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The Impact of Problem-Based Learning on Mathematics Education: A Systematic Literature Review

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Abstract

This study aims to analyze the impact of the Problem-Based Learning (PBL) model on mathematics education through a Systematic Literature Review (SLR) method. The primary issue addressed is the low mathematical proficiency of Indonesian students as reflected in international standards such as PISA and TIMSS. The study identifies student abilities, learning media, educational levels, and topics best suited for PBL implementation. Data were collected from 27 articles selected using the PRISMA protocol based on inclusion criteria, such as type of literature and publication years ranging from 2020 to 2024. The findings indicate that PBL is most commonly implemented to enhance mathematical problem-solving skills. High school education (SMA) is the most frequently studied level, with topics such as geometry, algebra, and statistics being the focus. Technology-based media, such as GeoGebra, support PBL implementation by providing visualizations of abstract concepts. This study concludes that PBL significantly contributes to improving students' conceptual understanding, critical thinking, and problem-solving skills.

Keywords: Mathematics Learning, Problem-Based Learning, SLR

INTRODUCTION

Mathematics education holds a strategic role in the education system as it not only teaches numerical and abstract concepts but also trains logical, analytical, and systematic thinking skills. These competencies are crucial in various aspects of daily life and the workplace, making mathematics a fundamental foundation for the development of science and technology. According to Resnick (1987), as cited by Setiawati, the benefits of mathematics education include developing problem-solving skills, critical thinking, and rational decision-making. Furthermore, mathematics helps students understand the relationship between abstract concepts and their real-world applications, enhances mathematical communication skills, and fosters creativity in finding innovative solutions (Kilpatrick et al., 2001).

However, in Indonesia, students' mathematics proficiency, as measured by international standards such as the National Council of Teachers of Mathematics (NCTM), remains relatively low compared to developed countries. This is reflected in international survey results like the 2022 Programme for International Student Assessment (PISA), which shows that the average PISA mathematics score for 15-year-old Indonesian students is 366 points, far below the OECD average of 472 points. In the fields of science and reading, Indonesia's scores are 383 points and 359 points, respectively, also below the OECD average. Additionally, the 2019 Trends in International Mathematics and Science Study (TIMSS) reports that Indonesian eighth-grade students achieved an average score of 397 points in mathematics, which is below the international average of 500 points. In science, Indonesian students scored 396 points, indicating a limited understanding of basic concepts. This low performance highlights significant challenges in improving the quality of mathematics and science education in Indonesia. Several contributing factors have been identified, including socioeconomic disparities, the quality of teaching, and limited educational resources.

To maximize the benefits of mathematics education and improve achievement in international standards (NCTM, PISA, and TIMSS), a learning approach that fosters critical, creative, and analytical thinking in students is needed. One widely recommended solution is the implementation of Problem-Based Learning (PBL), a problem-based learning approach that focuses on developing students' ability to understand and solve real-world problems (Allen et al., 1996; BARROWS, 1986; Hmelo-Silver, 2004). The PBL model has unique characteristics, such as using contextual problems as the starting point for learning, actively engaging students in the learning process, and emphasizing the development of higher-order thinking skills (Savery, 2006; Stepien et al., 1993). Furthermore, PBL promotes collaboration among students and positions teachers as facilitators, ultimately helping students gain a deeper understanding of concepts.

Various studies have shown that Problem-Based Learning (PBL) has a significant positive impact on mathematics education (Strobel & van Barneveld, 2009). One of its effects is the enhancement of students' problem-solving abilities, as PBL encourages them to identify, analyze, and find solutions to contextual problems relevant to real life. Additionally, this approach effectively trains students to think logically, creatively, and systematically when facing mathematical challenges (Juandi & Tamur, 2020).

PBL has also been proven to enhance critical thinking skills, which are essential for processing information and constructing logical arguments. Through group work and guided discussions, students can develop analytical skills and learn to evaluate alternative solutions (Slavin, 1996). Furthermore, PBL helps students gain a deeper understanding of mathematical concepts, as problem-based learning emphasizes the exploration of concepts rather than mere memorization of formulas.

