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Trends in Students' Mathematical Problem-Solving Skills: A Systematic Review and Bibliometric Analysis of GeoGebra-Assisted Problem-Based Learning Research (2021–2025)

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Abstract : *Education plays a crucial role in developing high-quality human resources, and mathematics serves as a strategic discipline for strengthening logical, critical, and analytical thinking skills. One of the key competencies emphasized by the NCTM is mathematical problem-solving, which remains relatively low according to the 2022 PISA results. To address this issue, the GeoGebra-assisted Problem-Based Learning (PBL) model is applied because it fosters interactive and meaningful learning experiences. This study aims to analyze research trends and the implementation of mathematical problem-solving skills through the GeoGebra-assisted PBL model. This study employed a Systematic Literature Review (SLR) combined with bibliometric analysis using VOSviewer. A total of 200 articles were initially identified from the Google Scholar database through the Publish or Perish application (2021–2025); after applying inclusion and exclusion criteria and quality assessment procedures, 9 articles were selected for final synthesis and bibliometric mapping of keyword co-occurrence, network, and overlay visualizations. The analysis shows that the implementation of the GeoGebra-assisted PBL model consistently enhances students' mathematical problem-solving skills. PBL cultivates critical thinking skills, while GeoGebra supports concrete visualization of mathematical concepts. The integration of both has proven effective and innovative in improving mathematics learning outcomes in the digital era.*
Keywords: *mathematical problem-solving skills; problem-based learning; geogebra.*

Abstrak : Pendidikan berperan penting dalam membentuk sumber daya manusia yang berkualitas, dan matematika menjadi bidang strategis dalam melatih kemampuan berpikir logis, kritis, serta analitis. Salah satu kompetensi utama menurut NCTM adalah kemampuan pemecahan masalah matematis, yang saat ini masih tergolong rendah berdasarkan hasil survei PISA 2022. Untuk mengatasinya, model PBL berbantuan GeoGebra digunakan karena mampu menciptakan pembelajaran yang interaktif dan bermakna. Penelitian ini bertujuan untuk menganalisis tren penelitian dan implementasi kemampuan pemecahan masalah matematis melalui model PBL berbantuan GeoGebra. Penelitian ini menggunakan metode *Systematic Literature Review* (SLR) dan analisis bibliometrik menggunakan VOSviewer dengan mengacu pada langkah-langkah Klaveren & Wolf (2019). Data diperoleh dari database Google Scholar melalui aplikasi Publish or Perish pada rentang tahun 2021–2025 dan terdapat 9 artikel memenuhi kriteria dan dianalisis lebih lanjut. Hasil analisis menunjukkan bahwa penerapan model PBL berbantuan GeoGebra secara konsisten meningkatkan kemampuan pemecahan masalah matematis siswa. Model PBL menumbuhkan kemampuan berpikir kritis, sementara GeoGebra membantu memvisualisasikan konsep matematika secara konkret. Integrasi keduanya terbukti efektif dan inovatif dalam meningkatkan hasil belajar matematika di era digital.
Kata kunci: kemampuan pemecahan masalah matematis; *problem based learning*; geogebra

INTRODUCTION

Education plays a crucial role in shaping high-quality human resources amid the rapid advancement of science and technology. It not only equips students with essential knowledge but also prepares them to face contemporary and future challenges. Moreover, education contributes to national intellectual development by strengthening students' potential and fostering character formation (Harefa, 2022). Mathematics is considered a strategic discipline because it cultivates logical, analytical, critical, and creative thinking.

In addition to serving as the foundation of modern technological development, mathematics also supports problem-solving and cognitive growth (Somawati, 2018). According to the National Council of Teachers of Mathematics (NCTM), mathematical proficiency consists of five components: problem-solving, reasoning, communication, connections, and representation (Meika et al., 2021). Among these competencies, problem-solving is regarded as a central aspect of mathematics learning (Rahmawati et al., 2021).

