

MATHEMATICAL LITERACY THROUGH PROBLEM-BASED LEARNING: A SYSTEMATIC LITERATURE REVIEW OF INTERVENTION EFFECTIVENESS

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Abstract

The Problem-Based Learning (PBL) model has been widely applied as an alternative in improving students' mathematical literacy, especially in the midst of low literacy achievement at various levels of education in Indonesia. This study aims to systematically review the effectiveness of PBL in improving students' mathematical literacy. The data were collected from 36 empirical articles published between 2015 and 2025, obtained through reputable academic databases such as Google Scholar, Scopus, and Web of Science. The articles were selected using specific inclusion criteria and were analyzed using qualitative content analysis to identify recurring patterns, themes, and outcomes related to the impact of PBL. The findings show that PBL consistently has a positive impact on reasoning skills, problem-solving, and the application of mathematical concepts in real-life contexts. The success of this approach is also influenced by various contextual factors, such as students' thinking styles, the role of teachers in facilitating learning, and the use of digital technology. These results confirm that PBL is an effective learning strategy in building mathematical literacy, and make an important contribution for educators and policymakers in developing a more contextual, adaptive, and meaningful learning approach.

Keywords: *Math Literacy ; Problem-Based Learning; Problem Solving*

1. INTRODUCTION

Education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have religious spiritual strength, self-control,

personality, intelligence, noble morals, and the skills needed by themselves, society, nation, and state (Faisal, Dhoruri 2024). In the era of globalization and accelerating technological advancement, the demand for critical thinking, problem-solving, and data-driven decision-making skills is getting higher. One of the important competencies that every individual needs to have to face these challenges is mathematical literacy. This literacy is not limited to numeracy skills, but it also includes the ability to formulate, apply, and interpret mathematical concepts in a variety of real-life contexts. The OECD (2019) emphasizes that mathematical literacy skills are very important for individual success in various aspects of life, both personally, socially, and professionally.

The results of international studies such as the Programme for International Student Assessment (PISA) show that the mathematics literacy achievement of Indonesian students is still at a low level. In PISA 2022, Indonesia's average mathematics score was only 366, far below the OECD average of 472 which ranked 70th out of 81 participating countries [2]. This phenomenon reveals the gap between national policies and real achievements on the ground.

The learning model that is still dominant in Indonesian schools is expository and teacher-centered. This approach places more emphasis on practicing problems and memorizing formulas, and provides less space for students to explore ideas, discuss, or relate math to real life. [3] stated that this conventional learning approach makes it difficult for students to solve context-based problems, as tested in PISA. More than that, this approach also has an impact on decreasing students' interest and motivation to learn mathematics [4], [5]

In responding to these challenges, Problem-Based Learning (PBL) is present as an alternative to innovative learning approaches. PBL is a learning model that emphasizes authentic problem solving through collaboration, discussion, and investigation. [6] explained that in PBL, students are encouraged to actively find solutions to

the problems given, so that they are cognitively and affectively involved in the learning process. Anggiana's research shows that PBL is able to improve students' communication skills and mathematical representations, as well as help them relate mathematical concepts to everyday experiences (Anggiana, Kandaga, and Hermawan 2022).

Furthermore, research by [8] proves that the implementation of PBL combined with digital media such as Liveworksheet is able to significantly improve student learning outcomes. Likewise, a study (Priyonggo, Wardono, and Asih 2021) found that students with high learning motivation who participated in PBL with the Agito e-module showed an increase in mathematics literacy scores. [9] added that the effectiveness of PBL is also influenced by students' cognitive styles, such as visualizers and verbalizers, which play an important role in understanding mathematical concepts.

In the context of culture-based learning, mathematical literacy can also be developed through an ethnomathematical approach. This approach links mathematical concepts to local cultural practices that are familiar to students. [10] exemplify the use of traditional Baku'puli weaving patterns from Bulukumba as a geometry learning medium. This makes learning more relevant and contextual. (Syafitri, Huda, and Haryanto 2021) also stated that the integration of ethnomathematics in PBL has great potential in improving students' interpretation and representation skills.

