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Research Exploration of Problem-Based Learning (PBL) Model and Metacognition Ability in Mathematics Learning: A Systematic Literature Review

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Abstract: The Problem-Based Learning (PBL) model is one of the practical approaches to increase students' active participation, independent thinking skills, and awareness of the learning process, which will improve students' metacognition skills. Metacognition enables students to organize their learning strategies and improve learning outcomes. This research aims to identify, classify, and evaluate research results from primary studies that apply the PBL Model in measuring the improvement of students' metacognition skills in Indonesia using the systematic literature review (SLR) method. The protocol used in SLR refers to The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement, which includes the following four stages: (1) identification, (2) screening, (3) eligibility, (4) included. This systematic review leveraged covidence for comprehensive article screening and analysis, focusing on 30 carefully selected academic publications spanning from 2015 to 2024. This study examines the implementation of Problem-Based Learning (PBL) and its impact on students' mathematical metacognition skills. The analytical framework encompassed multifaceted research dimensions, including educational levels, geographical research contexts, publication timelines, mathematical domains, research methodologies, journal indexing criteria, and research outcomes. The analysis unveiled that publication frequency peaked in 2024, with a notable emphasis on secondary school-level investigations. The methodological analysis indicated a predominant preference for quantitative research approaches, particularly in studies examining spatial geometry concepts. The consolidated results provided substantial evidence that the implementation of the PBL model yielded positive and significant improvements in students' mathematical metacognition capabilities.

Keywords: metacognition, problem-based learning model, systematic literature review.

▪ INTRODUCTION

Mathematics learning is important in developing logical thinking, analytical, and problem-solving skills (Cresswell & Speelman, 2020; Lovianova et al., 2022). Mathematical problem-solving skills extend beyond academic comprehension, proving essential for addressing real-world challenges. Individuals who excel in this domain typically exhibit higher self-confidence, creativity in approach, and self-reliance (Hoshino, 2018; Nurhalisa et al., 2022).

Mathematics holds an important role in cultivating students' intelligence, allowing students to explore and understand a variety of complex and intangible concepts that require higher cognitive abilities (Liu et al., 2018). Students' difficulties in understanding mathematical principles stem from two challenges: lack of cognitive maturity and passive learning techniques, which in turn hinder students' engagement in the learning process (Deslauriers et al., 2019; Kuncorowati et al., 2017; Lima et al., 2019). Sometimes students also tend to take mathematical information at face value, without fully understanding its underlying benefits or meaning (Wu, 2023). This situation indicates the need to develop active learning that will encourage critical and analytical thinking, as well as improve students' metacognitive understanding throughout the educational process.

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Problem-Based Learning (PBL) comes as an innovative pedagogical approach that effectively responds to current educational challenges. PBL provides opportunities for students to solve problems at hand, by encouraging students to work collaboratively, as independent learners, and as problem solvers (Ali, 2019; Santos et al., 2021). This method will significantly increase student involvement and metacognitive skills (Nicholus et al., 2023; Wulandari & Taufik, 2020). Students produce advanced concept maps, indicating a detailed understanding of conceptual complexities (Dochy et al., 2003). Learners will build a more thorough framework of knowledge by replacing conventional learning with an active and interactive educational experience using PBL (Anjelina et al., 2021; Parwata et al., 2023; Siagian et al., 2019).

Metacognition is a progressive ability to understand, manage, and evaluate individual cognitive processes (Fleur et al., 2021; Rhodes, 2019). Metacognition stands as an important foundation for educational success, empowering students to strategically guide their learning process (Fleur et al., 2021; Silistraru & Vetrila, 2023). Metacognition skills in mathematics learning consist of students' awareness of what they know and don't know, planning problem-solving solutions, monitoring and managing the use of their strategies, and evaluating the results and learning process (Fyfe et al., 2022; Mertasari et al., 2023; Wang et al., 2021; William & Maat, 2020). Having metacognitive skills will support students in organizing and monitoring the mathematics learning process, and help students solve mathematical problems independently (Noor, 2022).

Students who develop metacognitive skills will be able to turn math learning into a systematic process. Students will become skilled in managing their learning process, strategically solve math problems, and gradually improve their academic performance (Hoang et al., 2022; Lytra & Drigas, 2021). This approach allows them to become active learners of their own cognitive development. In the end, the metacognitive framework encourages students to solve math problems confidently, accurately and deeply (William & Maat, 2020).

The PBL model stimulates students to present new challenges and find solutions, which leads to the use of higher order metacognition. This happens because students have to think more critically and reflectively when facing new situations or when solutions are not directly visible (Siregar & Djulia, 2022). Students are encouraged to consider what they know and how they know it. Thus, the PBL model can help students develop confidence in their cognitive abilities, which will automatically turn students into explorative and self-directed learners (Parwata et al., 2023).

Some research has analyzed how metacognition skills can be enhanced by applying the PBL model to mathematics learning. Through PBL learning series, students can think creatively, efficiently, and effectively in solving real problems, increasing problem solving ability (Khakim, 2019; Nicholus et al., 2023). The learning stages in the PBL Model, which consists of several phases, begin with the teacher introducing the problem or material to be learned to students, initial discussion, independent learning, presentation and discussion, further problem solving, evaluation and reflection, and ends with concluding the learning (Ariyanto, 2020).

There have been many primary studies with various research methods that analyze the effects of the PBL model on students' metacognition skills. Quantitative research was conducted by Setiawan & Supiandi (2019), Shamdas et al. (2024) and Triana & Azis (2020), qualitatively describing students' abilities in each indicator Santoso et al. (2018)

and Wulandari & Listiana (2021). Besides that, there is also development research related to this topic Bachri et al. (2022), Faizal Amir & Darmawan Kusuma (2018) and Khoeriah et al. (2024). Each of these studies is still individual, revealing students' metacognition abilities after applying the PBL Model. On the other hand, it is necessary to see its development by identifying, classifying, and analyzing various research studies. This can be done by Systematic Literature Review (SLR).