Mathematical problem-solving skills are essential for preparing students to navigate global challenges. NCTM defines problem-solving as the application of prior knowledge to new and unfamiliar situations (Muflihatusubriyah et al., 2021). These skills enable students to apply mathematical concepts to real-life contexts (Andayani & Lathifah, 2019) and construct knowledge through problem-oriented activities (Mauleto, 2019). However, conventional lecture-based instruction remains predominant in many classrooms, limiting students' engagement in higher-order thinking processes. This issue is reflected in the PISA 2022 results, in which Indonesia again scored far below the OECD average in mathematics. The OECD (2023) report highlights that Indonesian students continue to struggle with mathematical problem-solving tasks requiring analysis, reasoning, and the application of concepts in unfamiliar contexts. PISA 2022 results show that Indonesian students scored 366 in mathematics, far below the OECD average, with only 18% of students reaching at least Level 2 proficiency, compared to 69% across OECD countries, indicating weak mathematical problem-solving skills.

To address this challenges, an effective instructional model is needed to improve students' mathematical problem-solving skills. Problem-Based Learning (PBL) is considered one of the effective alternatives, as it emphasizes learning through authentic problems that promote active engagement, critical and analytical thinking, and collaborative processes (Wardani & Setyadi, 2020). PBL typically follows several stages, including problem orientation, investigation, discussion, and evaluation (Aini et al., 2019). Previous research has shown that PBL supports the development of higher-order thinking skills and enhances student engagement. Alongside appropriate instructional models, the integration of technology has also become increasingly important to support learning objectives.

Technological advancements have significantly influenced various sectors, including education. GeoGebra is one of the most widely used interactive digital tools in mathematics learning. Its dynamic features assist teachers and students in visualizing mathematical concepts more clearly, making learning more efficient and engaging. Interactive media such as GeoGebra also increase students' interest in mathematics, particularly in topics such as geometry, vectors, and functions. By providing dynamic visual representations, GeoGebra facilitates deeper conceptual understanding and enhances students' mathematical problem-solving skills (Firdayati, 2020). However, existing studies vary widely in terms of educational level, mathematical content, research design, and sample size, making it difficult to identify consistent research patterns.

A substantial body of experimental research, quasi-experimental research, and Classroom Action Research (CAR) has demonstrated the effectiveness of GeoGebra-assisted PBL in improving problem-solving skills. However, to date, no comprehensive Systematic Literature Review (SLR) or bibliometric analysis has specifically mapped research trends related to GeoGebra-assisted PBL in strengthening students' mathematical problem-solving skills. Previous studies exhibit several limitations, including the absence of trend mapping, limited analysis of relationships among keywords and research themes, narrow research contexts, and a lack of critical synthesis regarding the weaknesses of earlier studies. Despite the growing number of studies, the literature remains fragmented and lacks a systematic synthesis through an SLR combined with bibliometric analysis focusing on GeoGebra-assisted PBL and mathematical problem-solving skills.

Addressing this research gap, the present study aims to map the development of GeoGebra-assisted PBL research from 2021-2025 through an SLR and bibliometric approach. This article contributes by identifying publication trends, mapping research focuses, analyzing the strengths and weaknesses of existing studies, and providing a synthesized overview that can serve as a foundation for future research and for enhancing effective mathematics learning practices. Therefore, this study aims to systematically map research trends (RQ1) and thematic clusters (RQ2) of GeoGebra-assisted PBL studies published between 2021 and 2025 through SLR and bibliometric analysis, contributing theoretically to the understanding of research development in this field.

METHOD

This study employed the Systematic Literature Review (SLR) method. SLR is a research design used to systematically synthesize existing evidence through a series of structured procedures, including searching for relevant studies, conducting critical appraisal, and producing a final synthesis to answer the research questions (Yunita & Gunawan, 2025). The SLR procedures used in this study refer to the framework proposed by Klaveren & Wolf (2019), which consists of the following stages: (1) formulating research questions; (2) establishing inclusion and exclusion criteria; (3) developing a search strategy; (4) selecting relevant literature; (5) coding research findings; (6) conducting quality assesment; and (7) synthesizing the results.

