



## Meta-Synthesis: The Effect of Problem-Based Learning Model on Students' Mathematical Connection Ability

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### abstract

Mathematical connection ability plays a crucial role in enabling students to understand relationships among mathematical concepts, apply mathematical ideas in real-life contexts, and develop higher-order thinking skills. However, evidence from the field indicates that students' mathematical connection ability remains relatively low due to instructional practices that emphasize procedural mastery rather than conceptual understanding. This study aims to analyze the effect of the Problem-Based Learning (PBL) model on students' mathematical connection ability through a meta-synthesis approach. The meta-synthesis reviewed six primary research articles selected systematically from Google Scholar, ERIC, and reputable national and international journals published between 2020 and 2025. The findings reveal that PBL consistently enhances students' mathematical connection ability through contextual problem-solving activities, the use of visual representations and learning media, and collaborative reflection. These results indicate that PBL is an effective instructional model for strengthening students' mathematical connections in a meaningful and applicable learning environment.

#### Keywords:

Mathematical Connection Ability; Problem-Based Learning; Meta-Synthesis



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## INTRODUCTION

Mathematical connection ability is one of the essential competencies in mathematics education. The National Council of Teachers of Mathematics (NCTM, 2000) states that mathematical connections are part of the process standards that students must master, as this ability enables learners to link mathematical ideas, both between concepts and with their applications in real-life contexts. Some indicators of mathematical connection ability according to NCTM include recognizing relationships among concepts, applying concepts in different situations, and accurately interpreting mathematical representations. Mastery of mathematical connections not only deepens conceptual understanding but also plays a role in developing critical thinking skills and problem-solving abilities (Weingarden, 2024).

Evidence from the field shows that students' mathematical connection ability remains relatively low. Many students struggle to relate previously learned concepts to new problems and are not yet proficient in using appropriate mathematical representations. Setiawati (2023) found that students' conceptual understanding tends to be partial, limiting their ability to connect mathematical ideas. This situation highlights the need for innovation in mathematics teaching so that students not only master procedures but also understand the relationships between concepts in a more meaningful way (Septian & Komala, 2022).

Problem-Based Learning (PBL) is regarded as an instructional model capable of addressing this issue. PBL places contextual problems as the starting point of learning and guides students through systematic steps, namely identifying problems, analyzing information, formulating solutions, and reflecting on results. This structured PBL syntax provides opportunities for students to actively discuss, collaborate, and investigate solutions, allowing them to discover connections among mathematical concepts and relate them to everyday experiences (Riyanto et al., 2023). The inquiry-based nature of PBL aligns with the goals of mathematical connections, namely linking, applying, and interpreting mathematical ideas in various real-world situations (Nicholus et al., 2023; Implementation of PBL, 2022).

Previous studies provide evidence of PBL's effectiveness. Septian & Komala (2022) reported that junior high school students learning with PBL achieved higher mathematical connection scores compared to conventional teaching. Setiawati (2023) demonstrated that implementing PBL enhanced both students' mathematical connection ability and engagement in specific topics. International studies, such as *Fostering Mathematical Connections* (2024) and Weingarden (2024), also confirm the significant impact of PBL on improving mathematical connection skills. Additionally, literature reviews by Nicholus et al. (2023) and *Implementation of PBL* (2022) reinforce the findings that PBL consistently contributes positively to developing students' mathematical connection abilities across educational levels.

Based on the discussion above, this study aims to synthesize and analyze empirical findings from previous studies in order to systematically examine the effect of the Problem-Based Learning model on students' mathematical connection ability across different educational contexts. The results are expected to provide valuable insights for teachers, researchers, and policymakers in designing mathematics instruction that is more effective, innovative, and contextually meaningful.

## METHODS

### Research Design

This study employed a meta-synthesis approach, which aims to integrate and interpret findings from previous studies to obtain a more comprehensive understanding of the

research topic. In this context, the meta-synthesis was conducted to identify, analyze, and synthesize various research findings related to mathematical connection ability through the Problem-Based Learning (PBL) model. This approach was chosen because it allows for an in-depth exploration of patterns, similarities, and differences in previous research results, thereby providing a broader perspective on the effectiveness of PBL in improving students' mathematical connection ability.

### **Data Sources and Article Selection Criteria**

The data sources of this study consisted of national and international journal articles relevant to the research topic. Articles were obtained from Google Scholar, ERIC, and reputable national and international journals in the field of mathematics education. These sources were selected due to their accessibility, relevance, and credibility in providing peer-reviewed studies related to Problem-Based Learning and mathematical connection ability. The inclusion criteria applied in this meta-synthesis were as follows:

1. Articles published between 2020 and 2025.
2. Articles focusing on mathematical connection ability through the implementation of the Problem-Based Learning model.
3. Articles employing qualitative or mixed-methods research approaches.
4. Articles available in full text with sufficient data for synthesis.