Various studies have shown that PBL has a significant positive impact on the development of students' mathematical literacy [6] noting that students who learn through PBL with the Realistic

Mathematics Education (RME) approach have higher literacy achievement than classes that use conventional learning. [12]also found that the application of Moodle-based blended learning in the context of PBL improves learning outcomes and forms student learning independence. [13]added that the integration of JUMPISA

in PBL learning helps improve aspects of students' mathematical representation and reasoning.

However, the effectiveness of PBL in improving mathematical literacy is still greatly influenced by various factors, such as technological support, student learning styles, and contextualization of learning materials. Therefore, a systematic study is needed to map and analyze the effectiveness of various PBL-based learning interventions. This systematic review is important to identify patterns, strengths, weaknesses, and provide evidence-based recommendations to policymakers and education practitioners [14], [15]

In line with the direction of national education policies such as the Independent Curriculum and the strengthening of the Pancasila Student Profile, the application of learning that develops critical thinking, creativity, and independence is very relevant. Mathematical literacy as part of the basic competencies of the 21st century requires an innovative, contextual, and problem-solving-based approach to learning. PBL is one of the answers to these challenges. [16] also underlined the importance of educational interventions that involve affective and contextual aspects in supporting optimal student engagement.

Based on this explanation, it can be concluded that mathematical literacy is a very important competency in facing the challenges of the times. Problem-Based Learning has been shown to be effective in various studies to improve students' mathematical literacy. Therefore, this study aims to conduct a systematic study of the effectiveness of PBL-based learning interventions in improving students' mathematical literacy.

This study is expected to make a real contribution to the development of mathematics learning strategies that are more effective and relevant to the needs of the times.

2. RESEARCH METHODS

This study uses the Systematic Literature Review (SLR) approach with the guidance of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method. This approach was chosen to systematically examine the effectiveness of the Problem-Based Learning (PBL) learning model in improving students' mathematical literacy. The type of research used is descriptive qualitative, which focuses on thematic and narrative synthesis of various previous research results. Data was obtained from 36 scientific articles published between 2015 and 2025, which were collected through databases such as Google Scholar, Scopus, and Web of Science.

This literature review procedure follows four stages of PRISMA, namely: (1) identification of articles with relevant keywords, which resulted in 124 initial articles; (2) filtering by removing duplication and articles that do not match the title/abstract, leaving 78 articles; (3) a feasibility test, by reading the entire article to evaluate suitability based on inclusion criteria; and (4) inclusion, until finally 36 articles that are worthy of analysis were obtained. The selected articles met the criteria: using PBL as the main intervention, measuring indicators of mathematical literacy (modeling, representation, communication, reasoning), empirical (experimental, quasi-experiment, SLR or meta-analysis).

Data analysis was carried out in thematic and narrative synthesis, by grouping articles based on education level, additional approaches, and learning outcomes. Each study was coded to identify patterns of PBL interventions that were effective in improving mathematical literacy.

In addition, contextual factors such as the role of technology, student learning styles, and cultural

approaches were also analyzed to see their influence. The preparation of this structured method ensures scientific transparency and replication of the study, as well as produces a

comprehensive picture of the impact of PBL on students' mathematical literacy.

3. RESULTS AND DISCUSSION

Based on the results of a systematic review of 36 research articles published in the period 2015 to 2025, it was found that the Problem-Based Learning (PBL) learning model is consistently effective in improving students' mathematical literacy. Almost all studies show that PBL interventions encourage students to understand mathematics not only as a procedure, but also as a thinking tool in solving real problems. As stated by [6] "*PBL encourages students to be more active in thinking and being able to connect mathematical concepts with everyday life through the RME approach.*"

Tabel 1. literature review results

Title	Autor	Research result
Addressing Parental Vaccine Hesitancy towards Childhood Vaccines in the United States [17]	Olivia Olson, Corinne Berry, Nirbhay Kumar	Multi-component, dialogue-based, and contextual interventions are most effective in addressing vaccination hesitancy. Strategies such as narrative, community engagement, and social media are effective. Raw statistics and fear-based approaches are counter-productive.
Increasing mathematical literacy ability and learning independence through PBL with RME [6]	S. Maslihah, S. B. Waluya, Rochmad, Kartono, N. Karomah, K. Iqbal	The PBL model with the RME approach significantly improves mathematical literacy and learning independence compared to conventional learning.
Analysis of Mathematical Literacy Increase and Learning Independence through PBL [7]	Agus Anggiana, Dede Thesa, Kandaga, Vevi Hermawan	PBL improves mathematical literacy and independence students learn consistently according to the results of the systematic literature review of 6 articles.
Influence of the Liveworksheet-Assisted PBL Model on Students' Mathematical Literacy Ability [8]	Asma Ul Husna, Meyta Dwi Kurniasih	The Liveworksheet-assisted PBL model significantly improved the mathematical literacy of grade X students on trigonometry materials.