The first step involved formulating research questions based on the selected topic. The research questions (RQ) of this study were as follows: (RQ1) What are the research trends from 2021–2025 concerning mathematical problem-solving skills through the GeoGebra-assisted Problem-Based Learning (PBL) model? (RQ2) How are students' mathematical problem-solving skills improved through the GeoGebra-assisted PBL model?

The second step was determining the inclusion and exclusion criteria before conducting the literature search. These criteria are presented in the table below.

Table 1. Inclusion and Exclusion Criteria

	Inclusion Criteria	Exclusion Criteria
Publication Year	Between 2021-2025	Before 2021
Research Theme	Studies focusing on students' mathematical problem-solving skills through the GeoGebra-assisted Problem-Based Learning (PBL) model	Studies not related to mathematical problem-solving skills, PBL, or GeoGebra
Article Type	Original research articles published in journals or conference proceedings	Review articles, systematic reviews, meta-analyses, theses, dissertations, book chapters, and conceptual papers
Learning Model	Explicit implementation of PBL assisted by GeoGebra	Studies using PBL without GeoGebra or GeoGebra without PBL
Literature Source	Journals or proceedings indexed in Sinta or Google Scholar	Sources not indexed in Sinta or Google Scholar
Research Subjects	Students at primary, secondary, or higher education levels	Non-students

The third step involved developing a search strategy by identifying relevant data sources through Google Scholar using the Publish or Perish application. The keywords used in the search process were "Kemampuan Pemecahan Masalah Matematis," "Problem-Based Learning," and "GeoGebra" for the publication period 2021–2025. The next step was literature selection, in which titles and abstracts were screened to determine their relevance to the study. Only studies meeting the inclusion criteria were retained. A total of 200 articles were initially identified. After applying the inclusion and exclusion criteria through title and abstract screening, 23 articles were considered relevant and proceeded to the next evaluation stage.

The next stage was coding the research findings. Each selected study was assigned a code to facilitate data analysis. High-quality studies were identified based on national indexing status and relevance to the research topic. To refine the list of selected studies, titles and abstracts were reviewed first, followed by full-text examination to complete the screening process. The collected data were then evaluated using the following Quality Assessment (QA) criteria:

(QA1) Was the article published between 2021 and 2025?

(QA2) Does the study explicitly examine students' mathematical problem-solving skills through the GeoGebra-assisted PBL model?

(QA3) Is the article an original empirical research study (not a review, thesis, or conceptual paper)?

(QA4) Does the study explicitly implement the Problem-Based Learning (PBL) model assisted by GeoGebra as the main learning intervention?

(QA5) Is the article published in a journal or proceeding indexed in Sinta or Google Scholar?

(QA6) Are the research subjects students?

Each criterion was scored using a binary system, where a score of 1 indicated that the criterion was met and a score of 0 indicated that it was not met, resulting in a

maximum possible score of 6. The final step was synthesizing the findings derived from the selected literature to answer the research questions.

RESULT AND DISCUSSION

Based on the literature search, 200 articles were initially identified using Harzing's Publish or Perish application from the Google Scholar database. These articles were then screened using the predetermined inclusion and exclusion criteria, resulting in 23 studies relevant to the research topic. The selected articles were further evaluated using Quality Assessment (QA) criteria. A total of 9 studies passed the QA stage, consisting of 6 nationally indexed Sinta articles and 3 nationally indexed conference proceedings listed in Google Scholar. These nine studies were reviewed to address the research questions (RQ) formulated in this study. The research findings incorporated into this literature review are presented in Table 2.

Table 2. Research Findings from Selected Literature

Literature Code	Author(s), Year	Journal/Proceedings	Indexing	Research Findings
A01	(Furqoni & Syahlan, 2025)	JURNAL ILMU PENDIDIKAN, 6(1), 82-89.	Sinta 5	This study employed a Classroom Action Research (CAR) method conducted in two cycles by implementing the Problem-Based Learning (PBL) model assisted by GeoGebra on three-dimensional geometry material. The results showed an improvement in students' mathematical problem-solving skills, with the average score increasing from 52.95 (pre-cycle) to 66.38 (cycle I) and 80.48 (cycle II). Learning mastery also rose from 28.57% to 85.71%.
A02	(Nisa et al., 2025)	JUMLAHKU: Jurnal Matematika Ilmiah Universitas Muhammadiyah Kuningan, 11(1), 33-49.	Sinta 4	This study applied the Arikunto model of Classroom Action Research (CAR) conducted in two cycles. In cycle I, learning was carried out using the Problem-Based Learning (PBL) model without media assistance, while in cycle II, PBL was implemented with the support of the GeoGebra application. Data were collected through observation sheets and problem-solving tests based on Polya's four indicators. The findings show a significant improvement in students' mathematical problem-solving skills. The