However, the effectiveness of PBL varies depending on several factors, such as students' educational level, socioeconomic background, and teachers' skills in managing this learning model (BARROWS, 1986; Hmelo-Silver, 2004). Some studies report that although PBL successfully enhances student engagement, the outcomes in certain aspects, such as academic achievement or learning retention, are not always consistent across educational contexts (Walker & Leary, 2009). For instance, students who are less familiar with collaborative learning may require more time to adapt to this method. These mixed results highlight the need for systematic studies to consolidate existing findings. Therefore, this research is conducted in the form of a Systematic Literature Review (SLR) to comprehensively analyze the impact of PBL on mathematics educatione

METHOD

This study aims to provide conclusions from research examining the impact of Problem-Based Learning on critical thinking skills using a Systematic Literature Review (SLR). A Systematic Literature Review (SLR) is a systematic research method used to organize, evaluate, and synthesize findings from other studies related to the topic of discussion. SLR is conducted through structured and transparent steps to identify, evaluate, and present evidence from various studies on the subject. The SLR method aims to draw conclusions from the overall research findings on the topic by objectively and comprehensively considering the available evidence (Triandini et al., 2019).

The research questions are formulated based on the background and the needs of the research topic, as follows:

1. What student skills in mathematics learning can be improved through the implementation of PBL?
2. What learning media are commonly used in the implementation of PBL in mathematics education?
3. At which educational levels is PBL most frequently applied in mathematics learning?
4. Which learning materials are most often enhanced through the PBL approach?

The search process was conducted to gather primary sources relevant to the research, particularly previous studies that can comprehensively address the research questions. To ensure the quality and credibility of the data, the search was carried out using Scopus, one of the most trusted bibliographic databases. Scopus covers various types of academic publications, including scientific journals, books, and conference proceedings from diverse fields such as science, technology, medicine, social sciences, arts, and humanities.

With features designed to support academic research, Scopus serves as a vital tool for researchers in identifying research trends, evaluating the relevance of literature, and discovering the latest works in specific fields. The strength of Scopus lies not only in its broad coverage but also in its ability to provide citation metrics, helping researchers assess the impact of the articles found. Therefore, Scopus is used as the primary reference source in the literature search process to ensure that the data obtained is not only relevant but also valid and up-to-date.

Inclusion criteria are a stage carried out to determine whether the obtained literature is suitable for use as research data or not. At this stage, the researcher establishes inclusion criteria to select the literature that will be used in the study. The inclusion criteria are presented in Table 1.

Tabel 1 - Inclusion Criteria

No	Inclusion
1	The literature discusses Problem-Based Learning in mathematics education.
2	The literature is in the form of journal articles or conference proceedings.
3	The publication year of the literature is within the last 5 years (2020-2024).
4	The journal articles or conference proceedings are open access.
5	The research subjects in the literature are students or university students.
6	The article is not a meta-analysis or SLR.

Data were collected by searching for literature published online, both in the form of scientific journals and conference proceedings, using the Scopus database. The collection process was carried out based on the established inclusion criteria to ensure the relevance and quality of the sources. In the search process, a strategy based on specific keywords such as "Problem-Based Learning" and "Mathematics Learning" was used, designed to find articles directly related to the research topic.

In addition, the literature search was optimized by applying additional filters on Scopus, such as publication date range, document type, and specific academic fields, to obtain more focused and relevant results. By using these filter features, the literature collected not only provides up-to-date information but also reflects the latest trends and contributions in research on Problem-Based Learning in mathematics education. This systematic approach ensures that the data used has academic validity and comprehensively supports the research objectives. Table 2 presents the categorization of literature based on publication time and document type.

Table 2 - The Categorization of Literature Based on Publication Time and Document Type

Inclusion criteria	Inclusion	Total
Document Type	Journal articles	6
	The literature is in the form of journal articles or conference proceedings.	21
Publication Time	2020	11
	2021	11
	2022	2
	2023	1
	2024	2

The population in this study includes all research on the Problem-Based Learning (PBL) model in mathematics education that has been published in journals indexed by Scopus. This study uses the PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) as a guideline for conducting the systematic review. The selection process for primary studies follows the four main PRISMA steps: identification, screening, eligibility, and inclusion, as outlined by Juandi & Tamur (2020) and Liberati et al. (2009). Through article searching using the Scopus search engine, a total of 96 relevant articles were obtained for further analysis.