Based on the description previously presented, this research will answer three main questions: (1) How is the description of the research results of the PBL Model and metacognition skills in terms of education level, location, year, subject matter, research methods and article sources; (2) Can the PBL Model improve students' metacognition skills; and (3) How can the PBL Model improve students' metacognition skills?

▪ METHOD

Research Design

This study used the systematic literature review (SLR) method. SLR is a scientific method used to collect data available in the literature regarding a specific research question and compare the quality of various studies to get the best possible answer (Landewe, 2017; Pati & Lorusso, 2018). SLR differ to the usual data collection in that it follows a structured and stringent methodology to provide assurance that all relevant literature is suitably covered and concluded (Juandi, 2021). The outcome of this study is to contribute to mathematics learning, specifically in applying the PBL model to increase students' metacognition skills.

Research Strategy

The protocol applied in the SLR is based on The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, which has four stages: (1) identification, (2) screening, (3) eligibility, (4) inclusion (Liberati et al., 2009). To get a systematic and quality literature review that serves the aims of the study, these steps should be applied.

The research identification process was carried out through a strategic search using key targeted words such as “Problem-Based Learning Model” and “Metacognition Skills in Mathematics” to ensure the appropriate selection of articles. The researchers reviewed multiple academic databases including SCOPUS, Education Resources Information Center (ERIC), Semantic Scholar, and Google Scholar to secure relevant primary research that fit the specific inclusion criteria. After collecting the articles, researchers used Covidence management software to streamline the systematic review process. This customized digital support tool offers an intuitive interface that supports online team collaboration and enables efficient reference filtering and conflict resolution. The software's custom capabilities help researchers manage data more systematically while minimizing unintentional research bias (Babineau, 2014). All collected data were meticulously extracted into an Excel spreadsheet, ensuring organized and transparent documentation. By leveraging Covidence, researchers could conduct their systematic literature review more efficiently, maintaining high standards of academic rigor and methodological precision (Cleo et al., 2019).

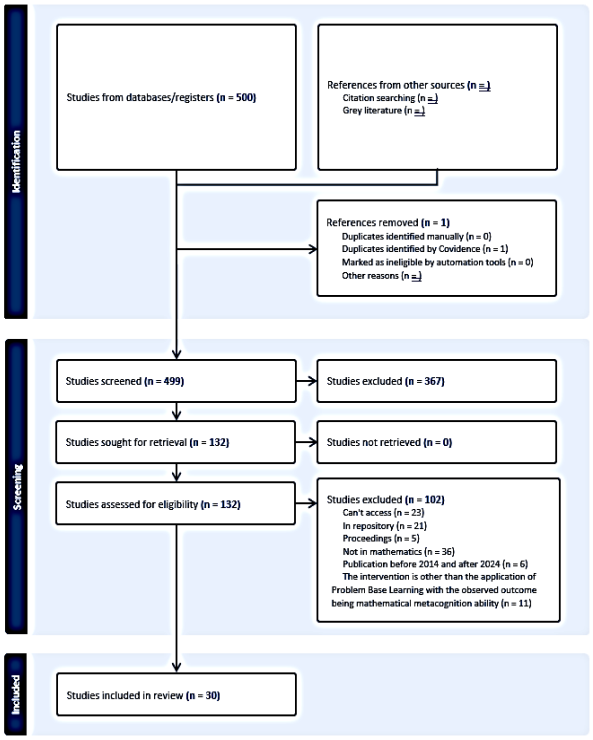

Figure 1. PRISMA protocol flow chart

The systematic literature review (SLR) screening process followed three main stages. First, the researchers review the abstracts and identifiers of the articles based on established inclusion and exclusion criteria. Next, an eligibility assessment was conducted by carefully examining the full paper to ensure it matched the specified research criteria. Finally, a thorough review of each shortlisted article was conducted to extract specific findings. The PRISMA methodology allows the selection process to remain systematic, transparent and unbiased. By implementing these strict measures, researchers enhance the validity and credibility of their research results, giving them a strong framework for comprehensive literature analysis.

Figure 1 describes the systematic review screening process of the 500 articles that are initially identified through database searches, one duplicate is excluded by Covidence. At the screening stage, 367 out of 499 primary studies were removed for not meeting inclusion criteria during title and abstract screening, leaving 132 studies for further review. During the eligibility stage, 103 primary studies were excluded for various reasons. Consequently, 30 primary studies were retained for in-depth analysis and review.

Inclusion and Exclusion Criteria

This study's population includes all research on PBL model and metacognition ability in mathematics. The sample was carefully selected based on the predetermined inclusion criteria, which are described in Table 1 below.

Table 1. Inclusion criteria

Inclusion Criteria	Reason
Articles relevant to the topic of PBL model and metacognition ability in mathematics	This research focuses on exploring the relationship between PBL and metacognition in the context of mathematics will help understand the effectiveness of this model in improving students' skills.
The research subjects are elementary school, junior high school and senior high school	This research wants to explore the extent to which the PBL model and metacognition skills are applied in each school level.
Research location in Indonesia	By reviewing research in Indonesia, it can be seen to what extent PBL has been implemented in Indonesian schools and how it impacts on students' metacognitive skills in mathematics.
Research published between 2015-2024	The specified time frame was selected to ensure the analyzed data reflected contemporary insights and methodological approaches in mathematics education research.
Math subject matters	This research focuses only on mathematics because mathematics is a core subject in all levels of education.
Research method	The selected articles used quantitative, qualitative, mixed-method, and development research methods, so that SLR results have a more valid basis and the data obtained is reliable.
Articles published in indexed journal	The articles selected should come from indexed journals, such as Scopus, Sinta or Garuda. This is done to ensure that the article has gone through a peer review process, so that the results are more reliable and can be used to support research synthesis.