Articles that did not meet these criteria were excluded. Based on the systematic screening process, six primary articles were selected as the main sources for analysis in this meta-synthesis.

### **Research Procedure**

The research procedure followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, consisting of four main stages:

1. Identification: Searching for articles through various online databases using relevant keywords.
2. Screening: Selecting articles based on titles and abstracts to ensure topic relevance.
3. Eligibility: Reading the full text of each article to confirm its compliance with the inclusion criteria.
4. Inclusion: Analyzing and synthesizing the articles that met all criteria.

These stages are illustrated in the PRISMA flow diagram shown in Figure 1.

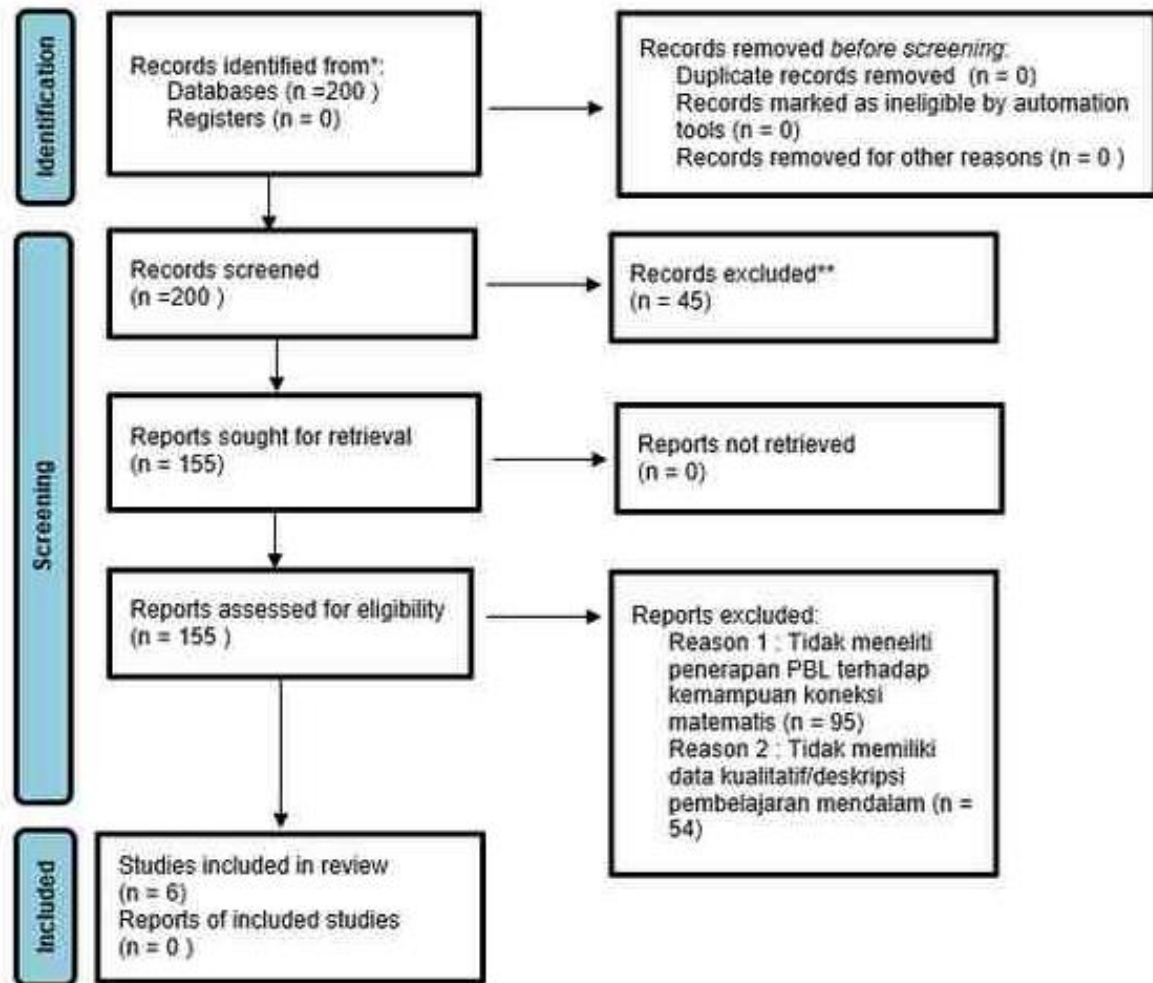


Figure 1 PRISMA Flow Diagram of Article Selection Process

### Data Analysis Technique

The data analysis process consisted of three main stages:

1. Data Extraction: Collecting essential information from each article, including authors, publication year, research objectives, methodology, participants, and findings related to mathematical connection ability and PBL.
2. Categorization and Coding: Classifying the main themes derived from the research findings, such as the *application of PBL in mathematical concept connections, problem-solving ability, and student engagement*.
3. Synthesis of Findings: Integrating the results of all selected studies to identify common patterns, similarities, and differences in the implementation of PBL to improve students' mathematical connection ability.

The results of this synthesis were then used to draw general conclusions regarding the effectiveness of the Problem-Based Learning model in enhancing students' mathematical connection ability across different educational levels.

## RESULT AND DISCUSSION

### Description of test result

After collecting data in the form of research articles obtained using the keywords “Problem-Based Learning” and “mathematical connection ability” through databases such as Google Scholar and ERIC, the articles were classified based on their relevance to the focus of this study, namely the influence of the Problem-Based Learning model on students’ mathematical connection ability. From this classification process, six primary articles were identified that met the inclusion criteria and were selected for further analysis in this meta-synthesis.

Table 1 Summary of the Main Articles Analyzed

No	Article Title	Author (Year)	Research Method	Research Findings
1	<i>Improving Students’ Understanding and Mathematical Connection Ability Through Problem Based Learning</i>	Setiawati, K. L. (2022)	Quasi-Experiment with qualitative descriptive data	The implementation of PBL improved students’ ability to connect concepts across mathematical topics, particularly in SPLDV material. Group discussions and contextual problem solving encouraged students to reason about the relationships between algebraic and geometric concepts.
2	<i>Students’ Mathematical Connection Ability and Learning Motivation Using the GeoGebra-Assisted Problem Based Learning Model</i>	Septian, A. & Komala, E. (2023)	Mixed Method (quantitative & qualitative)	The integration of PBL with GeoGebra had a significant impact on improving mathematical connection ability and learning motivation. Visualization through digital media helped students understand relationships between concepts in graphical and symbolic contexts.
3	<i>Implementation of Problem-Based Learning to Improve Students’ Mathematical Understanding Ability and Mathematical Connection Ability</i>	Komariah, E. N., Nurdin, I. T., Putra, H. D., & Yuliani, A. (2023)	Field Descriptive	PBL effectively enhanced vocational students’ mathematical connection ability, especially in linking mathematical concepts with their applications in real-world industrial contexts. Students were able to identify relationships between theory and practice.

4	<i>Fostering Mathematical Connections and Habits of Mind: A Problem-Based Learning Module for Elementary Education</i>	Purnomo, Y. W., Nabillah, R., Aziz, T. A., & Widodo, S. A. (2024)	Developmental and Evaluative Study	The developed PBL-based module effectively fostered reflective thinking habits and the ability to connect mathematical ideas across contexts. Pre-service teachers showed improved understanding of conceptual interrelationships and their applications in teaching mathematics.
5	<i>The Role of Mathematical Connections in Object-Level and Meta-Level Learning</i>	Weingarden, M. (2024)	Qualitative	PBL helped students shift from object-level learning to meta-level learning, enabling them to understand conceptual interconnections and reflect on mathematical thinking processes.
6	<i>The Role of Problem-Based Learning Approach in Developing Students' Thinking and Learning Processes: A Review</i>	Nicholus, G. et al. (2023)	Systematic Review	PBL consistently strengthened higher-order thinking skills, including mathematical connection ability. The approach encouraged students to connect prior and new knowledge, solve contextual problems, and develop reflective and collaborative abilities.

The meta-synthesis of the six primary studies presented in Table 1 demonstrates a consistent pattern indicating that the Problem-Based Learning (PBL) model enhances students' mathematical connection ability across various educational levels through shared instructional mechanisms rather than isolated instructional outcomes. Mathematical connection ability refers to students' capability to relate different mathematical ideas, concepts, and procedures, both among mathematical topics and between mathematics and real-life applications (NCTM, 2000). Through PBL, students not only focus on procedural completion but also construct conceptual relationships and comprehend mathematical ideas more meaningfully.

