Bibliometric Analysis of Research on Mathematical Problem-Solving Ability Using VOSviewer and Google Scholar (2010–2025)

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Abstract

Mathematical problem-solving skills are a key competency of the 21st century and are an important focus in mathematics education. This study aims to map the development of research on mathematical problem-solving skills in the period 2010–2025 using a bibliometric approach based on Google Scholar. Data were collected through Harzing's Publish or Perish (PoP) using keywords related to *mathematical problem solving/problem solving ability* and exported in .CSV and .RIS formats. The metadata were then cleaned and normalized using Microsoft Excel, then analyzed using VOSviewer to produce *network*, *overlay*, and *density visualizations*. The results of the analysis show an increasing publication trend since 2015, peaking in 2021–2022, then declining in 2023–2025, which is thought to be influenced by the limited coverage of current data. *Co-occurrence* mapping formed several main clusters: (1) learning models and problem-solving development, (2) skills/abilities as learning outcomes, (3) educational context and learning influences, (4) problem-solving processes and strategies as well as affective factors (*self-efficacy*), and (5) assessment and ability indicators. The *overlay* findings indicate that current topics for 2021–2025 are shifting toward affective factors and self-regulation, such as *self-efficacy*, *mathematical resilience*, *independence*, and the study of strategies and processes. Overall, research is still dominated by cognitive and pedagogical factors, while integrative exploration of affective aspects and the development of comprehensive assessment instruments remain limited. This mapping provides a basis for formulating directions for further research and strengthening the design of learning and assessment of mathematical problem-solving skills.

Keywords: bibliometrics; mathematical problem-solving skills; VOSviewer; Google Scholar.

Introduction

Mathematical problem-solving skills are one of the key competencies that students must possess in the 21st century. According to Polya (1973), the problem-solving process involves four important stages, namely understanding the problem, planning the solution, implementing the plan, and checking the results. Research by Sumarmo (2013) confirms that this ability is an indicator of *higher-order thinking skills*, which are the focus of modern curricula.

However, a number of studies show that Indonesian students' mathematical problem-solving abilities are still low (Khaesarani & Ananda, 2022; Andayani, Fuad, & Rahaju, 2023). This condition has prompted many researchers to examine various strategies, learning models, and affective factors that influence the improvement of mathematical problem-solving skills.

Therefore, bibliometric analysis is needed to map the development of research on mathematical problem-solving skills in a systematic and measurable manner.

Several previous studies have applied bibliometric analysis in mathematics education with different focuses. Santosa et al. (2020) mapped trends in mathematical literacy, Pratiwi & Hidayat (2021) examined the relationship between problem solving and creative thinking, while Kusnadi et al. (2022) and Fitria & Ramadhan (2023) highlighted the direction of problem-based learning research. Studies by Nurhasanah et al. (2021) and Mulyono & Farida (2023) showed the development of Scopus and Dimensions indexed research, while Zhang et al. (2024) reviewed global collaboration among researchers. Lin et al. (2024) and Dwiastuti et al. (2025) expand on the theme of problem-solving skills with topic network analysis. However, most studies still focus on international databases such as Scopus, so Google Scholar-based research is important to describe national research developments more comprehensively. This study does not restrict its scope exclusively to Indonesia; however, the use of Google Scholar as the data source allows for stronger representation of Indonesian and regional publications compared to international databases. Therefore, the findings primarily reflect trends in both national and internationally accessible research indexed by Google Scholar, with particular relevance to the Indonesian mathematics education research context.