Literature Code	Author(s), Year	Journal/Proceedings	Indexing	Research Findings
				average student score increased from 22.16 in cycle I to 72.25 in cycle II. All indicators improved, with the most notable increase in the skills to understand problems, rising from 0% to 84.64%.
A03	(Aulya et al., 2024)	FARABI: Jurnal Matematika dan Pendidikan Matematika, 7(2), 240-247.	Sinta 5	This study employed a quasi-experimental method using a nonequivalent post-test control group design. The experimental class was taught using the Problem-Based Learning (PBL) model assisted by GeoGebra, while the control class received conventional instruction. The results show a significant increase in students' mathematical problem-solving skills after the implementation of PBL assisted by GeoGebra. The experimental class obtained a higher average post-test score of 88.80 compared to the control class with 77.74. The Wilcoxon and Mann–Whitney tests yielded an Asymp. Sig value of 0.000 < 0.05, indicating that the hypothesis was accepted.
A04	(Rahmawati et al., 2024)	VARIABLE RESEARCH JOURNAL, 1(01), 224-232.	Google Scholar (Non-Sinta Journal)	This study employed a quasi-experimental method with a nonequivalent post-test control group design. The experimental class was taught using the Problem-Based Learning (PBL) model assisted by GeoGebra, while the control class received conventional instruction. The findings revealed that the experimental class achieved a higher average post-test score of 86.32 compared to 67.73 in the control class, with a t-test significance value of 0.000 < 0.05, indicating a significant difference between the two groups. In addition, the learning independence of students in the experimental class reached 87%, categorized as very strong.
A05	(Sahela &	Jurnal Riset Rumpun	Sinta 5	This study used a Classroom

Literature Code	Author(s), Year	Journal/Proceedings	Indexing	Research Findings
	Frisnoiry, 2023)	Ilmu Pendidikan, 2(2), 162-173.		Action Research (CAR) method with the Kemmis and McTaggart model, conducted over two cycles. The results indicate a significant improvement in students' problem-solving skills after the implementation of the PBL model assisted by GeoGebra. The average student score increased from 42.19% in the initial test to 57.81% in cycle I and 88.50% in cycle II.
A06	(Suratno & Waliyanti, 2023)	International Journal of Research in Mathematics Education, 1(1), 63-75.	Google Scholar (Non-Sinta Journal)	This study employed a quasi-experimental method using a nonequivalent control group design. The experimental class was taught using the Problem-Based Learning (PBL) model assisted by the GeoGebra application, while the control class was taught using a conventional learning model. The research instruments included a mathematical problem-solving skills test, student activity observation sheets, and student response questionnaires. The results showed that the experimental class achieved a higher average post-test score of 80.43 compared to 67.26 in the control class. The t-test results (Sig. 0.000 < 0.05) indicated a significant difference between the two groups. In addition, student learning activities and responses toward the learning process were categorized as very good.
A07	(Wulandari et al., 2023)	Jurnal Amal Pendidikan, 4(3), 240-250.	Sinta 4	This study used a quasi-experimental method with a posttest-only control group design. The experimental class was taught using the Problem-Based Learning (PBL) model assisted by GeoGebra, while the control class received PBL instruction without GeoGebra. The findings showed that the experimental class achieved a higher average mathematical problem-solving score of 75.35 compared to 64.14 in