Articles that did not meet the inclusion criteria were included in the exclusion criteria, namely (1) articles that were not relevant to the topic of PBL model and metacognition ability in mathematics; (2) research subjects are not elementary school, junior high school, and senior high school; (3) research location not in Indonesia; (4) research published other than 2015-2024; (5) subject matter is not math; (6) research methods other than quantitative, qualitative, mixed-method, and development research; and (7) articles published in proceedings or repository.

Data Analysis

A descriptive qualitative data analysis methodology was employed to interpret the selected studies' results. The analysis process unfolded through four primary stages. First, each article underwent thorough reading and comprehensive examination to acquire a profound understanding of the findings and their research relevance. Second, the primary findings from each study were synthesized, concentrating on the interconnection between PBL model and students' mathematical metacognition skills. Third, the findings were critically compared to identify prevalent trends or potential research gaps. Finally, the researcher formulated comprehensive conclusions based on the findings' synthesis, which included identifying areas requiring further investigation and potential practical educational applications.

▪ RESULT AND DISSCUSSION

There are three main research questions: (1) How is the description of the research results of the PBL Model and metacognition skills in terms of education level, location, year, subject matter, research methods and article sources; (2) Can the PBL Model improve students' metacognition skills; and (3) How can the PBL Model improve students' metacognition skills?

RQ1: How is the description of the research results of the PBL Model and metacognition skills in terms of education level, location, year, subject matter, research methods and article sources

From the literature search results, 30 primary studies were obtained that could be included in the analysis stage. The distribution of student participation in empirical research examining the implementation of Problem-Based Learning (PBL) for enhancing metacognitive skills in mathematics education is presented in Figure 2.

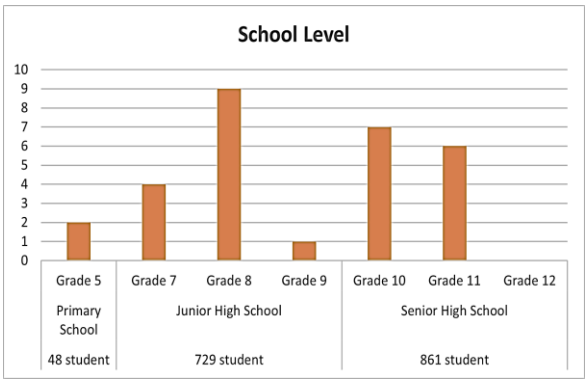

Figure 2. Number of students at each level of education

The analysis of studies conducted between 2015 and 2024 revealed that PBL interventions were most extensively implemented at the senior high school level, with 861 participants, predominantly from grade 10. At the junior high school level, 729 students participated in the studies, with the majority being grade 10 students. Research in elementary schools is very rare, involving only 48 fifth graders. The total number at all levels of education consisted of 1,638 participants. The main focus of research on Problem-Based Learning (PBL) and mathematics metacognition is on secondary education. This is because secondary school students learn increasingly complex mathematical concepts, where metacognitive skills become very important to achieve learning success. At this stage of education, students must perform more abstract mathematical reasoning, making the development of metacognitive skills very important. The PBL model provides an effective approach to developing these thinking skills, so that students can better understand, monitor and evaluate their own learning processes in mathematics.

In a mapping of comprehensive research on Problem-Based Learning (PBL) models and mathematical metacognition skills, North Sumatra is the top region with nine successfully completed studies, followed by West Java with five studies. This highlights a strong academic ecosystem with adequate institutional support to conduct research on innovative educational approaches.

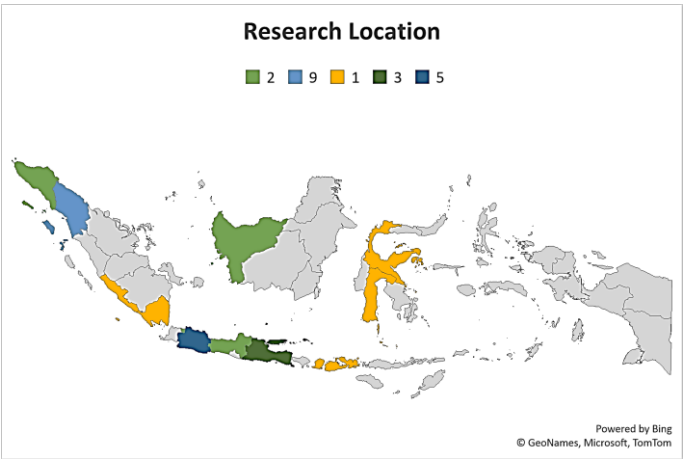

Figure 3. Number of articles by research location

Although this research covers several provinces in Indonesia including Aceh, Bengkulu, Lampung, Central Java, East Java, Jakarta, West Kalimantan, NTB, Central Sulawesi and South Sulawesi, participation is still inequitable. These regions have contributed between one and three studies each, indicating a stark gap in the number of studies across regions.

The inequality of research activity points to a critical need to expand research efforts, especially in eastern Indonesia where academic research is still very sparse. The researchers propose strategic interventions such as implementing supportive policies, providing more research funding opportunities, and forging stronger collaborative partnerships between universities and educational institutions. This could help stimulate increased research capability and encourage a more balanced exploration of PBL and mathematical metacognition development across academic settings in Indonesia.