RESULTS AND DISCUSSION

Results of the Search Process and Inclusion Criteria Selection

The literature search on the Scopus search engine using the keywords "Problem-Based Learning" and "Mathematics Learning" yielded 96 sources. First, these 96 sources were identified based on inclusion criteria, specifically the publication years within the range of 2020 to 2024, resulting in 67 sources. Second, the 67 sources were identified based on the type of literature, focusing only on open access materials, which resulted in 43 sources. Third, the 43 sources were identified based on the research subjects and methods, excluding meta-analysis or SLR, leading to 27 sources.

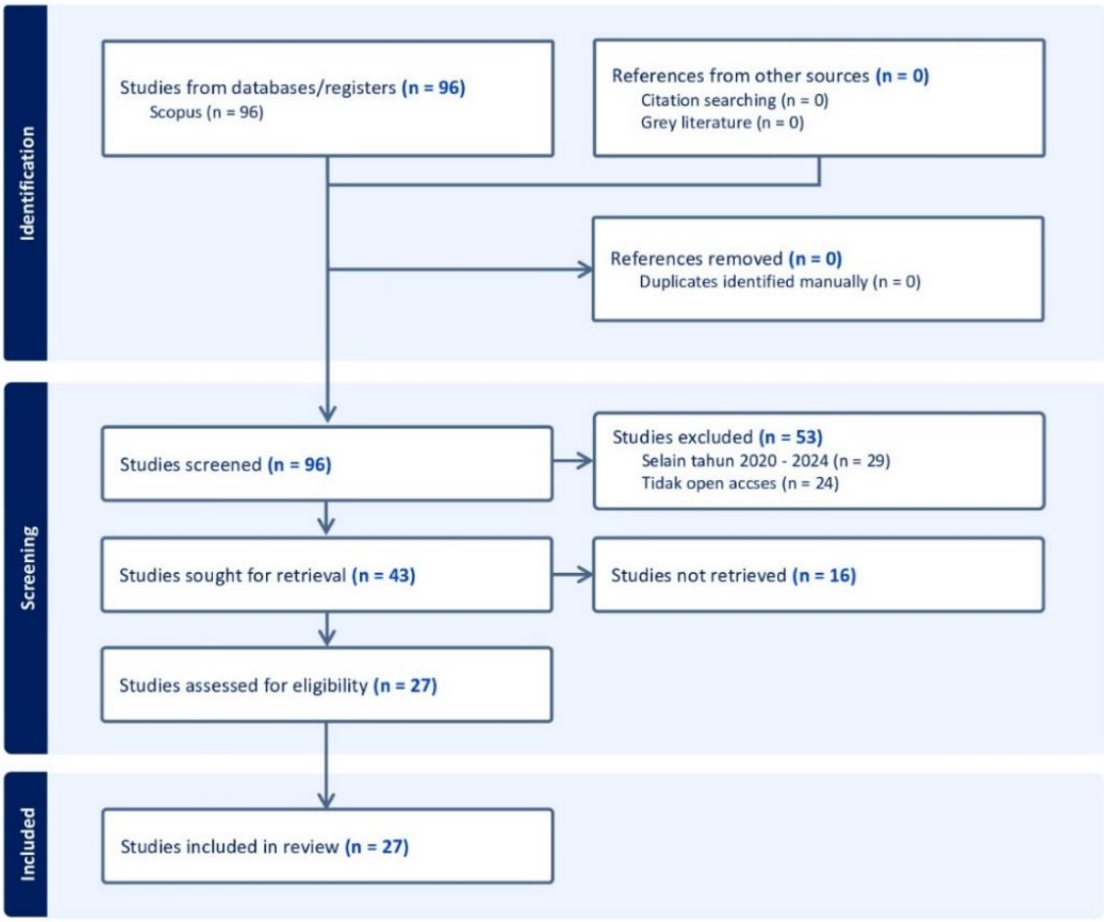

Fig. 1 - PRISMA Diagram of the Study on the Impact of Problem-Based Learning and Mathematics Education.

Results of Data Analysis on the Distribution of Literature Based on the World and Indonesia Maps

Fig. 2 - Distribution of Articles Based on the World Map

Based on the world map, it can be observed that the majority of articles related to Problem-Based Learning (PBL) in mathematics education originate from Southeast Asia, particularly Indonesia, highlighted in dark blue. This indicates that the contribution of research on PBL from Indonesia is quite dominant in the global context, with a total of 25 Scopus-indexed articles. The distribution of articles outside Southeast Asia appears limited, with only a few regions contributing, such as East Asia, specifically in Pakistan. This suggests that the focus of research on the application of PBL in mathematics education remains concentrated in Asia, particularly in Indonesia.

