



A SYSTEMATIC LITERATURE REVIEW OF THE PROBLEM-BASED LEARNING ON STUDENTS' MATHEMATICAL COMMUNICATION SKILLS IN PRIMARY AND SECONDARY EDUCATION

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Abstract

Mathematical communication skills are among the most important skills in mathematics education, helping students convey ideas, explain their thought processes, and represent concepts mathematically. The development of these skills remains a focus of various studies in mathematics education. The purpose of this study is to systematically analyze research trends regarding the application of the PBL model to students' mathematical communication skills. This study employed a Systematic Literature Review (SLR) method with a qualitative descriptive approach and adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The literature search was conducted via the Google Scholar database using the Publish or Perish version 8 application to identify publications from 2022 to 2026. From an initial search yielding 600 articles, 16 articles that met the inclusion and exclusion criteria were selected for analysis. The data were analyzed descriptively through a process of extraction, categorization, and synthesis based on educational level, instructional content, research methods, and research findings. The results indicate that the majority of studies on the application of the PBL model to mathematical communication skills were conducted at the junior high school level, accounting for 56% of the total. Regarding research methods, quantitative methods were the most prevalent, particularly quasi-experimental designs, which accounted for 62%. The variety of instructional materials used was also quite diverse. Overall, the research findings indicate that the implementation of the PBL model effectively improves students' mathematical communication skills. Additionally, several studies also show that the use of instructional media in PBL can enhance student engagement and support the process of mathematical communication in the classroom. Thus, the PBL model can be considered one of the relevant instructional models to help develop students' mathematical communication skills.

Keywords: *Mathematical Communication Skills; Problem-Based Learning; Systematic Literature Review*

Abstrak

Kemampuan komunikasi matematis merupakan salah satu kemampuan terpenting dalam pembelajaran matematika yang membantu siswa menyampaikan gagasan, menjelaskan proses berpikir, serta merepresentasikan konsep secara matematis. Pengembangan kemampuan menjadi perhatian dalam berbagai penelitian pendidikan matematika. Tujuan penelitian ini adalah untuk menganalisis secara sistematis kecenderungan penelitian tentang penerapan model PBL terhadap kemampuan komunikasi matematis siswa. Penelitian ini menggunakan metode *Systematic Literature Review* (SLR) dengan pendekatan deskriptif kualitatif serta berpedoman pada *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA). Pencarian artikel dilakukan melalui basis data *Google Scholar* menggunakan aplikasi *Publish or Perish* versi 8 terhadap publikasi tahun 2022-2026. Dari hasil pencarian awal sebanyak 600 artikel, diperoleh 16 artikel yang memenuhi kriteria inklusi dan eksklusi untuk dianalisis. Data dianalisis secara deskriptif melalui proses ekstraksi, pengelompokan, dan sintesis berdasarkan jenjang pendidikan, materi ajar, metode penelitian, dan temuan penelitian. Hasil penelitian menunjukkan bahwa sebagian besar penelitian tentang penerapan model PBL terhadap kemampuan komunikasi matematis dilakukan pada jenjang pendidikan SMP dengan persentase sebesar 56%, sedangkan berdasarkan metode penelitian, metode kuantitatif menjadi metode yang paling dominan diterapkan khususnya kuasi eksperimen dengan persentase sebesar 62%. Variasi materi ajar yang digunakan juga cukup beragam. Secara keseluruhan, temuan penelitian Menunjukkan bahwa penerapan model PBL secara efektif meningkatkan kemampuan komunikasi matematis siswa. Selain itu, beberapa penelitian juga menunjukkan bahwa pemanfaatan media pembelajaran dalam PBL dapat memperkuat keterlibatan siswa serta mendukung proses komunikasi matematis di kelas. Dengan demikian, model PBL dapat dianggap sebagai salah satu model pembelajaran yang relevan untuk membantu pengembangan kemampuan komunikasi matematis siswa.

Kata kunci: Kemampuan Komunikasi Matematis; Pembelajaran Berbasis Masalah; Tinjauan Pustaka Sistematis

INTRODUCTION

Mathematics is an important subject that plays a significant role in developing students' thinking skills. Through mathematics learning, students are expected not only to solve problems but also to explain, describe, and represent their mathematical ideas. This ability is known as mathematical communication skills. According to the National Council of Teachers of Mathematics (NCTM, 2000), communication is one of the essential process standards in mathematics learning because it helps students organize, clarify, and develop their mathematical thinking. In addition, mathematical communication skills enable students to express their ideas and opinions during the learning process, both orally and in writing (Syamsyiah et al., 2022).