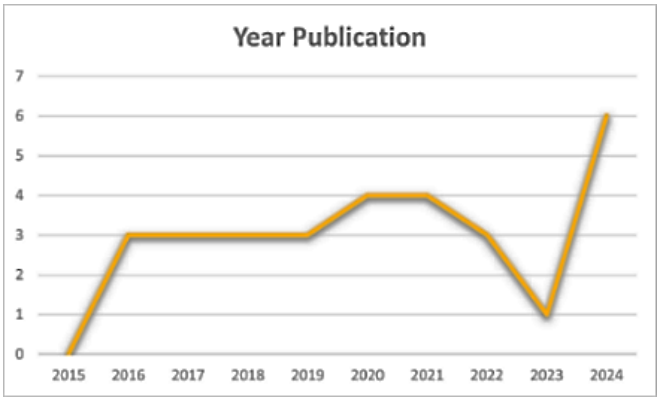

Figure 4. Number of articles by year of publication

The publication trend of primary studies on PBL models and metacognition skills in mathematics learning over the past decade, 2015-2024, is presented in Figure 4. The publication trend of primary studies on PBL models and metacognition skills in mathematics learning over the past decade shows that the largest number of primary studies was published in 2024, suggesting an increased research interest in PBL and

metacognition in mathematics learning. This could be caused by the increased focus on problem-based learning approaches and the application of metacognition in mathematics education. The significant increase in 2024 signals a resurgence of academic interest in the effectiveness of PBL in improving students' metacognitive skills in mathematics.

In 2015 no publications of primary studies were recorded, which may indicate that the application of PBL to improve metacognitive skills in mathematics learning was not a top priority at that year. Factors such as lack of awareness, lack of previous research, or the unpopularity of PBL methods in mathematics education could be the cause. There are fluctuations in research interest from year to year. The number of publications has fluctuated over the period 2016 to 2022, reflecting variations in research trends, as well as changes in academic focus on this topic. Fluctuations in the number of studies reflect changes in academic interest, but the spike in 2024 confirms that the method is increasingly relevant and deserves further study in the context of mathematics education.

Learning material needs to be considered when implementing a learning model. The 30 analyzed articles found quite diverse learning materials, but some did not mention the materials taught. The learning materials of each article are presented in Figure 5.

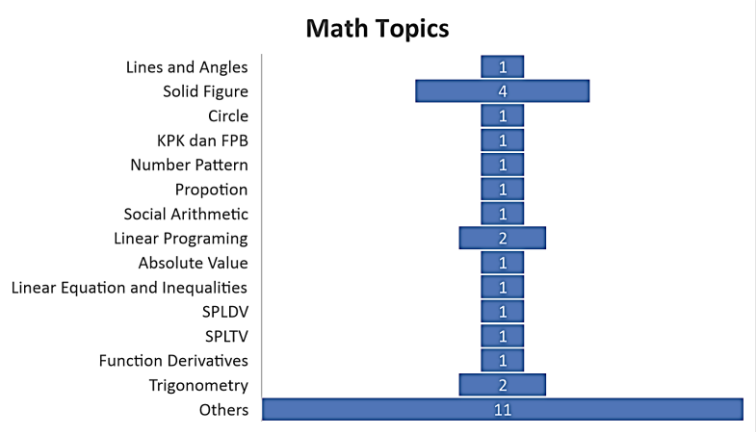

Figure 5. Number of articles by learning material

Material based on the analysis, most space-building materials were taught during the primary research implementation. Other learning materials include lines and angles, circles, KPK and FPB, number patterns, comparison, social arithmetic, linear programs, absolute value, linear equations and inequalities, SPLDV, SPLTV, function derivatives, and trigonometry. The distribution of each of these learning materials is the same. There are only 1 or 2 studies for each of these materials. Meanwhile, articles that did not include what material was taught during the research process were categorized as "other" materials.

Basic mathematical topics like lines, angles, patterns, and comparisons may not benefit as much from PBL implementation, as these simpler concepts can often be solved without requiring deep metacognitive engagement. In contrast, advanced topics such as function derivatives and trigonometry present greater cognitive demands through PBL, potentially overwhelming students. In these complex scenarios, facilitators play an essential role in managing cognitive load and guiding students' metacognitive development.

PBL in mathematics has been applied to a variety of learning materials, although the distribution is fairly even with only a few studies focusing on specific materials. Constructing space is the most researched material, possibly because of its characteristics that are suitable for a problem-based approach. Many studies did not include specific materials, so it is important for future research to be more explicit about the materials used so that results can be more easily compared and applied in a broader context. Given these findings, future research could consider strengthening the study on less explored materials to gain a more comprehensive understanding of the effectiveness of PBL with students' metacognition skills in various mathematical concepts.

Classification of articles is also carried out based on the research method used. Articles are grouped into 4 categories: quantitative, qualitative, mixed (quantitative and qualitative), and development research. The distribution of articles for each category of research methods is presented in Figure 6.

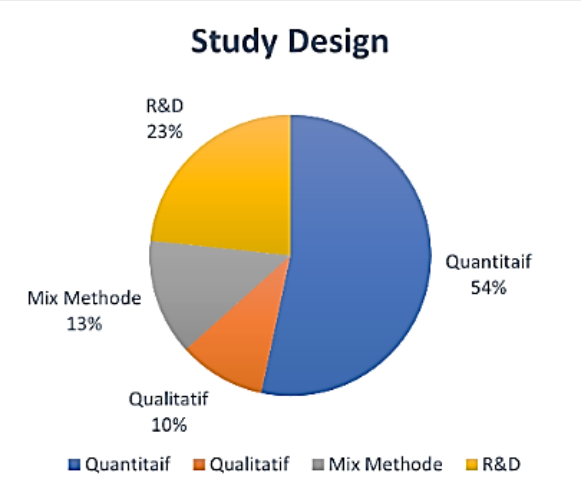

Figure 6. Number of articles by study design

From 2015 to 2024, research on the topic of PBL and metacognition skills in mathematics learning was dominated by quantitative research. In a comprehensive review of 30 research articles on the PBL model, the analysis revealed a clear methodological distribution: 16 articles used quantitative methods, 3 employed qualitative approaches, 4 utilized mixed methods, and 7 were development-focused studies. This composition underscores a strong quantitative research trend over the past decade.