Although several bibliometric studies have examined mathematical problem-solving research, most prior studies predominantly rely on international databases such as Scopus or Dimensions and emphasize global collaboration patterns. The novelty of the present study lies in its exclusive use of Google Scholar as the primary data source, which enables a more comprehensive representation of both national and regional research outputs that are often underrepresented in international databases. Furthermore, this study extends previous bibliometric analyses by integrating trend analysis, co-occurrence clustering, and thematic evolution with a specific emphasis on the shift toward affective factors such as self-efficacy, mathematical resilience, and self-regulation. By mapping research developments over a fifteen-year period (2010–2025), this study provides updated and context-sensitive insights that complement and enrich existing bibliometric literature in mathematics education. Based on the urgency of research mapping and the absence of a comprehensive review of the Google Scholar database, this study was formulated to answer the following questions.

Research Questions (RQ)

RQ1. How have research publications on mathematical problem-solving abilities developed and trended between 2015 and 2025 based on the Google Scholar database?

RQ2. What themes and research clusters have emerged in the study of mathematical problem-solving abilities based on *co-occurrence* analysis of terms?
RQ3. What research topics show *emerging* trends in the last five years (2021–2025)?
RQ4. What factors (cognitive, pedagogical, and affective) are predominantly studied in research on mathematical problem-solving abilities?
RQ5. What research gaps can be identified for further research development based on the results of bibliometric mapping?

Method

The method used in this study is bibliometric analysis, which is a quantitative approach that systematically assesses, measures, and maps scientific literature to obtain an overview of the development and structure of a field of research (Donthu et al., 2021). This approach includes two main components: *performance analysis*, which examines productivity (e.g., number of publications, number of authors, citations), and *science mapping*, which maps the relationships between research elements such as keywords, authors, institutions, or journals. Donthu et al. (2021) state that bibliometric methods provide "proven metrics" for assessing research contributions and thematic trends globally.

The data in this study were collected using Harzing's Publish or Perish (PoP) software with data sources from Google Scholar, because this database has extensive national and international literature coverage and is openly accessible (Hakim, 2020). The search was conducted using the keywords *("mathematical problem solving" OR "problem solving ability") AND ("learning model" OR "problem solving stage")*, with a publication year range of 2010–2025. Relevant articles were then exported in .CSV and .RIS formats, processed with Microsoft Excel for descriptive analysis, and analyzed visually using the latest version of VOSviewer.

The bibliometric analysis in this study was conducted systematically through several interrelated steps. The first step was data collection using Harzing's Publish or Perish (PoP) software with data sourced from Google Scholar, as this database has extensive national and international publication coverage and is easily accessible (Hakim, 2020). The article search was conducted using the keywords *("mathematical problem solving" OR "*problem-solving skills*")* with a publication time limit between 2010 and 2025. The search results were then exported in .CSV and .RIS formats for further processing.

The second stage is *data cleaning* and normalization, which aims to ensure the accuracy of the metadata to be analyzed. This process is carried out using Microsoft Excel by removing duplicate data, correcting inconsistencies in the writing of author names, titles, and publication years, and filtering out irrelevant articles. This data cleaning process is important to ensure the validity of the analysis because metadata errors can cause distortion in the results of bibliometric network visualization (Yani & Soebagyo, 2024).

The third stage is descriptive analysis and scientific network mapping (*science mapping*) using VOSviewer software (van Eck & Waltman, 2010). At this stage, *co-occurrence* analysis of keywords is carried out to see the relationship between research concepts and identify dominant themes. VOSviewer produces three main types of visualizations, namely *Network Visualization* to display clusters and co-occurrence relationships between keywords, *Overlay Visualization* to show the development of themes based on the year of publication, and *Density Visualization* to show the density or intensity of the most frequently studied research topics (Nurhasanah et al., 2025). Through this mapping, researchers can observe the connections between concepts, the frequency distribution of keywords, and the thematic position within a broader research network.

The next step is interpreting the visualization results, where researchers examine clusters and relationship patterns that appear on the bibliometric map to identify main themes, research trends, and *research gaps* that can serve as a basis for further research (Purnama, 2024; Donthu et al., 2021). The results of this interpretation form the basis for concluding the direction of research development in mathematical problem-solving skills in both national and international contexts. By following these steps, this study not only describes the quantity of publications but also comprehensively maps the conceptual structure and thematic evolution of the field of study.