However, mathematics learning in schools indicates that students' mathematical communication skills are still relatively low. Arina and Nuraeni (2022) reported that students have difficulties understanding mathematical problems, solving mathematical tasks, and using mathematical symbols correctly. Similarly, Hidayat et al. (2023) found that students still experience difficulties in communicating mathematical ideas through reading, discussion, writing, interpretation, and the proper use of mathematical symbols. These findings indicate that improving students' mathematical communication skills remains an important challenge in mathematics education. Therefore, an appropriate learning model is needed to facilitate the development of these skills.

One learning model that has the potential to improve students' mathematical communication skills is Problem-Based Learning (PBL). PBL is a student-centered learning model that encourages students to actively solve real-life and complex problems. Through this model, students are encouraged to identify problems, collect relevant information, and develop solutions individually or collaboratively (Ningrum et al., 2024). These learning activities provide opportunities for students to improve their mathematical communication skills in both oral and written forms. Several previous studies have also reported the positive effect of PBL on students' mathematical communication skills (Hafriani et al., 2025; Putra & Sarumaha, 2024; Wahyuni & Swastika, 2024; Aprila & Fajar, 2022; Cholily et al., 2024; Siregar et al., 2023).

Although many studies have investigated the implementation of PBL to improve students' mathematical communication skills, no Systematic Literature Review (SLR) has specifically synthesized the findings of these studies. Previous review studies have focused on different topics. Angela and Subekti (2022) reviewed various instructional media and learning models that improve mathematical communication skills, while Ningrum et al. (2024) examined the implementation of PBL in developing students' mathematical reflective thinking. Rachman et al. (2025) focused on the effect of PBL on mathematical problem-solving skills, whereas Dewi et al. (2026) analyzed research trends in mathematical communication from the perspectives of research topics, methods, forms of communication, and indicators. Therefore, a review that specifically discusses the implementation of PBL in improving students' mathematical communication skills is still limited.

Based on this gap, this study aims to systematically review research on the implementation of Problem-Based Learning to improve students' mathematical communication skills. This study addresses four research questions: (1) What are the characteristics of studies based on educational level? (2) What are the characteristics of studies based on the mathematics topics taught? (3) What are the characteristics of studies based on the research methods used? and (4) What are the main findings regarding the implementation of PBL to improve students' mathematical communication skills? The findings of this review are expected to provide a comprehensive overview of research trends and empirical evidence regarding the implementation of PBL in mathematics education.

METHOD

This study employed the Systematic Literature Review (SLR) method using a descriptive qualitative approach. The SLR method was used to identify, analyze, evaluate, and interpret the findings of previous studies (Angela & Subekti, 2022). The article search was conducted on June 11, 2026, using Publish or Perish (PoP) version 8 with the Google Scholar database. The search was carried out three times, with a maximum of 200 articles for each search, resulting in a total of 600 articles. The search used a combination of keywords in both Indonesian and English, including "Problem Based Learning OR Pembelajaran Berbasis Masalah" AND "Komunikasi Matematis OR Kemampuan Komunikasi Matematis OR Mathematical Communication Skills." The publication period of the articles was limited to 2022–2026. The article selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which consist of four stages: identification, screening, eligibility, and inclusion (Setyowati et al., 2026). To identify articles relevant to the objectives of this study, inclusion and exclusion criteria were established, as presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Research Focus	Studies that implemented the Problem-Based Learning (PBL) model and measured students' mathematical communication skills.	Studies that did not implement the PBL model or did not measure students' mathematical communication skills.
Educational Level	Elementary School, Junior High School, and Senior High School.	Studies conducted outside the elementary, junior high, and senior high school levels.
Research Field	Mathematics education.	Studies outside the field of mathematics education.
Research Method	Quantitative, qualitative, and mixed methods.	Development research and literature review studies.