The research primarily concentrated on evaluating PBL's impact on students' learning outcomes and metacognitive development. While quantitative studies dominated, qualitative research remained notably limited, despite its potential to offer profound insights into students' cognitive processes during problem-based learning. Mixed and development research demonstrated promising efforts to integrate diverse methodological approaches and develop more sophisticated learning models. Researchers recommend expanding future investigations, particularly increasing qualitative and mixed-method studies. These approaches could provide deeper understanding of students' metacognitive thinking and explore PBL's broader learning influences.

The articles were categorized based on journal indexing, specifically Garuda, Sinta, and Scopus, further establishing their academic credibility. The distribution of articles for

each category is presented in Figure 7. Most journal publications are in the Sinta 3 category, totalling 9 journals; Sinta 2, Sinta 4, and Sinta 5, totalling 5 journals; Garuda, totalling 4 journals; and Sinta 1 and Scopus, totalling 1 journal.

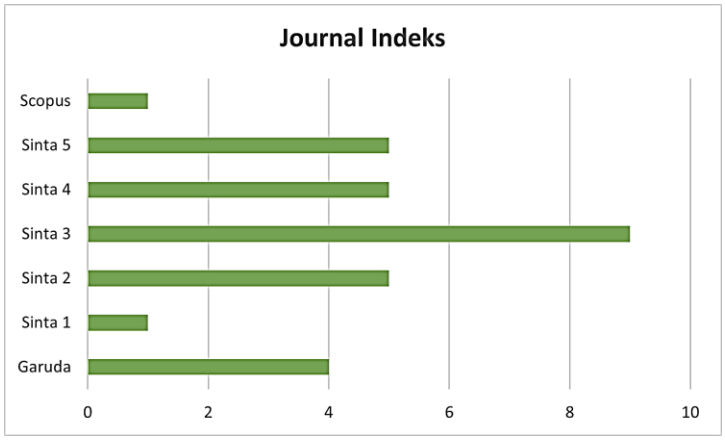

Figure 7. Number of articles by journal index

Most of the research was published in journals with Sinta 3 to Sinta 5 categories, indicating that the publication trend of this topic is still dominated by national journals with medium rankings. The number of publications in highly reputable journals (Sinta 1 and Scopus) is still very limited, so there are opportunities for researchers to improve the quality of research and publications in international journals or national journals with higher rankings. For future research development, it is recommended that more research be published in Sinta 1 and Scopus journals, so as to increase the scientific contribution of PBL research and metacognition in mathematics at the national and international levels.

RQ 2: Can the PBL Model improve students' metacognition skills?

Based on the analysis of 30 primary studies with various research methods, the results vary from one another in the context of implementing the Problem-Based Learning (PBL) model. In its application to mathematics learning, the PBL model does not always have a uniform impact on students' metacognition skills. Some studies indicate less significant results, while others show substantial improvement. Research consistently shows that the PBL model effectively boosts students' cognitive abilities in mathematics. This success shows up in several ways-students get better at solving problems, develop stronger mathematical reasoning, and gain a deeper grasp of concepts.

However, its success rate may vary depending on several key factors. These will include how ready the teacher is to use the PBL model, the unique character of the students, how challenging the math content is, and whether the learning environment provides appropriate support.

Table 2. Data analysis research

Category	Description	n
Effect	PBL has a significant effect	13
	PBL has good support	3
	PBL effectively improves metacognition skills	4

	PBL learning instruments can improve students' metacognition.	7
No effect	PBL has no significant effect	3

In the research of Hamimah & Kartika (2019), Ikhsan & Fitria (2017) dan Shamdas et al. (2024) showed that the PBL model proved to have a better effect in improving students' metacognition skills compared to other learning models, because PBL puts students at the center of learning and requires students to analyze, formulate problems, design solutions, and reflect on their learning process (Mudrikah et al., 2020). This helps students to actively manage, monitor, and evaluate their own learning strategies, which is the essence of metacognition (Pandey & Mohan, 2024; Rasheed & Zafar, 2023). The PBL model will also provide space for students to work collaboratively, discuss, and integrate various perspectives, so that students will be better trained to recognize their way of thinking and develop a deep understanding (Magdalena et al., 2023; Sisrayanti et al., 2024). Thus, the application of PBL not only improves cognitive learning outcomes but also helps students become more independent and critical learners (Saputri & Kesumawardani, 2021; Suryani et al., 2024).

RQ 3: How can the PBL Model improve students' metacognition skills?

Problem-Based Learning (PBL) follows a structured approach that moves through five key steps. It starts with getting students familiar with the problem at hand, then organizing how they'll learn. Next, teachers guide students as they investigate, followed by having students develop and share their solutions. The final step involves looking back at how well the problem was solved (Lestari & Aziz, 2022; Srikan et al., 2021). At its heart, PBL gets students actively involved in tackling real problems. The main goal is for students to build their own understanding by finding solutions themselves, which helps them become better independent problem solvers (Bachri et al., 2022). When working towards answers, students need to pull together everything they already know - from facts and information to thinking skills and problem-solving techniques. This way of combining different thinking strategies while learning helps students develop deeper awareness of how they think and learn.

In their research Istiqomah et al. (2020) dan Saputri & Kesumawardani (2021) explained that the learning process was still not optimal at the first meeting when applying the PBL model. Many students still have difficulty following the learning process with the PBL model. Then, the researcher evaluates what is lacking and what needs to be developed in the learning process. Moreover, at the next meeting, students began to understand how the learning process in the classroom began to run effectively, and some students solved the problems presented. Learning involves meaningful interactions between teachers and their students, as well as among the students themselves. These dynamic exchanges play a crucial role in sparking students' metacognitive development - helping them think about their own thinking and learning processes (Sutarto et al., 2022).