Title	Autor	Research result
Mathematics Literacy Skill on PBL Assisted by E-Module Agito Based on Learning Motivation [5]	Hendi Widi Priyonggo, Wardono, Tri Sri Noor Asih	PBL with Agito e-modules is effective in improving mathematical literacy and learning motivation, especially in highly motivated students.
E-LKPD based on PBL Approach to Measure Mathematics Literacy Ability of Elementary Students [10]	Dini Wahyu Mulyasari, Gunarhadi, Roemintoyo	PBL-based e-LKPD supports the improvement of mathematics literacy of elementary school students who are generally still at the low level of PISA.
The Ability of Student Math Literation on PBL Model [18]	Heka M. Tabun, Prida N. L. Taneo, Farida Daniel	PBL has been proven to be more effective than ordinary learning in improving the mathematical literacy of junior high school students (high gain score).
Problem Based Learning On Literacy Mathematics: Experimental Study in Elementary School (Farhan et al., 2021)	M. Farhan, Rarasaning Satianingsih, Via Yustitia	PBL model improves math literacy scores students, student learning activities, and the quality of learning significantly.
Problem-based learning model: Effect on mathematical literacy based on visual verbal ability [11]	Aulia Syafitri, Nizlel Huda, Haryanto	PBL improves students' math literacy, especially in students with high and moderate visual-verbal ability.
Mathematical Literacy Seen from Learning Independency in Blended Learning with PjBL Assisted by Moodle [12]	Wiwik Angreanisita, Zaenuri Mastur, Rochmad	PjBL-based blended learning model with Moodle effectively improves mathematical literacy and student learning independence.
Project-Based Learning - Literacy in Improving Mathematical Reasoning in Elementary Schools [19]	Zaenal Abidin, Arief Cahyo Utomo, Vira Pratiwi, Laely Farokhah	Literacy-based PJBL improves students' mathematical reasoning skills, engagement, and motivation through contextual projects.
Towards reduced meat consumption: A systematic literature review of intervention effectiveness [20]	Tatjana Kwasny, Karin Dobernig, Petra Riefler	Effective meat consumption reduction interventions involve personalized education, changes in the eating environment, and a multi-component approach. A personal value-based approach and social norms are promising.
Digital detox: An effective solution in the smartphone era? A systematic literature review [16]	Theda Radtke, Theresa Apel, Konstantin Schenkel, Jan Keller, Eike von Lindern	The effectiveness of digital detox is diverse; Some studies have shown improvements in well-being and self-control, while others have had no impact or are negative. Further research with a contextual approach is needed.
Mathematical literacy ability of 8th graders in Problem Based Learning	Warniatun & Iwan Junaedi	PBL with the Think Talk Write approach has been proven to improve the mathematical