Results and Discussion

RQ1. How has research publication on mathematical problem-solving skills developed between 2010 and 2025?

Figure 1. Trends in Research Publications on Mathematical Problem-Solving Skills (2010-2025)

Based on the diagram above, the results of data searches from Google Scholar using *Publish or Perish* show that the number of research publications on the topic of mathematical problem-solving skills has increased significantly since the middle of the observation period. In the early phase (2011–2014), the number of publications was still relatively low and tended to fluctuate. Starting in 2015, publications showed a gradual increase, then experienced rapid growth in the 2017–2019 period. The peak number of publications was recorded in 2021 and 2022, before experiencing a decline in 2023–2025. It should be noted that the low number of publications in 2024 and 2025 is likely influenced by data limitations, as both years are ongoing at the time of data collection.

The trend of increasing research publications on mathematical problem-solving skills reflects the growing attention of researchers to this competency as a primary goal of mathematics education. Globally, problem solving and mathematical literacy are seen as essential 21st-century skills, as emphasized in international assessment frameworks and education policies (OECD, 2019; NCTM, 2020). This has encouraged the development of research that places problem-solving skills as an important indicator of success in mathematics learning.

In addition, the surge in publications during the 2017–2022 period is also related to the development of studies linking mathematical problem-solving abilities with cognitive and affective factors. Research shows that problem-solving success depends not only on mastery of concepts, but also on thinking strategies, metacognition, and students' self-confidence in facing mathematical problems (Schukajlow et al., 2018; Zhang et al., 2020). This increasingly broad research focus has contributed to the increased intensity of publications in the last decade.

Furthermore, attention to higher-order thinking skills and the application of innovative learning approaches, such as problem-based learning and technology integration, also strengthen the position of mathematical problem-solving skills as a central theme in mathematics education research (Hwang et al., 2021). Recent studies also confirm that problem solving remains at the core of mathematics education discourse, both in theoretical and empirical contexts, and continues to evolve in line with the challenges and needs of future education (Li & Schoenfeld, 2023).

Overall, these findings indicate that mathematical problem-solving ability is a consistently and strategically developing research topic. The results of this publication development analysis provide a strong basis for further analysis of trends in themes, dominant keywords, and future research directions, which will be discussed in the next research question.

RQ2. What themes and research clusters have emerged in the study of mathematical problem-solving skills based on *co-occurrence* analysis of terms?