Students face several challenges with their metacognitive thinking during the learning process. They often find it hard to grasp basic elements like facts and concepts, as well as more complex aspects like principles and procedures (Santoso et al., 2018). When it comes to mathematics, many students struggle to work with mathematical symbols and create mathematical models to solve problems. They also have trouble

figuring out how to use mathematical formulas and rules correctly, and making connections between different concepts to find solutions (Nisa Rambe & Sinaga, 2020).

Learning modules serve as valuable educational tools that help students navigate the learning process and better understand course materials (Barbosa & Maldonado, 2011; Listiadi, 2018). These modules promote independent learning, allowing students to progress at their own speed and grasp concepts according to their individual learning capabilities. Dewi et al. (2024), Faizal Amir & Darmawan Kusuma (2018) dan Siagian et al. (2019) mentioned in their research that studies indicate that learning materials developed using the PBL model whether in the form of modules or student worksheets - have proven to be valid, effective, and practical tools for enhancing students' cognitive abilities. Additionally, students have responded positively to this PBL based approach to learning.

▪ CONCLUSION

This study analyzed 30 articles that discussed applying the Problem-Based Learning (PBL) model to improve students' metacognition skills in mathematics learning from 2015 to 2024. The analysis was conducted by classifying articles based on various aspects, including education level, research location, year of publication, learning materials, research methods, journal index, and research results. Regarding publication characteristics, it was found that the highest frequency of publications occurred in 2024, with most applications carried out at the senior high school. Regarding methodology, most studies used a quantitative approach focusing on learning materials on building space. The analysis results show that applying the PBL model positively impacts students' metacognition skills in learning mathematics.

The findings from this SLR study can be used as a reference for academics and mathematics teachers in developing research and implementing learning methods in the classroom. A more comprehensive review of the article is needed for future research through a meta-analysis or meta-synthesis approach to produce a deeper understanding of applying the PBL model to metacognition skills.

▪ REFERENCES

Ali, S. S. (2019). Problem based learning: a student-centered approach. English Language Teaching, 12(5), 73. https://doi.org/10.5539/elt.v12n5p73

Anjelina, Z., Usman, U., & Ramli, M. (2021). Students' metacognitive ability mathematical problem-solving through the problem-based learning model. Jurnal Didaktik Matematika, 8(1), 32–44. https://doi.org/10.24815/jdm.v8i1.19960

Ariyanto. (2020). Improve learning results using the problem based learning model. https://jurnal.uns.ac.id/shes

Babineau, J. (2014). Product review: covidence (systematic review software). journal of the canadian health libraries association. Journal de l'Association Des Bibliothèques de La Santé Du Canada, 35(2), 68. https://doi.org/10.5596/c14-016

Bachri, S., Sugianto, L., Bondan Kriswinarso, T., & Lihu, I. (2022). *Pengembangan perangkat pembelajaran matematika berbasis masalah untuk melatih keterampilan metakognitif peserta didik.* ITQAN: Jurnal Ilmu Ilmu Kependidikan, 13(1), 103–116. https://doi.org/10.47766/itqan.v12i2.132

Barbosa, E. F., & Maldonado, J. C. (2011). IMA-CID: An integrated modeling approach for developing educational modules. Journal of the Brazilian Computer Society, 17(4), 207–239. https://doi.org/10.1007/s13173-011-0043-5

Cleo, G., Scott, A. M., Islam, F., Julien, B., & Beller, E. (2019). Usability and acceptability of four systematic review automation software packages: A mixed method design. In Systematic Reviews (Vol. 8, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s13643-019-1069-6

Cresswell, C., & Speelman, C. P. (2020). Does mathematics training lead to better logical thinking and reasoning? A cross-sectional assessment from students to professors. PLoS ONE, 15(7 July). https://doi.org/10.1371/journal.pone.0236153

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. Proceedings of the National Academy of Sciences of the United States of America, 116(39), 19251–19257. https://doi.org/10.1073/pnas.1821936116

Dewi, N. A., Rajagukguk, W., & Dewi, R. (2024). Development of mathematics learning modules with PBL models on the metacognitive skills of students. Inovasi Kurikulum, 21(2), 835–848. https://doi.org/10.17509/jik.v21i2.68893

Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: a meta-analysis. Learning and Instruction, 13(5), 533–568. https://doi.org/https://doi.org/10.1016/S0959-4752(02)00025-7

Faizal Amir, M., & Darmawan Kusuma, M. W. (2018). *Pengembangan perangkat pembelajaran berbasis masalah kontekstual untuk meningkatkan kemampuan metakognisi siswa sekolah dasar*. Journal of Medives, 2(1), 117–128. http://e-journal.ikip-veteran.ac.id/index.php/matematika/article/view/538

Fleur, D. S., Bredeweg, B., & van den Bos, W. (2021). Metacognition: ideas and insights from neuro- and educational sciences. In npj Science of Learning (Vol. 6, Issue 1). Springer Nature. https://doi.org/10.1038/s41539-021-00089-5

Fyfe, E. R., Byers, C., & Nelson, L. J. (2022). The benefits of a metacognitive lesson on children's understanding of mathematical equivalence, arithmetic, and place value. Journal of Educational Psychology, 114(6), 1292–1306. https://doi.org/10.1037/edu0000715

Güner, P., & Erbay, H. N. (2021). Metacognitive skills and problem-solving. International Journal of Research in Education and Science, 715–734. https://doi.org/10.46328/ijres.1594

Hamimah, A., & Kartika, E. D. (2019). *Pengaruh penerapan problem based learning (pbl) terhadap metakognisi siswa.* Laplace : Jurnal Pendidikan Matematika, 2(2), 99–105. https://doi.org/10.31537/laplace.v2i2.247

Hoang, Y. N. T., Hai, Y. P. T., & Bich, T. D. T. (2022). Developing metacognition skills through STEAM education in students with learning disabilities: from a theoretical point of view. Journal of Science Educational Science. https://api.semanticscholar.org/CorpusID:258003349

Hoshino, R. (2018). Supporting mathematical creativity through problem solving. In A. Kajander, J. Holm, & E. J. Chernoff (Eds.), Teaching and learning secondary school mathematics: canadian perspectives in an international context (pp. 367–375). Springer International Publishing. https://doi.org/10.1007/978-3-319-92390-1_34

Ikhsan, M., & Fitria, L. (2017). *Kemampuan berpikir kritis dan metakognisi siswa dalam menyelesaikan masalah matematika melalui pendekatan problem solving.* 6(2).