Fig. 3 - Distribution of Articles Based on the Indonesia Map

Based on the map of Indonesia, the articles analyzed in this study have an uneven distribution across various provinces. The province with the highest contribution is West Sumatra, marked in yellow, with a total of 6 Scopus-indexed articles. Aceh is the second-highest contributing province, with 4 Scopus-indexed articles, marked in dark gray. West Java, Central Java, and East Java each contribute 2 Scopus-indexed articles, indicated in orange. Several other provinces, such as Riau, South Sumatra, West Nusa Tenggara, and South Sulawesi, contribute a lower number of articles, with 1 Scopus-indexed article each. This varied distribution indicates that research on PBL in mathematics education in Indonesia is more dominant in certain provinces, especially on the islands of Sumatra and Java, while contributions from other regions remain relatively limited. This finding can serve as a basis for recommending the expansion of similar research to other regions and countries to achieve a more widespread and in-depth understanding and application of PBL in mathematics education.

Studies Based on Student Abilities

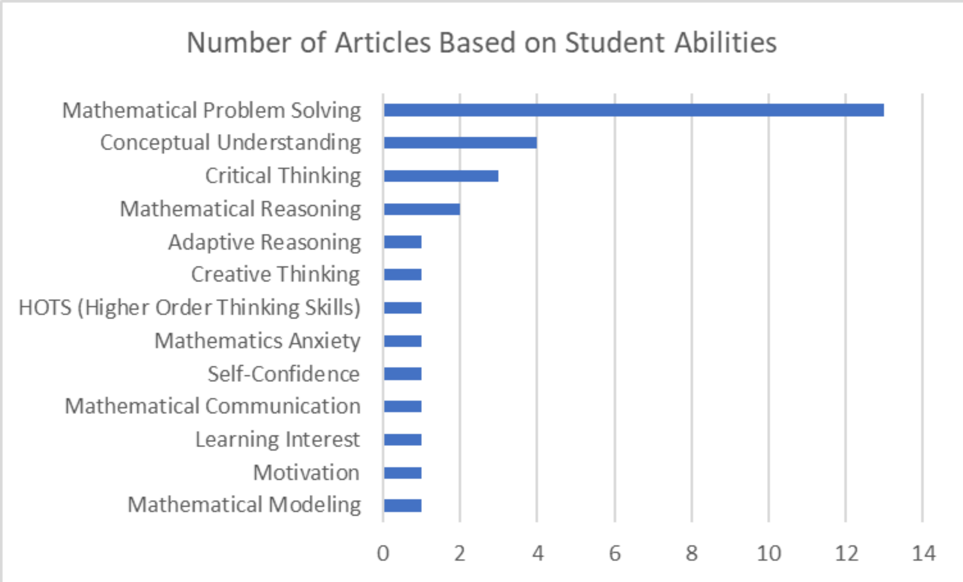

Fig. 4 - Number of Articles Based on Student Abilities

Based on the diagram, it can be observed that mathematical problem-solving is the most frequently researched skill in the application of PBL, with 13 Scopus-indexed articles. Additionally, other skills that can be improved through PBL include conceptual understanding with 4 Scopus-indexed articles, critical thinking with 3 Scopus-indexed articles, and mathematical reasoning with 2 Scopus-indexed articles. Meanwhile, motivation, learning interest, mathematical communication, self-confidence, math anxiety, HOTS (Higher Order Thinking Skills), creative thinking, adaptive reasoning, and mathematical modeling each have 1 Scopus-indexed article. Therefore, it can be concluded that the application of PBL is most commonly associated with improving mathematical problem-solving as the primary skill, followed by conceptual understanding and critical thinking.