Literature Code	Author(s), Year	Journal/Proceedings	Indexing	Research Findings
				the control class. The t-test results (t-count = 2.591; Sig. = 0.012 < 0.05) indicated a significant difference between the two groups. Teacher and student activity also increased in each meeting, reaching good to very good categories.
A08	(Silalahi & Panjaitan, 2022)	*Journal Of Comprehensive Science, 1(4), 919-931.*	Google Scholar (Non-Sinta Journal)	This study employed a Classroom Action Research (CAR) method carried out in two cycles, each consisting of two meetings. The findings indicate an improvement in students' mathematical problem-solving skills. The class average increased from 45.80% (pre-cycle) to 68.81% (cycle I) and 80.86% (cycle II). The percentage of learning mastery also rose from 12.91% to 87.09%. In addition, the teacher's skills to manage learning increased from a score of 2.7 to 3.06, categorized as good.
A09	(Hidayatsyah, 2021)	Jurnal Cendekia, 5(1), 458-470.	Sinta 4	This study employed a quasi-experimental method involving two classes: an experimental class taught using the Problem-Based Learning (PBL) model assisted by GeoGebra, and a control class taught through direct instruction supported by GeoGebra. Data were collected using a mathematical problem-solving test. The findings show that students' problem-solving skills in the PBL class assisted by GeoGebra were higher than those of students taught through direct instruction with GeoGebra. This result is supported by the statistical value of $F_h$itung = 52.19, which is greater than $F_t$abel = 3.99. The regression equation for the experimental class was also higher than that of the control class.

Six articles were published in Sinta-indexed journals, while three articles were published in nationally indexed in Google Scholar. Based on Table 2, the selected studies demonstrate methodological diversity in terms of research design, educational level, and mathematical content, while consistently reporting positive effects of the GeoGebra-assisted PBL model on students' mathematical problem-solving skills. Instead of reiterating individual findings, the discussion focuses on cross-study patterns, variations, and methodological considerations that emerge from the synthesis of the nine studies. The following discussion is presented to address the research questions (RQ).

(RQ1) What are the research trends from 2021–2025 regarding mathematical problem-solving skills through the Problem-Based Learning (PBL) model assisted by GeoGebra?

The reviewed studies involve students across different educational levels, including junior secondary schools (SMP/MTs) and senior secondary schools. Most studies were conducted at the junior secondary level, indicating that GeoGebra-assisted PBL is predominantly implemented during early stages of formal mathematical reasoning development. This concentration suggests a research gap in applying the model at the primary or higher education levels, where cognitive demands and abstraction levels differ significantly.

In terms of mathematical content, the studies cover diverse topics such as three-dimensional geometry, equations of circles, and solid figures. Geometry-related topics dominate the selected studies, likely because GeoGebra provides strong visual support for spatial reasoning. However, this dominance also limits the generalizskills of findings to other mathematical domains such as algebra, calculus, or statistics, which remain underexplored in the context of GeoGebra-assisted PBL.

The sample sizes across studies vary considerably, ranging from single-class CAR settings to multi-class quasi-experimental designs. Most studies were conducted in Indonesian school contexts, reflecting a geographically concentrated research landscape. While this strengthens contextual relevance, it also suggests that further studies across diverse regions and educational systems are necessary to enhance external validity.

The research trends on mathematical problem-solving skills using the GeoGebra-assisted PBL model during the last five years (2021–2025) were examined using a bibliometric approach supported by VOSviewer software. This approach mapped the development of research themes, the relationships among topics, and the distribution of publications relating to the integration of PBL and GeoGebra in improving students' mathematical problem-solving skills.