Istiqomah, N., Yuli, T., & Siswono, E. (2020). *Pengaruh pembelajaran problem based learning terhadap kemampuan metakognitif dan pemecahan masalah matematika di kelas Xi Sma Negeri 1 Jombang.* MATHEdunesa Jurnal Ilmiah Pendidikan Matematika.

Juandi, D. (2021). Heterogeneity of problem-based learning outcomes for improving mathematical competence: A systematic literature review. Journal of Physics: Conference Series, 1722(1). https://doi.org/10.1088/1742-6596/1722/1/012108

Khakim, A. A. (2019). Problem-Based learning in programming lesson.

Khoeriah, N., Mahmudi, A., & Sudrajat, S. (2024). *Pengembangan lks berbasis pbl berbantuan geogebra untuk meningkatkan kemampuan pemecahan masalah dan kesadaran metakognitif siswa.* AKSIOMA: Jurnal Program Studi Pendidikan Matematika, 13(1), 65. https://doi.org/10.24127/ajpm.v13i1.8534

Kuncorowati, R. H., Mardiyana, M., & Saputro, D. R. S. (2017). The analysis of student's difficulties based on skemp's understanding theorem at the grade VII in Quadrilateral Topic. International Journal of Science and Applied Science: Conference Series, 2(1), 318. https://doi.org/10.20961/ijsascs.v2i1.16736

Landewe, R. (2017). The systematic literature review to the formulation of recommendations. Annals of the Rheumatic Diseases, 76(Suppl 2), 8. https://doi.org/10.1136/annrheumdis-2017-eular.7212

Lestari, N. P., & Aziz, T. A. (2022). Griya journal of mathematics education and application volume 2 nomor 4, desember 2022 desain pembelajaran sistem pertidaksamaan linear dengan model problem based learning untuk Siswa SMA. Journal of Mathematics Education and Application, 2(4), 893. https://mathjournal.unram.ac.id/index.php/Griya/indexGriya

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Annals of Internal Medicine, 151(4), W-65-W-94. https://doi.org/10.7326/0003-4819-151-4-200908180-00136

Lima, P. D. S. N., Silva, L. D. A., Felix, I. M., & Brandao, L. D. O. (2019). Difficulties in basic concepts of mathematics in higher education: a systematic review. Proceedings - Frontiers in Education Conference, FIE, 2019-October. https://doi.org/10.1109/FIE43999.2019.9028658

Listiadi, A. (2018). Integrated module learning in accounting: evidence of Indonesia. www.tojned.net

Liu, J., Li, Z., & Tu, C. (2018). Develop students' thinking ability in math class.

Lovianova, I. V., Yu Kaluhin, R., Kovalenko, D. A., Rovenska, O. G., & Krasnoshchok, A. V. (2022). Development of logical thinking of high school students through a problem-based approach to teaching mathematics. Journal of Physics: Conference Series, 2288(1). https://doi.org/10.1088/1742-6596/2288/1/012021

Lytra, N., & Drigas, A. (2021). STEAM education- metacognition – Specific Learning Disabilities. Scientific Electronic Archives, 14(10). https://doi.org/10.36560/141020211442

Magdalena, I., Fauziah Fadhillahwati, N., Amalia, R., & Farhana, S. (2023). Improving mathematics learning outcomes through problem based learning (pbl) learning model for 4th grade students. https://ojs.transpublika.com/index.php/ROMEO/

Mertasari, N. M. S., Sastri, N. L. P. P., & Pascima, I. B. N. (2023). Performance assessment: Improving metacognitive ability in mathematics learning. Journal of Education and E-Learning Research, 10(4), 837–844. https://doi.org/10.20448/jeelr.v10i4.5260

Mudrikah, A., Muhammadiyah, S. D., Khusus, P., & Boyolali, A. (2020). Problem based learning as part of student-centered learning. https://jurnal.uns.ac.id/shes

Nicholus, G., Muwonge, C. M., & Joseph, N. (2023). The role of problem-based learning approach in teaching and learning physics: a systematic literature review. F1000Research, 12, 951. https://doi.org/10.12688/f1000research.136339.1

Nisa Rambe, K., & Sinaga, B. (2020). *Analisis kemampuan metakognisi dalam pemecahan masalah matematis pada pembelajaran berbasis masalah ditinjau dari gaya belajar siswa.*

Noor, B. (2022). Students' meta-cognition skills and problem-solving strategies in math: a preliminary literature review. Global Social Sciences Review, VII(IV), 82–88. https://doi.org/10.31703/gssr.2022(vii-iv).09

Nurhalisa, T., Ibnatul Azizah, I., Qoofa Putri Tsania, F., & Kunci, K. (2022). Indonesian journal of science and mathematics education exploration of mathematics problem solving processes of junior high school students with different levels of logical thinking ability *eksplorasi proses pemecahan masalah matematika siswa smp dengan tingkat kemampuan berpikir logis berbeda abstrak.* https://doi.org/10.24042/ijsme.v5i1.11182