Studies Based on Learning Media

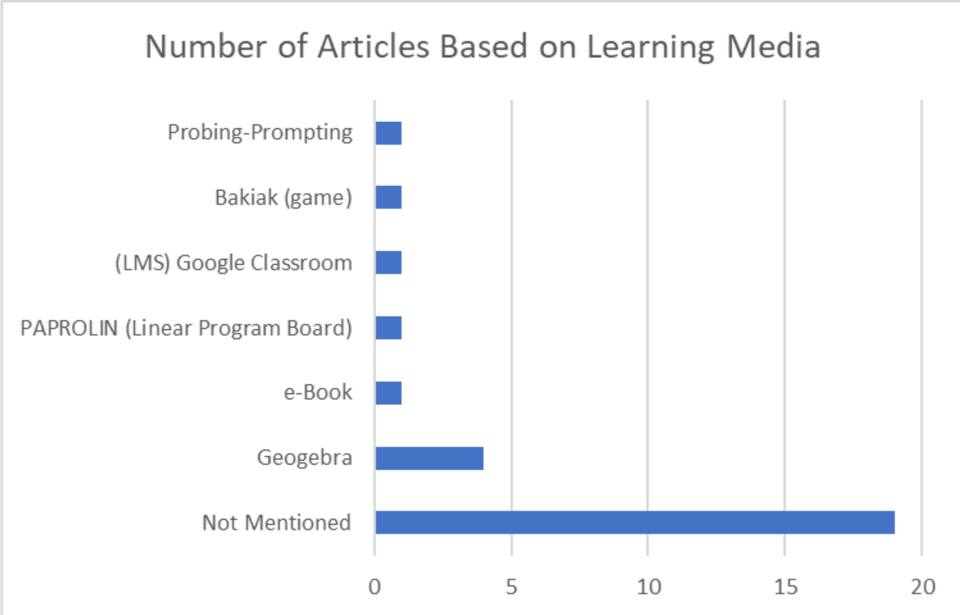

Fig. 5 - Number of Articles Based on Learning Media

Based on the diagram, it can be seen that the use of learning media in the application of PBL is highly varied, but most of the literature does not specifically mention the learning media used. The learning media mentioned include Geogebra, with 4 Scopus-indexed articles. Other media, such as Probing-Prompting, Google Classroom (LMS), Bakiak (game), e-Book, and PAPROLIN (Linear Program Board), each have 1 Scopus-indexed article. Therefore, it can be concluded that the majority of research on PBL does not detail the learning media used. However, technology-based media, such as Geogebra, is increasingly being utilized to support the application of PBL in mathematics education. Geogebra has proven effective in transforming abstract content into more concrete representations, especially for certain educational levels and mathematical topics that require visual understanding.

Studies Based on Education Level

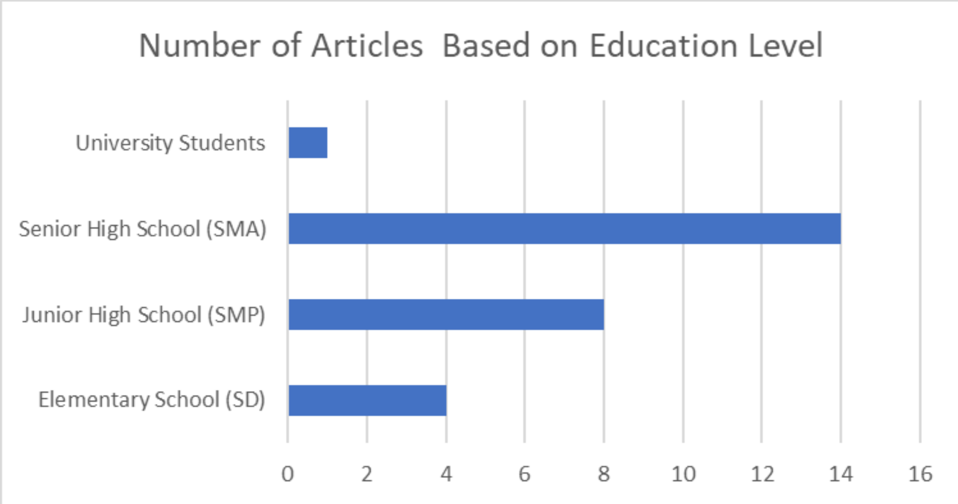

Fig. 6 - Number of Articles Based on Education Level

Based on the diagram, it can be seen that senior high school (SMA) is the most dominant education level in research related to the application of PBL, with 14 Scopus-indexed articles. In second place is junior high school (SMP) with 8 Scopus-indexed articles. Research at the elementary school (SD) level consists of only 3 Scopus-indexed articles. Meanwhile, research at the university level includes only 1 Scopus-indexed article. Therefore, it can be concluded that PBL can be applied at various education levels, from elementary to higher education, with adjustments made according to students' cognitive development stages. For elementary and junior high school levels, PBL is more effective when combined with concrete and contextual activities. Meanwhile, at the senior high school and university levels, technology-based and collaborative approaches have a significant impact on critical thinking and problem-solving skills.