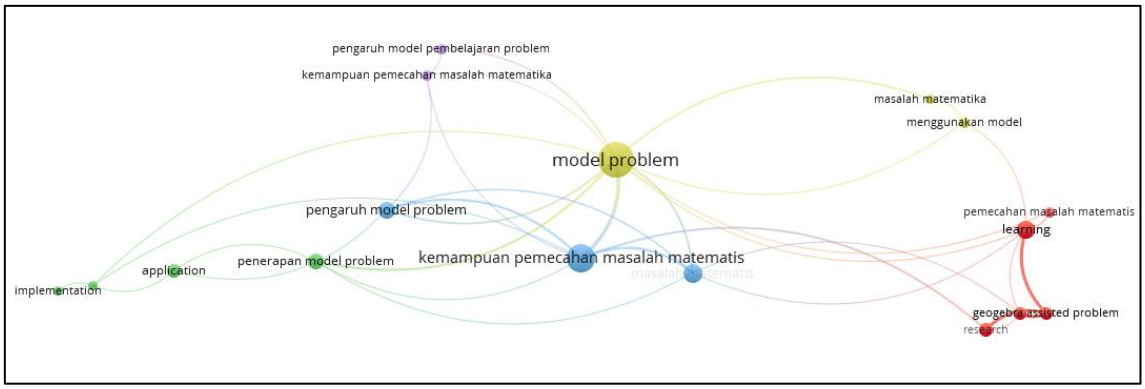

Figure 1. *Network Visualization*

The bibliometric analysis generated a network visualization that illustrated the relationships among keywords appearing in studies related to mathematical problem-solving skills through the GeoGebra-assisted PBL model. The visualization revealed five major clusters represented by different colors. Each color indicates a thematic grouping of related research topics. The size of each node reflects the frequency of a keyword's occurrence, where larger nodes indicate keywords that appear more frequently and play a more central role in the research domain.

The keyword "model problem" appeared as the largest node, indicating its central significance in studies exploring PBL and mathematical problem-solving skills. Lines connecting the nodes represent co-occurrence relationships between keywords; the thicker the line, the stronger the relationship. Strong links were observed between "model problem," "mathematical problem-solving skills," and "GeoGebra-assisted problem learning," suggesting that most studies focused on the implementation of GeoGebra-assisted PBL as a strategy to enhance students' problem-solving skills. Furthermore, the color differences indicate the grouping of research themes, namely the yellow cluster focuses on the application of problem-based learning models in the context of mathematics, the blue cluster highlights mathematical problem-solving skills and their indicators, the red cluster highlights the integration of GeoGebra in PBL, the green cluster emphasizes the application and implementation of learning models in educational practice, and the purple cluster discusses the influence of problem models on learning outcomes.

Overall, the findings suggest that research on GeoGebra-assisted PBL is strongly linked to mathematical problem-solving themes and has emerged as a rapidly developing research trend over the past five years.

Based on the VOSviewer keyword co-occurrence analysis, a total of 14 keywords met the minimum occurrence threshold and were included in the network. The most frequently connected keywords include "problem-solving skills," "Problem-Based Learning," "GeoGebra," and "mathematics learning," indicating that these concepts form the core focus of research on GeoGebra-assisted PBL.