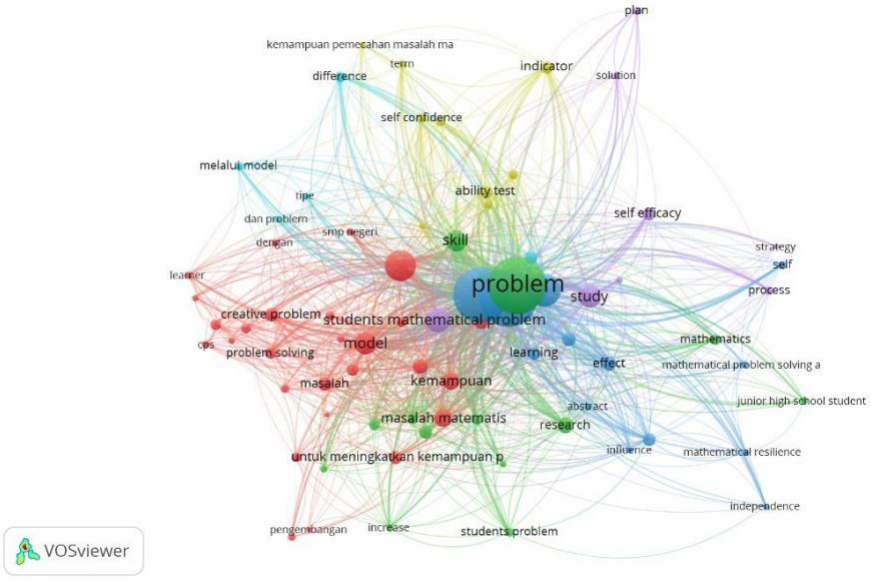

Figure 2. *Network Visualization* Output

Based on *the Network Visualization output* of the *co-occurrence* analysis of terms using VOSviewer, several research clusters were formed that represent the focus of studies on mathematical problem-solving abilities. The network visualization shows that the terms *problem*, *students' mathematical problems*, and *learning* are in a central position, indicating that mathematical problem-solving is at the core of various interconnected studies. The interrelationships between terms show that research on this topic is developing multidimensionally, covering aspects of learning, cognitive processes, affective factors, and assessment.

The first cluster focuses on learning models and problem-solving skills development, characterized by terms such as *model*, *problem solving*, *creative problem*, *CPS*, and *mathematical problems*. Research in this cluster generally examines the effectiveness of specific learning models in improving students' mathematical problem-solving skills. A number of studies show that the application of problem-solving-oriented learning models can encourage active student engagement and improve the quality of mathematical problem-solving strategies (Hidayat & Sariningsih, 2018; Lestari & Yudhanegara, 2019). These findings reinforce the position of problem solving as the main objective and indicator of success in mathematics learning.

The second cluster emphasizes problem-solving abilities and skills as learning outcomes, with the emergence of terms such as *skill*, *ability*, *student problems*, and *increase*. The focus of research in this cluster shows that mathematical problem-solving abilities are treated as competencies that can be developed through planned learning interventions. Recent studies confirm that the improvement of problem-solving abilities is closely related to conceptual understanding and the ability to connect mathematics with real-world contexts (Fitriani et al., 2020; Sari & Wijaya, 2021).

The third cluster represents the context of education and the impact of learning, which is characterized by the terms *learning*, *research*, *effect*, *influence*, and *junior high school student*. Research in this cluster largely examines the influence of learning approaches on problem-solving abilities at certain levels of education. The results of the study show that student characteristics, learning environment, and learning design have a significant influence on students' success in solving mathematical problems (Putri et al., 2019; Rahmawati & Marsigit, 2022).

The fourth cluster focuses on problem-solving processes and affective factors, characterized by the terms *process*, *strategy*, *plan*, *solution*, and *self-efficacy*. This cluster shows that research not only highlights the final results of problem solving, but also the thinking process and self-confidence of students in solving problems. Recent studies reveal that *self-efficacy* and mathematical self-confidence play an important role in determining students' persistence and success in solving non-routine problems (Utami & Wutsqa, 2020; Nurjanah et al., 2023).

The fifth cluster highlights assessments and indicators of problem-solving abilities, with the emergence of terms such as *indicator*, *ability test*, and *self-confidence*. Research in this cluster focuses on developing instruments and indicators to measure mathematical problem-solving abilities in a valid and reliable manner. These studies emphasize the

importance of assessments that measure not only the final answer, but also the process and strategies used by students to solve problems (Arifin & Retnawati, 2017; Pratiwi et al., 2021).

Overall, the cluster analysis results show that research on mathematical problem-solving skills has evolved from studies focusing on learning models to a more comprehensive approach that integrates cognitive processes, affective factors, and assessment. The interconnections between clusters on the VOSviewer map indicate that mathematical problem-solving ability is understood as a complex ability that is influenced by various internal and external factors. These findings provide a strong basis for identifying the direction of future research, particularly on the integration of learning models, affective factors, and the measurement of mathematical problem-solving ability.

RQ3. What research topics show *emerging* trends in the last five years (2021–2025)?