Based on the initial search conducted using Publish or Perish (PoP) version 8 through the Google Scholar database, a total of 600 articles were identified. These articles represented the initial pool of potentially relevant studies related to the research topic. The identified studies were subsequently filtered using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework by applying the predetermined inclusion and exclusion criteria to ensure a systematic, transparent, and reproducible selection process. During the identification stage, all retrieved articles were compiled and carefully examined to detect duplicate records. This process resulted in the removal of 62 duplicate articles, leaving 538 unique articles to be considered for the subsequent screening stage.

During the screening stage, the titles and abstracts of the remaining 538 articles were systematically reviewed to determine their relevance to the objectives and scope of the present study. Articles that clearly did not address the research topic, failed to satisfy the inclusion criteria, or met one or more exclusion criteria were eliminated at this stage. As a result, 505 articles were excluded, while 33 articles were retained and advanced to the eligibility stage for a more comprehensive assessment.

During the eligibility stage, the full text of each of the 33 remaining articles was thoroughly evaluated to ensure its compliance with the predefined inclusion criteria, alignment with the research objectives, methodological appropriateness, and relevance to the information required to answer the research questions. Attention was given to the quality of the studies, the completeness of the reported findings, and their contribution to the review objectives. Following this detailed assessment, 16 articles were found to fully satisfy all the selection criteria and were therefore included in the final analysis. The complete article selection process, following the PRISMA framework from identification to final inclusion, is illustrated in Figure 1.

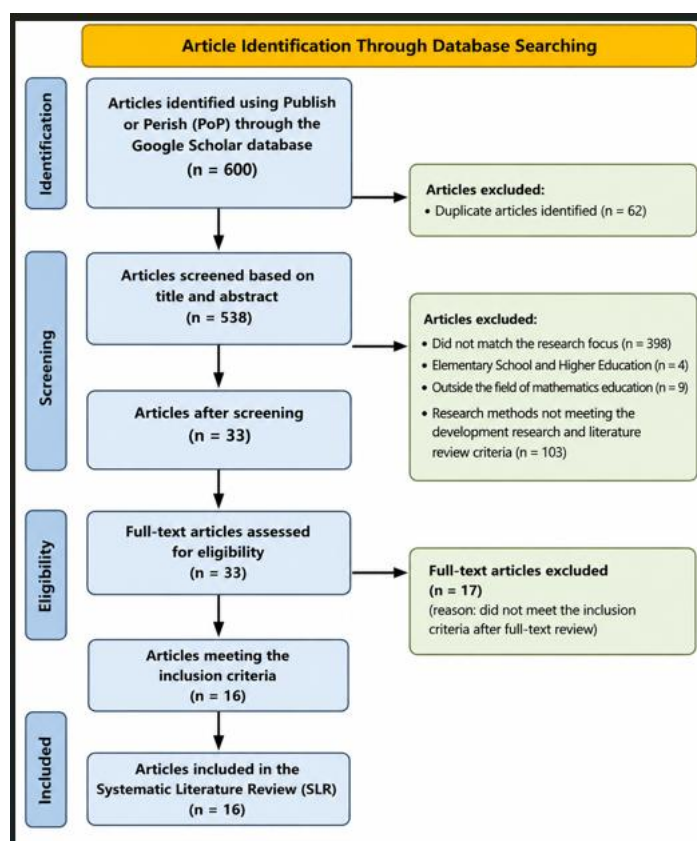


Figure 1. PRISMA Flow Diagram of the Article Selection Process

Next, data from the 16 articles that met the inclusion criteria were extracted using a data extraction form developed based on the research questions. The extracted information included the authors and publication year, educational level, instructional materials, research method, and research findings. To ensure data consistency, the extracted data were rechecked against the original articles before being analyzed descriptively and presented in the form of tables, figures, and descriptive narratives.

RESULTS AND DISCUSSION

The findings of this systematic literature review were obtained through a comprehensive process of searching, selecting, and analyzing studies relevant to the implementation of Problem-Based Learning (PBL) in improving students' mathematical communication skills. The review followed a systematic procedure to ensure that only high-quality and relevant studies were included in the analysis. The selected articles consisted of empirical research that satisfied the predetermined inclusion and exclusion criteria established during the review process.

Based on the PRISMA selection procedure, a total of 16 articles met all eligibility requirements and were included in the final analysis. These studies were then systematically examined to identify their main characteristics, including the educational level of the participants, the mathematical topics or instructional materials investigated, the research methods employed, and the major findings related to the effectiveness of PBL in enhancing mathematical communication skills. In addition, similarities and differences across the studies were identified to provide a comprehensive understanding of current research trends and evidence regarding the implementation of PBL in mathematics education. A detailed summary of the characteristics of the analyzed articles is presented in Table 2.

