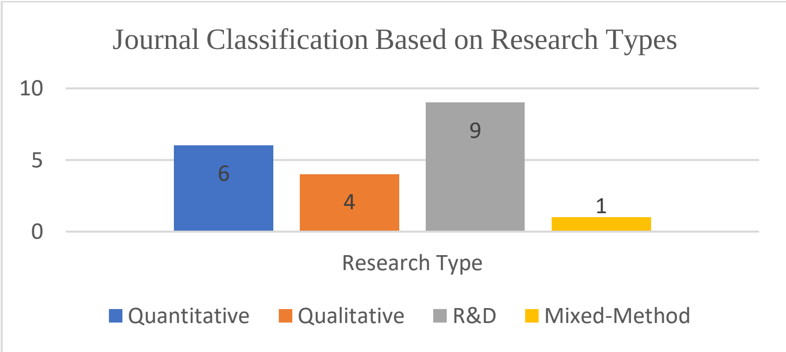

Figure 3. Diagram of Journal Classification Based on Research Types

Based on the figure above, six journals use quantitative research, four use qualitative research, nine use Research and Development (R&D), and one uses a mixed-method approach. This classification of research types is important in understanding how scholars approach the study of Problem-Based Learning (PBL) in mathematics education. Each method offers unique perspectives and contributions, enriching the field through varied analytical lenses and practical outcomes.

This analysis illustrates the distribution of research types used in journals relevant to the research topic. The data reveals that most studies employ a quantitative approach, with six journals adopting this method. Quantitative research allows for measurable outcomes, statistical analysis, and generalizable findings, which are essential in evaluating the effectiveness of the PBL model across different student populations. Qualitative research is also focused on several journals, with four journals using this approach. This method is valuable for exploring students' experiences, classroom interactions, and the depth of conceptual understanding developed during PBL implementation.

Meanwhile, nine journals focus on Research and Development (R&D), indicating a significant interest in designing, creating, and testing instructional tools, models, and media that support PBL-based learning. Lastly, one journal uses a mixed-method approach, combining quantitative and qualitative methods in its research. The presence of a mixed-method study highlights the potential for integrative approaches that capture both the measurable impact and the nuanced, contextual dynamics of PBL. The combination of different research methods across the selected articles contributes to a more comprehensive and multidimensional understanding of how PBL can enhance students' mathematical problem-solving skills.

2. The Effectiveness of the Problem-based Learning Model in Enhancing Students' Mathematical Problem-Solving Skills

Problem-based Learning (PBL) is an instructional method that uses the problem as a key to gaining insight and motivation toward concepts and knowledge application. PBL teaches mathematics in a more meaningful way through constructive thinking, group work, and real-world problem-solving. The studies above show that PBL improves students' capabilities in mathematical problems with respect to problem-solving strategies, logical reasoning skills, and retention of information.

Several scholars have investigated the impact of Problem-based Learning (PBL) on enhancing students' skills in solving mathematical problems.Siagian et al. (2021) created a valid, practical, and effective PBL tool that improved students' problem-solving in mathematics. Herdianto et al. (2021) observed that using mobile learning-based e-books with the PBL model enhanced learners' ability to solve mathematics problems, especially in statistics. Priyatno et al. (2021) developed PBL-based mathematics learning tools with the assistance of GeoGebra, which met the criteria for validity and practicality.

Isriani et al. (2021) found that PBL can significantly improve the problem-solving skills of middle school students and that the development of PBL-based mathematics learning tools aligned with the 2013 curriculum is necessary to support more effective learning. Erawati & Permana (2020) and Hayati et al. (2020) also showed that developing PBL-based learning tools effectively improve students' mathematical problem-solving skills and integrating local contexts through the PBL model significantly enhances middle school students' mathematical problem-solving abilities.

Permatasari et al. (2020) and Siagian et al. (2019) showed that creating PBL-based learning tools improves students' mathematical problem-solving skills. Learning materials based on metacognitive theory facilitate the growth of many important skills, including problem-solving and metacognition. Ahamad et al. (2017) and Surya & Syahputra (2017) found that the PBL model successfully improved students' higher-order thinking in solving mathematical problems and that implementing PBL positively impacted students' performance in geometry.

Jannah et al. (2021) demonstrated that the PBL model not only enhances learners' mathematical problem-solving skills but also is more effective than the STAD model at fostering students' overall problem-solving skills. Hasrawati et al. (2020) and Santuthi et al.

(2020) showed that the PBL model outperformed both 'traditional' learning models in enabling students to solve problems in mathematics and was more effective than the GDL model in helping students develop problem-solving as well as critical thinking skills.

Sagita et al. (2019) demonstrated that the Problem-based Learning (PBL) model effectively improves students' learning outcomes in probability lessons. Hendriana et al. (2018) found that the Problem-based Learning approach (PBL) improved students' mathematical problem-solving skills (MPSA) and mathematical self-confidence (MSC). Boye & Agyei (2023) showed that PBL interventions effectively teach mathematical concepts to prospective teachers.