Studies Based on Research Material

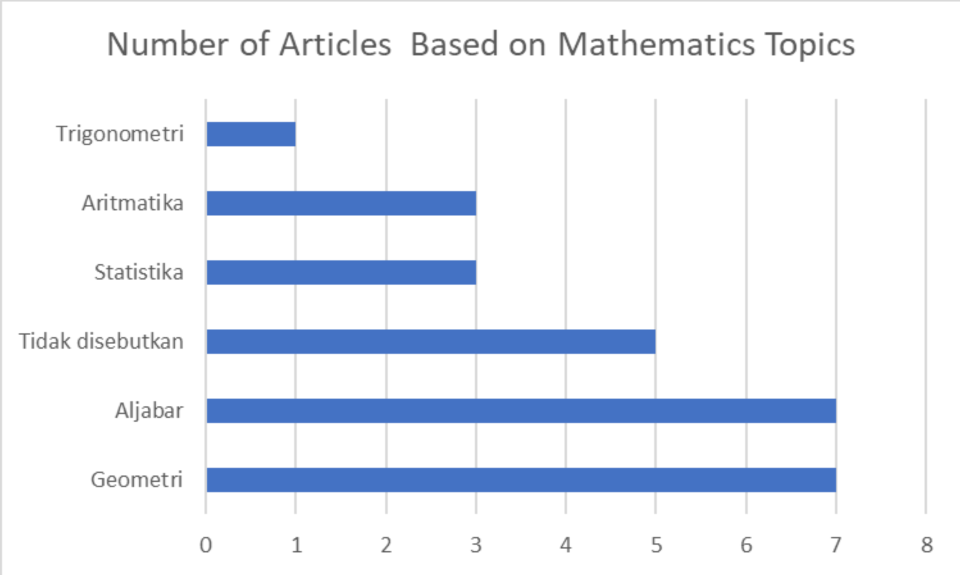

Fig. 7 - Number of Articles Based on Mathematics Topics

Based on the diagram, it can be seen that geometry and algebra are the topics most commonly used in the application of PBL, with 7 Scopus-indexed articles each. There are also topics that are not specifically mentioned, with 5 Scopus-indexed articles. Statistics and arithmetic have the same amount of research, with 3 Scopus-indexed articles each. Trigonometry is the least discussed topic in the application of PBL, with only 1 Scopus-indexed article. The topics chosen for PBL are typically contextual and applicable, allowing students to connect theory with practice. Topics that require problem-solving, critical analysis, and conceptual visualization are well-suited for the PBL model, especially when supported by technology or interactive learning tools. Therefore, it can be concluded that geometry and algebra are frequently studied in the application of PBL because these subjects allow students to connect theory with practice and develop problem-solving skills.

CONCLUSION

Based on the results of the Systematic Literature Review (SLR), this study concludes that the implementation of the Problem-Based Learning (PBL) model in mathematics education has a significant positive impact on students' abilities. This study found that PBL effectively enhances problem-solving skills, critical thinking, and mathematical concept understanding. Higher-order thinking skills, such as creative thinking and mathematical reasoning, are also strengthened through the application of PBL. Although most studies do not specify the learning media used, technology-based media such as GeoGebra have proven to be effective in helping to visualize abstract concepts into more concrete forms, especially in geometry and algebra. Geometry and algebra are often chosen in PBL implementation due to their contextual and practical nature. In terms of educational levels, PBL is widely applied in junior and senior high school, while research at the elementary school and higher education levels is still limited.

Further research is recommended to explore the application of PBL at various educational levels, particularly in elementary schools and higher education. The use of technology-based media such as GeoGebra should be enhanced to support mathematics learning, especially for topics that require concept visualization. Additionally, it is suggested to develop PBL research on topics that are less frequently explored, such as trigonometry and statistics, to provide a more comprehensive understanding.

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