Table 2. Summary of the Analyzed Articles

No	Author(s) (Year)	Educational Level	Instructional Material	Research Method	Findings
1	Hafriani et al. (2025)	Senior High School	Three- Variable System of Linear Equations	Mixed Methods	The findings showed that students' mathematical communication skills were in the good category after the implementation of the PBL model, although the overall improvement remained at the moderate and low levels.
2	Putra & Sarumaha (2024)	Junior High School	Quadrilaterals	Quantitative	The PBL model was more effective than the conventional learning model in improving students' mathematical communication skills.
3	Wahyuni & Swastika (2024)	Senior High School	Three- Variable System of Linear Equations	Mixed Methods	Students taught using the PBL model demonstrated better mathematical communication skills than those receiving conventional instruction, particularly in communicating, explaining, and consolidating mathematical ideas.
4	Kajori & Hendriana (2023)	Senior High School	Probability	Qualitative	The implementation of the PBL model assisted by Baamboozle improved students' mathematical communication skills, increasing from 63.64% in Cycle I to 78.79% in Cycle II, while making the learning process more active and enjoyable.
5	Salsabilla & Irwan (2025)	Junior High School	Statistics	Quantitative	Students' mathematical communication skills integrated with the PBL model assisted by GeoGebra were better than those achieved through conventional instruction.
6	Aprila & Fajar (2022)	Junior High School	Not Specified	Quantitative	Students who learned through the PBL model showed greater improvement in mathematical communication skills than those receiving conventional instruction. However, the PBL model did not demonstrate better results in improving students' learning independence. In addition, a positive relationship was found between mathematical communication skills and students' learning independence.
7	Wati & Sipahutar (2024)	Junior High School	Not Specified	Quantitative	Students who learned through the PBL model assisted by audiovisual media showed greater improvement in mathematical communication skills than those who received conventional instruction.

No	Author(s) (Year)	Educational Level	Instructional Material	Research Method	Findings
8	Manurung et al. (2024)	Elementary School	Fractions	Quantitative	The findings indicated that the PBL model assisted by interactive student worksheets had a positive effect on elementary school students' mathematical communication skills.
9	Syafira et al. (2025)	Junior High School	Statistics	Qualitative	Students' mathematical communication skills improved after the implementation of the PBL model, with the average score increasing from 15.63 in the pre-test to 38.66 in Cycle I and 77.25 in Cycle II. The implementation of PBL also improved the learning process by encouraging students to participate more actively in discussions and express mathematical ideas.
10	Cholily et al. (2024)	Junior High School	One-Variable Linear Equations	Quantitative	The PBL model resulted in greater improvement in students' mathematical communication skills than conventional instruction and received positive responses from students in mathematics learning.
11	Giovanti et al. (2023)	Senior High School	Linear Program ming	Quantitative	Students who learned through the PBL model assisted by GeoGebra demonstrated better mathematical communication skills than those taught using conventional instruction.
12	Kurniawati et al. (2023)	Junior High School	Plane Figures (Triangles)	Quantitative	Students taught using the PBL model demonstrated greater improvement in mathematical communication skills than those receiving conventional instruction, and they responded positively to the implementation of the PBL model.
13	Anggitawati et al. (2023)	Elementary School	Whole Number Operatio ns	Qualitative	Students' mathematical communication skills and self-confidence improved in every cycle after the implementation of the PBL model. Mathematical communication skills increased from 47.96% in the pre-cycle to 62.96% in Cycle I and 81.66% in Cycle II, while self-confidence increased from 42.59% in the pre-cycle to 62.96% in Cycle I and 77.77% in Cycle II.
14	Siregar et al. (2023)	Senior High School	Derivatives	Qualitative	The implementation of the PBL model improved students' mathematical communication skills from the pre-cycle to Cycle II, as indicated by an increase from 57.93% in the pre-cycle to 66.41% in Cycle I and 80.80% in Cycle II.