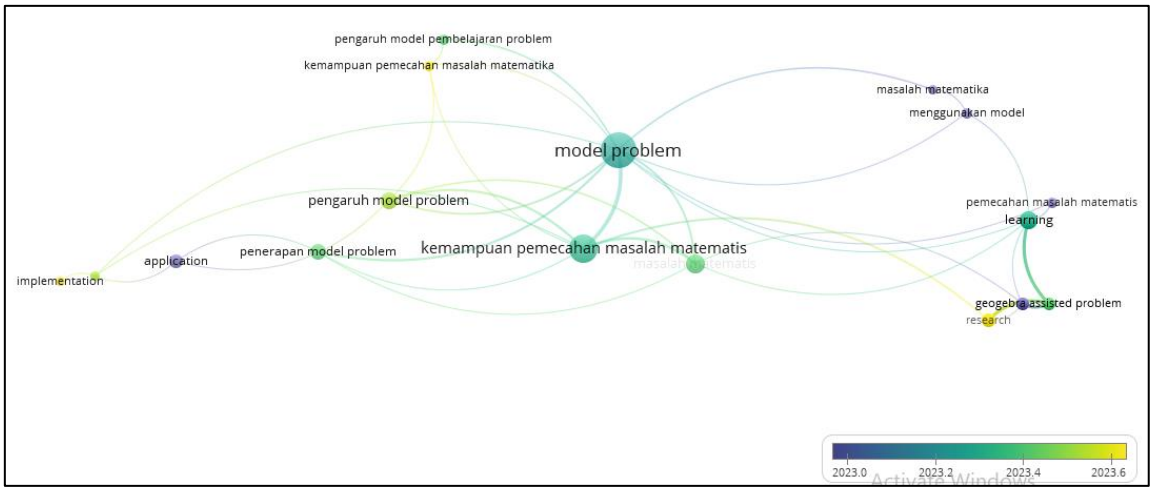

Figure 2. *Overlay Visualization*

Based on Figure 2, the bibliometric analysis generated through VOSviewer illustrates the research trends on mathematical problem-solving skills through the GeoGebra-assisted PBL model during 2021–2025. The color variations in the visualization indicate differences in publication years, where darker tones represent earlier studies and brighter tones reflect more recent publications. This visualization not only maps the relationships among key topics but also highlights the temporal development of research within this area.

The visualization shows that the topics "model problem" and "mathematical problem-solving skills" occupy central positions and maintain strong connections with other keywords such as "geogebra-assisted problem learning," "learning," and "research," as indicated by the thicker connecting lines. This pattern suggests that recent studies consistently focus on strengthening students' mathematical problem-solving skills through the integration of problem-based learning with GeoGebra. The emergence of bright-colored keywords such as "application," "implementation," and "research" indicates growing scholarly interest in the practical application of GeoGebra-assisted PBL in contemporary mathematics education.

Overall, the visualization demonstrates a positive progression in research trends related to mathematical problem-solving skills, PBL, and GeoGebra over the years. The shift from darker to brighter colors signifies increasing attention toward technology integration in mathematics learning, particularly in enhancing students' problem-solving skills through interactive and innovative instructional approaches.

The cluster visualization in Figure 2 reveals 5 thematic clusters. One cluster is dominated by keywords related to students' problem-solving skills and learning outcomes, another cluster centers on the integration of Problem-Based Learning and GeoGebra, while the remaining cluster highlights themes associated with student engagement and classroom implementation. The term "problem model" appearing in the visualization refers to the Problem-Based Learning model, as several authors use this keyword interchangeably to describe problem-oriented instructional approaches in mathematics education.

(RQ2) How are students' mathematical problem-solving skills enhanced through the PBL model assisted by GeoGebra?

Methodological Design Considerations

From a methodological perspective, the reviewed studies predominantly employ Classroom Action Research (CAR) and quasi-experimental designs. CAR-based studies are effective in documenting iterative improvements in classroom practice and providing contextual insights into instructional implementation. However, their lack of control groups and limited sample sizes restrict causal inference and generalizskills.

Quasi-experimental studies offer stronger comparative evidence by contrasting experimental and control groups, yet most studies do not implement random assignment, which may introduce selection bias. Additionally, variations in instructional duration, assessment instruments, and implementation fidelity across studies pose challenges for direct comparison of effect magnitude.

Despite these limitations, the consistency of positive findings across different designs strengthens the overall conclusion that the GeoGebra-assisted PBL model contributes meaningfully to the development of students' mathematical problem-solving skills. Nevertheless, future research should prioritize randomized or mixed-method designs to enhance methodological rigor and explanatory depth.

Based on the synthesis of the nine selected research articles presented in Table 2, it can be concluded that the implementation of the GeoGebra-assisted PBL model consistently yields positive and significant effects on improving students' mathematical problem-solving skills across various educational levels. In general, these studies employed Classroom Action Research (CAR) and quasi-experimental methods using several designs, such as nonequivalent control group design and posttest-only design. Despite variations in research design and instructional context, all findings indicate notable improvements in mathematical problem-solving skills, reflected in higher average scores, increased mastery learning, and strengthened critical and analytical thinking in solving mathematical tasks.

Studies utilizing CAR demonstrate that the application of GeoGebra-assisted PBL gradually enhances students' learning outcomes across each cycle of instruction (Furqoni & Syahlan, 2025; Nisa et al., 2025; Sahela & Frisnoiry, 2023; Silalahi & Panjaitan, 2022). The findings reported by Furqoni & Syahlan (2025) show an increase in students' average scores from 52.95 in the pre-cycle to 80.48 in cycle II. Similarly, Nisa et al., 2025 recorded an improvement from 22.16 to 72.25, with a significant rise in the indicator of understanding the problem, reaching 84.64%. These results indicate that the use of GeoGebra enables students to visualize abstract mathematical concepts more concretely, helping them better understand problem contexts and determine appropriate solution strategies.