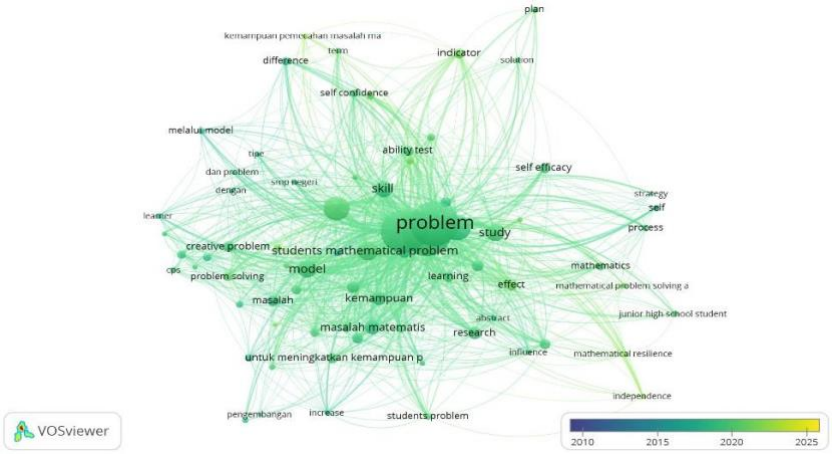

Figure 3. Output Overlay Visualization

Based on the results *of overlay visualization*, a number of terms show new trends in the last five years (2021–2025). Terms such as *self-efficacy*, *strategy*, *process*, *mathematical resilience*, *independence*, and *indicator* appear with higher average publication years, indicating increased researcher attention to these topics. This shift indicates that current research no longer focuses solely on problem-solving outcomes, but also on thought processes, problem-solving strategies, and affective factors that influence students' success in solving mathematical problems.

These findings are in line with international studies that emphasize the importance of self-regulation and self-efficacy in mathematical problem solving (Zhang, Zhou, & Leung, 2020; Li & Schoenfeld, 2023). In the national context, research has also begun to highlight the role *of self-efficacy* and mathematical resilience as important variables in students' problem-solving abilities (Utami & Wutsqa, 2020; Nurjanah, Mulyono, & Suyitno, 2023). Thus, these

topics can be categorized as *emerging topics* that have the potential to become the main direction of further research.

RQ4. Dominant Factors in Research on Mathematical Problem-Solving Ability

The *density visualization* results show that the terms *problem*, *learning*, *model*, and *skill* are in the area with the highest density. This indicates that cognitive and pedagogical factors are the most dominant factors studied in research on mathematical problem-solving abilities. Cognitive factors are reflected through a focus on thinking skills, strategies, and problem-solving processes, while pedagogical factors are evident through studies on learning models and approaches.

The dominance of cognitive and pedagogical factors is in line with various studies showing that learning design and mastery of thinking strategies have a significant influence on students' mathematical problem-solving abilities (Hwang et al., 2021; Fitriani, Widodo, & Hendroanto, 2020). Meanwhile, affective factors such as *self-efficacy*, *self-confidence*, and *mathematical resilience* appear with lower density, indicating that studies on affective factors are still relatively limited despite beginning to develop in recent years (Putri, Zulkardi, & Hartono, 2019).