### Data Analyze

The research findings indicated that the improvement of mathematical connection ability was not only reflected in students' learning outcomes but also in changes in their ways of thinking, interacting, and solving problems during the learning process. Initially, many students tended to solve problems mechanically by memorizing formulas without understanding the conceptual relationships. However, after participating in PBL, students were able to interpret, connect, and apply these concepts in contextual situations, demonstrating a qualitative enhancement in their mathematical connection ability.

According to Setiawati (2022), the implementation of PBL on the topic of Systems of Linear Equations in Two Variables (SPLDV) exposed students to contextual problems such as

price comparison, production cost, and speed. Initially, students found it difficult to relate variables to real-life meanings. After going through the PBL stages problem presentation, group discussion, independent investigation, and presentation students showed significant improvement in understanding relationships between equations and graphs, as well as the effect of one variable on another. This finding aligns with the indicators of mathematical connection ability described by NCTM (2000).

Further evidence was reported by Septian and Komala (2023), who applied GeoGebra-assisted PBL to enhance students' conceptual understanding. Through digital visualization, students observed relationships between symbolic forms and graphical representations of mathematical concepts. Before using GeoGebra, they tended to perceive concepts separately and statically. After engaging in PBL, students were able to link algebraic functions to graphs and explain the meaning of intersection points and slopes conceptually. This demonstrates an improvement in the ability to connect multiple mathematical representations.

Komariah et al. (2023) also provided qualitative evidence of PBL effectiveness in vocational education settings. In this context, students applied mathematical concepts directly to real-world industrial problems, such as calculating raw materials and production costs. Such activities trained students to think applicatively and to recognize the practical functions of mathematical principles, thereby improving their ability to link mathematics with real-life contexts.

International research findings are consistent with these results. Purnomo et al. (2024) found that PBL-based modules in pre-service teacher education improved participants' ability to connect mathematical concepts across topics through reflective discussion and collaboration. Similarly, Weingarden (2024) observed that PBL enabled students to transition from object-level learning to meta-level learning, in which they not only identified but also explained the relationships among mathematical ideas. Nicholus et al. (2023) concluded that PBL significantly contributes to the development of higher-order thinking skills, including mathematical connection ability, by encouraging investigation, discussion, and reflection.

Overall, the meta-synthesis results identified three main mechanisms through which PBL enhances mathematical connection ability:

1. Contextual problem solving, which integrates prior knowledge with new experiences.
2. Use of representations and learning media, which helps students visualize relationships among mathematical ideas.
3. Reflection and collaboration, which foster metacognitive awareness of conceptual interconnections.

From a theoretical perspective, these findings are consistent with Piaget's constructivist theory, which states that knowledge is constructed through the interaction between new experiences and existing cognitive structures. PBL provides learning conditions that enable the processes of assimilation and accommodation to occur naturally. Furthermore, Vygotsky's theory of the Zone of Proximal Development (ZPD) explains how social interaction and scaffolding during group discussions facilitate the formation of connections among ideas. These theories strengthen the (NCTM, 2000) framework, which places mathematical connection ability alongside problem-solving, communication, and reasoning skills.

From a practical perspective, teachers should shift from outcome-based to process-based instruction by designing PBL activities that present contextual problems, encourage collaboration, and employ visual media for exploration. Such learning promotes the

development of meaningful mathematical understanding and strengthens students' ability to connect and apply mathematical concepts in everyday life.

In summary, the improvement of mathematical connection ability through PBL occurs not merely due to problem-solving activities, but because of the alignment between PBL stages and cognitive processes that support conceptual connection. The relationship among PBL syntax, learning theories, and mathematical connection indicators (NCTM, 2000) demonstrates that each stage problem orientation, independent inquiry, collaboration, and reflection systematically develops students' higher-order thinking through active, reflective, and collaborative learning experiences.

## CONCLUSION

Based on the meta-synthesis of six primary studies, it can be concluded that the Problem-Based Learning (PBL) model has a positive and consistent impact on improving students' mathematical connection ability. PBL encourages students to actively construct knowledge through contextual problem solving, group discussion, and reflection on their own thinking processes. Through these activities, students are able to relate various mathematical concepts, understand relationships among multiple representations, and connect mathematical ideas to their applications in real-life situations. The improvement in mathematical connection ability occurs because PBL positions students as active learners and provides opportunities to integrate prior knowledge with new experiences. The synthesis also indicates that the use of learning media such as GeoGebra and reflective PBL modules strengthens students' visualization and conceptual understanding. Therefore, PBL can be considered an effective alternative learning model for mathematics teachers to create interactive, meaningful, and contextual learning environments. Teachers are encouraged to design problem-based activities that are relevant to real-world contexts to optimally develop students' mathematical connection abilities, both conceptually and applicatively.

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