No	Author(s) (Year)	Educational Level	Instructional Material	Research Method	Findings
15	N. A. Salsabilla et al. (2023)	Junior High School	Three- Dimensional Figures with Flat Surfaces	Quantitative	Students who learned through the PBL model assisted by GeoGebra demonstrated greater improvement in mathematical communication skills than those receiving conventional instruction.
16	Layliyyah et al. (2022)	Junior High School	Squares and Rectangles	Quantitative	Students who learned through the PBL model demonstrated better mathematical communication skills than those who received conventional instruction.

The analysis yielded several key findings that address the research questions..

Implementation of Problem-Based Learning on Students' Mathematical Communication Skills Across Educational Levels

The educational levels in the analyzed studies were classified according to the level of education of the research participants, namely elementary school, junior high school, and senior high school. This classification was conducted to identify research trends on the implementation of Problem-Based Learning (PBL) to improve students' mathematical communication skills across different educational levels. The distribution of the studies by educational level is presented in Figure 2.

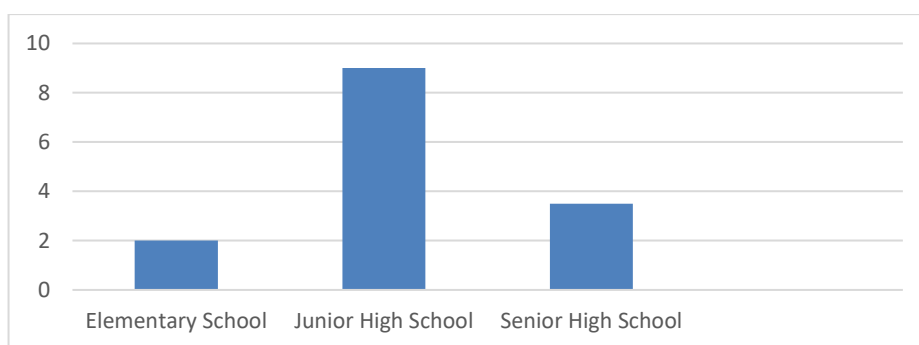


Figure 2. Distribution of Educational Levels in Studies on the Implementation of Problem-Based Learning for Students' Mathematical Communication Skills

As shown in Figure 2, studies on implementing Problem-Based Learning (PBL) to improve students' mathematical communication skills were most frequently conducted at the junior high school level, accounting for 9 of the 16 studies analysed (56%). The senior high school level ranked second with 5 studies (31%), while the elementary school level had the lowest proportion, with only 2 studies (13%). These findings are consistent with those reported by Dewi et al. (2026), who found that junior high school is the educational level most frequently examined in research on mathematical communication. This dominance may be attributed to the characteristics of mathematics learning at the junior high school level, where students begin to connect concrete understanding with symbolic and formal mathematical representations. Consequently, the Problem-Based Learning (PBL) model is considered well suited for developing students' mathematical communication skills.

Implementation of Problem-Based Learning on Students' Mathematical Communication Skills Based on Mathematics Topics

Mathematics topics are an important aspect to consider when implementing a learning model because they are closely related to the competencies to be developed. Therefore, an analysis was conducted on the mathematics topics used in studies investigating the implementation of Problem-Based Learning (PBL) to improve students' mathematical communication skills. The distribution of the mathematics topics is presented in Figure 3.