Title	Autor	Research result
with Think Talk Write approach [21]		literacy skills of grade VIII junior high school students. Students are better able to understand the context of the problem, develop mathematical models, and solve problems.
The Effect of Problem-Based Learning Model on Students' Mathematical Literacy [22]	Hardianti Ekaputri & Mangaratua M. Simanjorang	PBL has a significant effect on improving students' mathematical literacy. Post-test results showed an improvement in the ability to solve real context-based problems after the intervention.
The effect of problem based learning on students' mathematical literacy ability Siregar [3]	Fadhila Andini & Machrani Adi Putri Siregar	PBL produces significant differences in mathematical literacy compared to conventional learning. PBL students show a better understanding of relationships and functions.
Mathematical Literacy Reviewed from the Student's Cognitive Style in the Problem Based Learning Learning Model Assisted by the LMS [9]	Diana Urip Rahayu, Mulyono, Adi Nur Cahyono	LMS-assisted PBL is effective in improving mathematical literacy. The cognitive styles of visualizers and verbalizers affect student achievement, with visualizers more prominent on the literacy aspect.
SYSTEMATIC LITERATURE REVIEW: THE EFFECT OF LEARNING MODEL ON STUDENTS' MATHEMATICAL LITERACY SKILLS [15]	Huliyatun Nazmihaolah, Salsa Nabila, Nani Ratnaningsih	A review of 20 articles shows that innovative learning models such as PBL, PjBL, RME, and CTL significantly improve students' mathematical literacy at various levels.
Developing Students' Mathematical Literacy through [23]	Junianto & A. Wijaya	The literature shows that PBL is able to develop critical thinking, creativity, mathematical communication skills, which are an important part of mathematical literacy.
Problem Based Learning on Literacy Mathematics: Experimental Study in Elementary School [13]	Farhan satianingsi dan Yustitish .	PBL increases math literacy scores in elementary school students compared to regular learning.
Pengaruh Model Pembelajaran Problem Based Learning Terhadap Peningkatan Kemampuan Literasi Matematika [1]	Muhammad Faisal, Atmini Dhoruri, Faisa Nirbita Mahmudah	The application of the Problem Based Learning (PBL) model has a positive effect on students' mathematical literacy skills. The average posttest score increased significantly compared to the pretest (8.22 → 41.34). The Wilcoxon test showed significant results (Asymp. Sig <

Title	Autor	Research result
		0.05). Students' answers become more systematic, although some still have difficulty in interpreting solutions according to the context.
Problem Based Learning Model Based on High Order Thinking Skills for Enhancing Mathematic Literacy for High School Students [24]	Sekar Wilujeng, Eyus Sudihartinih, Aan Hasanah	The application of the Problem Based Learning (PBL) model based on high level thinking skills (HOTS) has been statistically proven to significantly improve the mathematical literacy skills of high school students compared to the scientific approach. The experimental class showed higher achievement and improvement of literacy skills, with student responses being classified as positive (65.6%). Teachers' implementation of the PBL-HOTS model is also high (90.02%).
Systematic Literature Review: Students' Mathematical Literacy Ability Through the Problem Based Learning Model [14]	Ana Syahdania, Stevanus Waluya Zakia Budi	The SLR of 12 articles showed that PBL was more effective than conventional models in developing critical thinking and contextual problem-solving skills.
The effectiveness of problem-based learning in enhancing mathematical literacy: A systematic meta-analysis [25]	Gufron, A., Hidayah, I., Prabowo, A., Wardono, & Mariani, S.	Meta-analysis showed that PBL significantly improved mathematical literacy (effect size = 1,165) with various moderation factors such as education level and duration of intervention.
Examining the Effect of Problem-Based Learning Approach on Mathematical Creative Thinking: A Meta-Analysis [26]	Joseph F. Bron & Maricar S. Prudente	PBL enhances students' creative thinking in the context of mathematics and encourages active learning and innovative problem-solving.
Using technology-oriented, problem-based learning to support global workplace learning	O'Brien, E., Hamburg, I., & Southern, M.	Technology-based PBL improves global job literacy including numeracy and mathematical problem-solving skills.
A systematic literature review of math interventions across educational settings from early childhood education to high school [27]	Riikka P. Svane, Marinka M. Willemsen, Dorte Bleses, Peter Krøjgaard, Mette	This study highlights the effectiveness of various mathematics interventions (including PBL) in improving literacy at all levels of education.