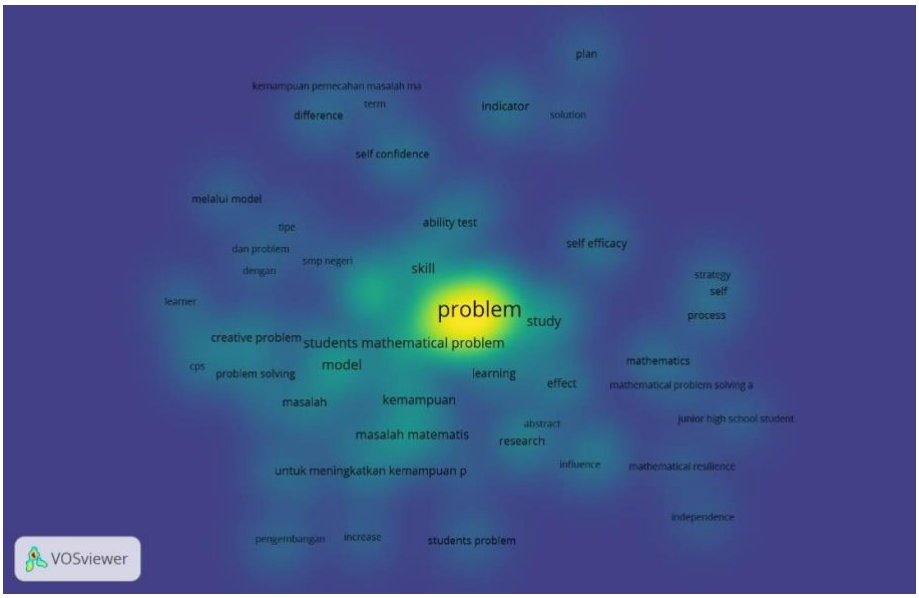

Figure 5. Output Density visualization

RQ5. Research Gaps in the Study of Mathematical Problem-Solving Ability

The synthesis of bibliometric mapping results shows that there are several research gaps that can be developed in future studies. First, although cognitive and pedagogical factors dominate, affective factors such as *self-efficacy* and *mathematical resilience* are still in areas

with low density. This opens up opportunities for further research that examines the role of affective factors more deeply and integratively in mathematical problem solving.

Second, the relationship between problem-solving processes (*process* and *strategy*) and affective factors has not been widely explored. Further research could integrate cognitive and affective aspects simultaneously to obtain a more comprehensive picture of mathematical problem-solving abilities. These findings are in line with recent research recommendations that emphasize the need for a holistic approach in mathematics education (Schukajlow, Kaiser, & Stillman, 2018; Li & Schoenfeld, 2023).

Third, although studies on learning models have been quite intensive, the development of assessment instruments capable of comprehensively measuring mathematical problem-solving abilities is still relatively limited. Therefore, future research can be directed towards the development and validation of assessment instruments that accommodate cognitive, affective, and problem-solving aspects in an integrated manner (Arifin & Retnawati, 2017).

Conclusion and Suggestion

Based on a bibliometric analysis of publications on mathematical problem-solving skills for the period 2015–2025 using Google Scholar and VOSviewer, it can be concluded that research on this topic has shown a significant increase since 2015 and peaked in 2021–2022. Keyword mapping formed the main clusters, which included learning models, abilities as learning outcomes, problem-solving processes and strategies, affective factors, and assessment. Thematic analysis showed a shift in the focus of recent research towards the study of thinking processes and affective factors such as self-efficacy and mathematical resilience. However, research is still dominated by cognitive and pedagogical aspects, so integrative studies linking processes, affect, and assessment are still relatively limited.

This study has several limitations that should be considered when interpreting the findings. First, the bibliometric data were obtained solely from Google Scholar, which, although comprehensive, may contain duplicate records, inconsistent metadata, or non-peer-reviewed sources. Second, the publication data for the most recent years (2024–2025) may be incomplete due to indexing delays, potentially affecting trend interpretation. Third, the analysis was limited to keyword co-occurrence and did not include citation or co-authorship network analysis, which could provide deeper insights into intellectual structure and collaboration patterns. Despite these limitations, the study offers a meaningful overview of research trends and thematic development in mathematical problem-solving research.

Based on these findings, further research should integrate cognitive, pedagogical, and affective aspects more comprehensively in examining mathematical problem-solving abilities. Researchers also need to develop assessment instruments that are capable of measuring processes, strategies, and affective dispositions in an integrated manner. In addition, further studies can be directed towards the development of process-based and self-regulated learning designs, as well as expanding bibliometric studies by combining Google Scholar and international databases to obtain a more comprehensive research mapping.

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