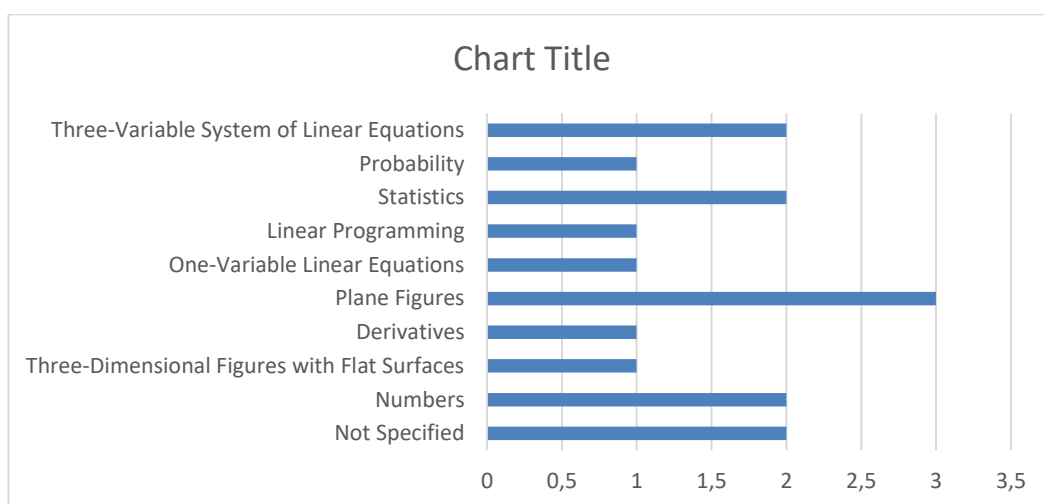


Figure 3. Distribution of Mathematics Topics in Studies on the Implementation of Problem-Based Learning for Students' Mathematical Communication Skills

Figure 3 shows that the implementation of Problem-Based Learning (PBL) to improve students' mathematical communication skills has been investigated across various mathematics topics, including Three-Variable Systems of Linear Equations, Probability, Statistics, Linear Programming, One-Variable Linear Equations, Plane Figures, Derivatives, Three-Dimensional Figures with Flat Surfaces, and Numbers. The mathematics topics most frequently examined generally possess characteristics that support students' mathematical communication activities, such as providing contextual problems that can be discussed, represented, and solved using various strategies. These findings indicate that, in many studies, the selection of mathematics topics was aligned with the need to optimize students' mathematical communication during problem-based learning.

Distribution of Research Methods in Studies on the Implementation of Problem-Based Learning for Students' Mathematical Communication Skills

The research methods employed in studies investigating the implementation of Problem-Based Learning (PBL) for improving students' mathematical communication skills were analyzed to identify methodological trends across the selected literature. Based on the analysis, the studies were classified into three categories: quantitative, qualitative, and mixed methods.

The findings indicate that researchers employed different methodological approaches according to their research objectives and educational contexts. Quantitative studies mainly examined the effectiveness of PBL through statistical analysis, while qualitative studies explored students' learning experiences and communication processes. Mixed-methods studies combined both approaches to provide a more comprehensive understanding of the impact of PBL on students' mathematical communication skills. The distribution of the research methods identified in the analyzed studies is presented in Figure 4.

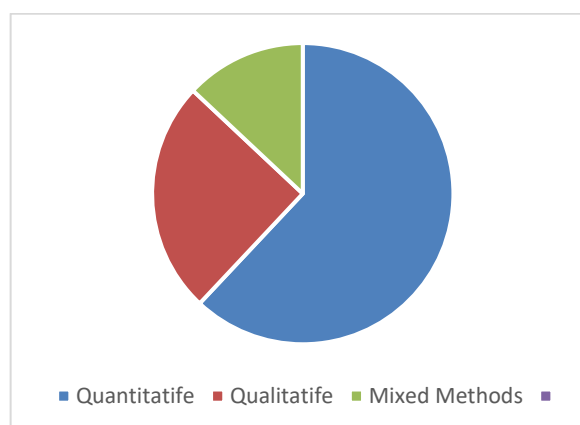


Figure 4. Distribution of Research Methods in Studies on the Implementation of Problem-Based Learning for Students' Mathematical Communication Skills

Figure 4 shows that the majority of studies on the implementation of Problem-Based Learning (PBL) for improving students' mathematical communication skills employed quantitative research methods, accounting for 62% of the analyzed studies. Qualitative research ranked second, representing 25%, while mixed methods research accounted for only 13%. These findings are consistent with those of a previous systematic literature review, which reported that quantitative methods, particularly quasi-experimental designs, are the most commonly used approaches in studies investigating the effects of PBL on students' mathematical abilities. This preference is attributed to the ability of quantitative methods to objectively examine relationships between variables and provide statistically analyzable data to support research findings (Rachman et al., 2025).

In contrast, 25% of the studies employed qualitative methods. The use of this approach indicates that research on the implementation of PBL has focused not only on learning outcomes but also on students' learning processes. This finding is consistent with Nurrasyid et al. (2025), who argued that qualitative methods provide deeper insights into the meaning of learning, the dynamics that occur during the learning process, and students' perceptions of their learning experiences. Meanwhile, the use of mixed methods remains relatively limited, accounting for only 13% of the analyzed studies. According to Creswell (2013), mixed methods research enables researchers to obtain a more comprehensive understanding of a phenomenon by integrating quantitative and qualitative data. Therefore, the application of mixed methods represents a promising direction for future research on the implementation of Problem-Based Learning (PBL) to improve students' mathematical communication skills.