Pandu & Prabaningrum (2020) showed that the PBL model helped students solve statistics-related problems. Suryani et al. (2020a) showed that the PBL model with a video assignment impacted students' mathematical problem-solving skills by classifying them into three levels of problem-solving ability. Nay & Rudhito (2020) proved that employing virtual manipulatives along with the PBL model assists students in mastering associative and distributive properties necessary for simplifying complex algebraic expressions.

Overall, these studies demonstrate that PBL is a powerful learning strategy that can improve various aspects of students' mathematical problem-solving skills and promote the development of 21st-century skills. It indicates that PBL can be used in various learning contexts and with various learning tools to enhance the effectiveness of mathematics education.

Regarding educational levels, the reviewed studies span various contexts, from elementary to higher education. At the elementary level, studies such as Permatasari et al. (2020) and Siagian et al. (2019) reported that implementing PBL helped students engage with contextual problems and strengthened their problem-solving skills from an early stage. At the junior high school level, several studies (e.g., Isriani et al., 2021; Erawati & Permana, 2020; Hayati et al., 2020; Nay & Rudhito, 2020) showed significant gains in students' problem-solving performance. These results suggest that PBL encourages critical thinking, conceptual understanding, and strategic reasoning at this level. At the senior high school level, studies by Hendriana et al. (2018), Sagita et al. (2019), and Ahamad et al. (2017) indicate that PBL remains effective, especially when applied to complex mathematical topics like probability and geometry. These studies highlight improvements in student performance and conceptual understanding through applying PBL. Meanwhile, Boye & Agyei (2023) emphasized how PBL fosters mathematical reasoning and instructional competencies among prospective teachers in higher education. PBL also supports collaborative learning and prepares students for professional roles as educators.

These findings suggest that PBL can be applied effectively across different levels of education. However, the design of problems, learning supports, and integration of learning tools may vary depending on students’ cognitive development and curricular expectations.

In addition to the diversity of topics and educational levels, the reviewed articles differ in the research methods employed. The most frequently used method is Research and Development (R&D), in which researchers create, validate, and implement PBL-based learning tools to enhance students' problem-solving abilities—for example, Siagian et al. (2021), Priyatno et al. (2021), and Isriani et al. (2021). These studies produce innovative learning products that align with curriculum goals and contextual needs.

Several studies applied a quantitative approach to evaluate the effectiveness of PBL using statistical analysis—such as those by Hasrawati et al. (2020) and Surya & Syahputra (2017)—to objectively measure the impact of PBL on students' outcomes. Others adopted a qualitative method to explore classroom dynamics, student responses, and contextual adaptations in implementing PBL, including studies by Hayati et al. (2020) and Erawati & Permana (2020). Meanwhile, only one study—Ahamad et al. (2017)—applied a mixed-methods approach, combining quantitative and qualitative data to provide a more comprehensive understanding of the impact of PBL in geometry lessons.

Each research method offers distinct benefits. R&D provides practical and applicable instructional tools; quantitative research contributes empirical evidence of PBL's impact; qualitative research provides deep insights into learning processes and implementation challenges; and mixed methods allow for a holistic analysis. The presence of various methodologies demonstrates that PBL is a versatile model that can be studied from multiple research angles, each enriching the understanding of its effectiveness in different educational contexts.

CONCLUSION

Based on this study, implementing the Problem-based Learning (PBL) model consistently demonstrates effectiveness in improving students' mathematical problem-solving skills. Research conducted by various scholars from 2015 to 2024 confirms that PBL enhances critical thinking, problem-solving, and knowledge retention across various mathematical topics.

PBL improves academic outcomes, motivates students to learn independently and collaboratively, and boosts their confidence in mathematics. Integrating PBL with technology, such as e-books and virtual manipulatives, and alignment with the national curriculum demonstrates that this approach can be adapted and integrated with other learning strategies to enhance instructional effectiveness. Other studies also show that PBL is more effective than conventional teaching methods and several alternative instructional models in improving students' mathematical problem-solving skills. This highlights the importance of a student-centered approach and problem-oriented learning experiences in mathematics instruction.

Furthermore, the review highlights that PBL has been successfully applied across all educational levels—from elementary to higher education—each with specific implementation strategies suited to students' developmental stages. The diverse research methods, including R&D, quantitative, qualitative, and mixed-methods approaches, contribute to a well-rounded understanding of PBL's effectiveness. This indicates that PBL is flexible and adaptable and supported by a wide range of empirical studies across contexts.

Overall, this article provides strong empirical evidence of the benefits of PBL in mathematics education and supports the recommendation for the broader adoption of this model in mathematics teaching across all levels of education.

Further research is recommended to examine the effectiveness of PBL in the context of more specific mathematical topics and at particular educational levels in greater depth. In addition, studies should evaluate the implementation of PBL on a broader classroom scale or across different schools to assess the consistency of results. Future studies are encouraged to develop and test PBL-based learning products tailored to curriculum needs and students' cognitive levels, ensuring practical applicability and wider adoption in real classroom settings.

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