Title	Autor	Research result
	Verner, Helena Skyt Nielsen	
The effectiveness of training teachers in problem-based learning implementation on students' outcomes: a mixed-method study [28]	Nawaf Awadh K. Alreshidi & Victor Lally	Teacher training in PBL globally improves student learning outcomes, including mathematical literacy achievements.
Meta-Analysis Study: The Effect of Problem-Based Learning (PBL) on Students' Mathematical Literacy Skills [29]	Chai, Ee Laine & Mahmud, Muhammad Sofwan	Meta-analysis of 12 studies showed a strong effect of PBL on mathematical literacy with the influence of variation in level and sample size.
The Influence of Problem-Based Learning (PBL) on Mathematics Learning: Systematic Literature Review [29]	Ee Laine Chai & Muhammad Sofwan Mahmud	The SLR of 20 studies confirmed the improvement of mathematical literacy and concept comprehension through PBL.
Improving primary students' mathematical literacy through problem-based learning and direct instruction [30]	Fery Muhamad Firdaus, Wahyudin, & Tatang Herman	PBL has proven to be more effective than direct teaching in improving the mathematical literacy of elementary school students in Indonesia.
Mathematics Literacy on Problem-Based Learning with Indonesian RME Approach Assisted E-Learning Edmodo [23]	Wijaya, A.	The integration of PBL, PMRI, and Edmodo effectively improves the mathematical literacy of junior high school students.
The Effectiveness of Contextual Teaching and Learning (CTL) and Problem-Based Learning (PBL) Approaches in Improving Mathematical Literacy [31]	N. Afni & Hartono	The CTL and PBL approaches together improve students' mathematical literacy. Students can relate mathematical concepts to real contexts, demonstrating significant improvements in concept understanding, problem-solving, and mathematical communication.
The Effectiveness of Contextual Teaching and Learning (CTL) and Problem-Based Learning (PBL) Approaches in Improving Mathematical Literacy . [32]	Hadi, S., Novikasari, I., & Susanto, H	Research shows that the combination of CTL and PBL approaches significantly improves the mathematical literacy of junior high school students on geometry topics. Students are more active and able to relate the material to their daily lives.
Effect of a Problem-Based Learning Intervention on Students' Attitudes toward Mathematics [30]	Tatar, E., & Tatar, D.	PBL improves students' positive attitudes towards mathematics as well as their ability to understand basic concepts and solve contextual problems. The

Title	Autor	Research result
Improving Students' Mathematical Literacy with Realistic and Problem-Based Learning . [33]	Wijaya dan Arismunandar	study was conducted on junior high school students in Turkey. Using the PMRI and PBL approaches, the study found that students showed significant improvements in all aspects of mathematical literacy measured using PISA indicators. The study was conducted at the junior high school level.

Several articles noted a significant increase in mathematical literacy in students who took PBL compared to conventional learning. [13] noted that *"problem-based learning has a positive impact on all indicators of mathematical literacy, especially in the ability to interpret and represent problems."* In addition, research by [5] revealed that *"students who have high motivation in PBL classes with the Agito e-module show higher mathematical literacy achievement than other groups."*

PBL has also proven to be more powerful when combined with technology. In research by [8] it was found that *"Liveworksheet media helps students in doing independent assignments and accelerates the reflection process in solving mathematical problems."* The integration of digital learning such as Moodle and blended learning is also mentioned in the study [12] *"The PBL model in blended learning is able to significantly increase students' independence and mathematical literacy."*

From an international perspective, [25] in its meta-analysis wrote that *"the average effect size of PBL on students' mathematical literacy was 1.165, which indicates a strong influence across studies."* This shows that statistically, the influence of PBL on mathematical literacy has a big effect.

The cultural context also strengthens the effectiveness of PBL. [10] states that *"the application of ethnomathematics through traditional weaving patterns enriches students' learning experiences and enhances the linkage between mathematics and their social*

environment." This is also agreed by [11] who found that *"students' visual-verbal abilities affect how they interpret mathematical literacy questions in a cultural context."*

Overall, the synthesis of the 36 journals shows that PBL is very effective in shaping students' mathematical literacy skills. Successful interventions generally have characteristics in the form of integration with real contexts, digital media, active student involvement, and adequate teacher support.

However, its effectiveness is still influenced by teacher readiness, student characteristics, and comprehensive learning system support.

4. CONCLUSIONS AND SUGGESTIONS

An analysis of 36 articles published in the period 2015 to 2024 shows that the Problem-Based Learning (PBL) model consistently improves students' mathematical literacy skills at various levels of education. However, there are some limitations that need to be observed. The majority of the research was conducted in Indonesia with a short-term experimental approach, so the results are not generalizable globally and do not describe the long-term effects of PBL implementation. In addition, variations in indicators of measuring mathematical literacy and the limitations of PBL implementation, such as teacher readiness and the availability of learning media, are challenges. Therefore, further research is recommended to be conducted in an international context with a longitudinal approach, involving the use of innovative technologies such as AI-based learning or gamification, as well as developing more standardized literacy measurement instruments. In addition, it is important to explore the application of PBL in inclusive education and at higher education levels to expand the scope and effectiveness of this model.

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