Research Findings on the Implementation of Problem-Based Learning for Students' Mathematical Communication Skills

Based on the 16 analyzed studies, the implementation of Problem-Based Learning (PBL) is effective in improving students' mathematical communication skills across various educational levels and mathematics topics. This effectiveness is closely related to the characteristics of the PBL model, which places students at the centre of the learning process through problem-solving, discussion, and collaborative activities. These characteristics are consistent with Lev Vygotsky's social constructivist theory, which posits that knowledge is constructed through social interaction, collaboration, and scaffolding. As a result, students have opportunities to develop their understanding, express mathematical ideas, provide arguments, and refine their understanding based on feedback from teachers and peers (Salsabila & Muqowim, 2024). Therefore, the learning process in PBL provides students with opportunities not only to construct knowledge but also to develop their mathematical communication skills more effectively.

The implementation of the PBL model contributes not only to the improvement of mathematical

communication skills but also to the development of students' affective attributes, such as self-confidence (Anggitawati et al., 2023). Several studies have also shown that instructional media can enhance the effectiveness of PBL in improving students' mathematical communication skills. GeoGebra helps students visualize abstract mathematical concepts through more concrete representations, making it easier for them to explain relationships among concepts, present graphs, and communicate mathematical ideas. Meanwhile, Baamboozle promotes a more active and enjoyable learning environment through game-based quizzes that encourage students to discuss, collaborate, and justify their answers. Audiovisual media help students understand problem contexts by presenting information through visual and auditory formats, whereas interactive student worksheets guide students in solving problems systematically through structured learning activities. These findings indicate that instructional media function not only as tools for delivering learning materials but also as effective means of facilitating interaction, mathematical representation, and the communication of mathematical ideas, thereby enhancing the effectiveness of the communication process (Kajori & Hendriana, 2023; H. Salsabilla & Irwan, 2025; Wati & Sipahutar, 2024; Manurung et al., 2024; Giovanti et al., 2023).

Furthermore, the findings indicate a significant difference between the PBL model and conventional instruction. Students who learned through the PBL model demonstrated better mathematical communication skills than those who received conventional instruction (Wahyuni & Swastika, 2024; Aprila & Fajar, 2022; Cholily et al., 2024; Kurniawati et al., 2023; Layliyyah et al., 2022). This difference suggests that student-centred learning provides greater opportunities for students to explore ideas, engage in discussions, express their opinions, and construct knowledge through problem-solving activities than teacher-centred instruction. However, the effectiveness of the PBL model is also influenced by teachers' readiness, students' readiness, and effective time management during the learning process (Hafriani et al., 2025). These findings suggest that the successful implementation of PBL depends not only on the model itself but also on how it is implemented in the classroom. Accordingly, learning activities should be carefully designed to achieve the intended learning objectives. Overall, the evidence indicates that Problem-Based Learning (PBL) has strong potential to improve students' mathematical communication skills when implemented effectively.

CONCLUSION

Based on the review of the 16 analyzed studies, this study provides an overview of research trends on the implementation of Problem-Based Learning (PBL) for improving students' mathematical communication skills in terms of educational level, mathematics topics, research methods, and research findings. The results indicate that most studies were conducted at the junior high school level and covered a wide range of mathematics topics. In terms of research methodology, quantitative methods, particularly quasi-experimental designs, were the most frequently employed. In contrast, qualitative and mixed methods approaches were used less frequently. These findings suggest that most studies have focused primarily on measuring students' learning outcomes rather than exploring the learning process in greater depth. Overall, the evidence indicates that the implementation of the Problem-Based Learning (PBL) model effectively improves students' mathematical communication skills. Furthermore, the integration of instructional media within PBL enhances students' engagement and supports the development of mathematical communication during classroom learning. This study has several limitations. First, the number of analyzed studies was relatively limited. Second, the scope of the review was restricted to selected publications, which may not fully represent the entire body of research on this topic. Therefore, future studies are encouraged to expand the range of literature included in the review, employ mixed methods to provide a more comprehensive understanding of both learning outcomes and learning processes, and investigate the implementation of Problem-Based Learning (PBL) integrated with a wider variety of instructional media to examine its impact on students' mathematical communication skills more comprehensively.

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