Pandey, K., & Mohan, A. (2024). Metacognitive skills in learning and pedagogy: a systematic review and analysis. Journal of Cognition and Culture, 24(3–4), 268–284. https://doi.org/https://doi.org/10.1163/15685373-12340189

Parwata, I. G. A. L., Jayanta, I. N. L., & Widiana, I. W. (2023). Improving metacognitive ability and learning outcomes with problem-based revised bloom's taxonomy oriented learning activities. Emerging Science Journal, 7(2), 569–577. https://doi.org/10.28991/ESJ-2023-07-02-019

Pati, D., & Lorusso, L. N. (2018). How to write a systematic review of the literature. Health Environments Research and Design Journal, 11(1), 15–30. https://doi.org/10.1177/1937586717747384

Rasheed, U., & Zafar, J. M. (2023). Effect of metacognitive strategies on secondary school students to achieve sustainable learning skills. Academy of Education and Social Sciences Review, 3(4), 521–529. https://doi.org/10.48112/aessr.v3i4.601

Rhodes, M. G. (2019). Metacognition. teaching of psychology, 46(2), 168–175. https://doi.org/10.1177/0098628319834381

Santos, S. C. dos, Reis, P. B. S., Reis, J. F. S., & Tavares, F. (2021). Two decades of pbl in teaching computing: a systematic mapping study. IEEE Transactions on Education, 64(3), 233–244. https://doi.org/10.1109/TE.2020.3033416

Santoso, F. E., Napitupulu, E., & Amry, Z. (2018). *Analisis metakognisi siswa sma dalam kemampuan pemecahan maasalah matematis pada model pembelajaran* problem based learning (PBL).

Saputri, V. N., & Kesumawardani, A. D. (2021). Problem-Based Learning (PBL) Model: how does it influence metacognitive skills and independent learning? In Journal of Advanced Sciences and Mathematics Education (Vol. 1, Issue 1). https://www.journal.foundae.com/index.php/jasme/index

Setiawan, B., & Supiandi, M. I. (2019). The contribution of metacognitive skills and reasoning skills on problem solving ability based on problem based learning (PBL) model. Anatolian Journal of Education, 3(2). https://doi.org/10.29333/aje.2018.327a

Shamdas, G. B. N., Laenggeng, Abd. H., Ashari, A., & Fardha, R. (2024). The influence of the problem-based learning model on metacognitive knowledge and science learning outcomes. Jurnal Penelitian Pendidikan IPA, 10(3), 1383–1395. https://doi.org/10.29303/jppipa.v10i3.5444

Siagian, M. V., Saragih, S., & Sinaga, B. (2019). Development of learning materials oriented on problem-based learning model to improve students' mathematical problem solving ability and metacognition ability. International Electronic Journal of Mathematics Education, 14(2). https://doi.org/10.29333/iejme/5717

Silistraru, N., & Vetrila, S. (2023). Metacognition as a component of intelligent behavior. Vector European, 2, 124–128. https://doi.org/10.52507/2345-1106.2022-2.25

Siregar, N., & Djulia, E. (2022). Development of tissue culture textbook based on scientific literacy as a student learning source. Siregar & Djulia. Jurnal Pelita Pendidikan, 9(4), 186–192. https://jurnal.unimed.ac.id/2012/index.php/pelita/index

Sisrayanti, Maksum, H., Waskito, & Sabrina, E. (2024). The effect of the problem-based learning model on 21st century student skills: A. Indonesian Journal of Computer Science, 13(2).

Srikan, P., Pimdee, P., Leekitchwatana, P., & Narabin, A. (2021). A problem-based learning (pbl) and teaching model using a cloud-based constructivist learning environment to enhance thai undergraduate creative thinking and digital media skills. International Journal of Interactive Mobile Technologies, 15(22), 68–83. https://doi.org/10.3991/IJIM.V15I22.24963

Suryani, A., Setiawan, I., Muhdar, S., & Oktaviani, F. S. (2024). The comparison of effectiveness of pjbl and pbl models on students' cognitive learning outcomes. AL-ISHLAH: Jurnal Pendidikan, 16(1), 194–207. https://doi.org/10.35445/alishlah.v16i1.4094

Sutarto, Dwi Hastuti, I., Fuster-Guillén, D., Palacios Garay, J. P., Hernández, R. M., & Namaziandost, E. (2022). The effect of problem-based learning on metacognitive ability in the conjecturing process of junior high school students. Education Research International, 2022. https://doi.org/10.1155/2022/2313448

Triana, R., & Azis, Z. (2020). The effect of the application of discovery learning and problem based learning model on metacognitive ability and students' mathematical connections. In IJEMS: Indonesian Journal of Education and Mathematical Science: Vol. x (Issue 1).

Wang, M.-T., Binning, K. R., Del Toro, J., Qin, X., & Zepeda, C. D. (2021). Skill, thrill, and will: the role of metacognition, interest, and self-control in predicting student engagement in mathematics learning over time. Child Development, 92(4), 1369–1387. https://doi.org/https://doi.org/10.1111/cdev.13531

William, S. K., & Maat, S. M. (2020). Understanding students' metacognition in mathematics problem solving: a systematic review. International Journal of Academic Research in Progressive Education and Development, 9(3). https://doi.org/10.6007/ijarped/v9-i3/7847

Wu, B. (2023). Research on the classroom application of english teaching method based on the cultivation of students' critical thinking. In Journal of Education and Educational Research (Vol. 5, Issue 1).

Wulandari, & Listiana, Y. (2021). Analysis of students' metacognition ability in mathematical problem solving in problem based learning. Jurnal MathEducation Nusantara, 4(1), 38–51.

Wulandari, O., & Taufik, T. (n.d.). *Penerapan model problem based learning (pbl) dalam pembelajaran tematik terpadu di kelas v sekolah dasar* (Vol. 8). http://ejournal.unp.ac.id/students/index.php/pgsd