Studies employing quasi-experimental methods further demonstrate that the GeoGebra-assisted PBL model is more effective than conventional instruction (Aulya et al., 2024; Rahmawati et al., 2024; Suratno & Waliyanti, 2023; Wulandari et al., 2023;

Hidayatsyah, 2021). The average mathematical problem-solving scores in the experimental classes were consistently and significantly higher than those in the control classes. Aulya et al. (2024) reported a posttest average of 88.80 in the experimental class compared with 77.74 in the control class, supported by an Asymp. Sig. value of 0.000 < 0.05. Rahmawati et al. (2024) also noted a mean score of 86.32 in the experimental group and 67.73 in the control group, with a t-test significance value of 0.000 < 0.05. These results strengthen the evidence that combining a problem-based approach with GeoGebra's visual support helps students connect mathematical concepts with real-life situations more effectively and meaningfully.

Several studies also highlight that implementing the GeoGebra-assisted PBL model positively influences students' learning independence and engagement during instruction (Rahmawati et al., 2024; Suratno & Waliyanti, 2023; Wulandari et al., 2023). Rahmawati et al. (2024) reported that students' learning independence reached 87% in the "very strong" category, while Wulandari et al. (2023) documented improvements in teacher and student activity, both falling within the "good" to "very good" categories. These findings suggest that GeoGebra not only serves as a visual learning tool but also functions as an interactive medium that encourages reflective thinking, active participation, and independent knowledge construction..

The main contribution that distinguishes this article from previous studies lies in its methodological approach and analytical depth. Instead of examining the effectiveness of GeoGebra-assisted PBL within a single experimental or classroom action research setting, this study offers a comprehensive synthesis through a Systematic Literature Review (SLR) combined with bibliometric analysis using VOSviewer. This approach enables the mapping of research trends, topic relationships, and developments from 2021 to 2025 in a systematic and visual manner, an aspect not commonly explored in similar studies in mathematics education.

Overall, the review concludes that the GeoGebra-assisted PBL model significantly enhances students' mathematical problem-solving skills. GeoGebra plays a crucial role in helping students visualize abstract mathematical ideas, while PBL provides a problem-centered learning framework that cultivates critical, creative, and analytical thinking. The integration of both creates an interactive, contextual, and meaningful learning environment, allowing students to understand, plan, execute, and evaluate mathematical problem-solving processes more effectively. Therefore, the adoption of the GeoGebra-assisted PBL model is strongly recommended as an innovative instructional strategy to improve the quality of mathematics learning, particularly in strengthening students' problem-solving skills in the digital era.

The synthesis of findings highlights that the effectiveness of the GeoGebra-assisted PBL model is not limited to a specific research design or educational context, but rather emerges as a robust instructional approach across varied settings. The added value of this review lies in its critical comparison of methodological approaches and contextual variations, rather than a mere aggregation of study outcomes.

CONCLUSION AND SUGGESTION

The analysis indicates that research trends on mathematical problem-solving skills through the GeoGebra-assisted Problem-Based Learning (PBL) model during the 2021–2025 period have shown consistent growth, as evidenced by strong keyword interconnections in the bibliometric analysis and increasing scholarly attention to technology integration in mathematics education. Across the nine reviewed studies, which employed both Classroom Action Research (CAR) and quasi-experimental designs, findings consistently demonstrated significant improvements in students' learning outcomes, mastery levels, and critical and analytical thinking skills through the implementation of GeoGebra-assisted PBL. This model effectively supports students in understanding abstract mathematical concepts through interactive visualization while fostering more contextual, collaborative, and meaningful learning experiences. Based on these findings, the recommendation is that future research expand the range of mathematical topics investigated and adopt more diverse methodological approaches, while educators are encouraged to integrate GeoGebra-assisted PBL as an innovative instructional strategy to strengthen students' mathematical problem-solving skills in the digital era.

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