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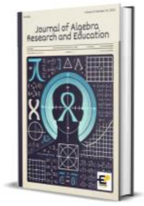

Research Trends on Mathematical Problem-Solving Ability Analysis From 2015 to 2024: Bibliometric Analysis

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Abstract

The purpose of this bibliometric analysis is to identify opportunities and trends in research related to mathematical problem-solving abilities on the topic of functions. This study uses a bibliometric method by collecting data from articles published between 2015 and 2024 through Google Scholar using the Publish or Perish software, with a total of 1,000 journal articles. Bibliometrics is used to provide a structural overview of a particular research era, containing the necessary information to analyze publications in fields relevant to the researcher's focus. The findings of this study show that from 2015 to 2024, there were 994 articles related to mathematical problem-solving abilities on the topic of functions. The highest number of publications occurred in 2020, with a total of 177 publications, while the lowest was in 2024, with only 21 publications, based on analysis using the VOSviewer software. Variables related to mathematical problem-solving abilities on the topic of functions that present opportunities and novelty for future research include critical thinking ability, high school, mathematical problem solving, PBL (problem-based learning), development, grade VIII, analysis, and learning. These variables have not been widely explored by other researchers, indicating the potential for innovation and further development by future researchers.

Keywords: Algebra; Bibliometric analysis; Mathematical Problem-solving; Research trends in mathematical.

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1. Introduction

Education is essential for developing high-quality human resources. It serves as the key to progress and quality development. Education enables individuals to realize their full potential both as individuals and as members of society. This aligns with the opinion of Paus et al. (2023), who state that education is a conscious and planned effort manifested in a learning process by teachers who can create an enjoyable and active learning environment, allowing students to actively develop their potential. According to the 1945 Constitution and Law Number 20 of 2003 on the National Education System, education is a fundamental and planned effort to create a learning environment and learning process in which students actively develop their capabilities. Education is also the influence of the environment on individuals to bring about lasting changes in behaviour, thought, and attitude.

Learning is the process of interaction between students and educators, and learning resources within a learning environment (Hanafi, 2014). It is a process of knowledge transfer involving key components in the educational system: teachers/educators, students, materials, objectives, and tools (Kurniawati, 2021). Learning is essentially a process of creating an environment in such a way that interaction occurs between students, educators, and learning resources, resulting in a learning experience for the students (Asrul et al., 2022). Planned learning must be effective and efficient so that learning objectives can be achieved and well-received by students.

Mathematics is one of the subjects that plays a crucial role in education. According to Lestari (2015), mathematics is considered a driving force for producing a superior generation ready to compete in a changing world. Usman et al. (2022) state that mathematics is a universal science that plays a vital role in the development of modern technology, with applications spanning various scientific fields and advancing human thinking. Therefore, mathematics is essential for students to learn well and acquire mathematical knowledge as early as possible to prepare for life in a continuously evolving world. However, mathematics is still often perceived as a difficult, boring, abstract subject that requires special abilities, which not all students possess. Such perceptions can lead to negative attitudes toward mathematics and a lack of confidence in solving mathematical problems (Imaroh et al., 2021).

One of the objectives of learning mathematics in schools is to enable students to solve problems (Maulana & Santosa, 2024). Mathematical problem-solving ability is a crucial aspect of mathematics learning because it is useful in daily life, both for current issues and as new knowledge for future use (Ngaeni & Saefudin, 2017). Therefore, problem-solving is an important activity in mathematics education, where the problem-solving skills gained in one context can generally be transferred to solve other problems. This is supported by the National Council of Teachers of Mathematics (NCTM), which states that the mathematical competencies students must have include: problem-solving, reasoning, proof, communication, connections, and representation.

Problem-solving ability is a skill or potential within students that enables them to solve problems and apply them in daily life (Gunantara, 2014). According to Suratmi & Purnami (2017), students need to possess problem-solving skills to address challenges related to their learning activities, such as solving mathematical problems. A student's intelligence can be seen through their skills in resolving issues, such as finding solutions and addressing problems in everyday life accurately, carefully, and appropriately, in line with the context and conditions of the problem (Diah Purwandari et al., 2022). Adinda Ramadhani et al. (2021) mention that the relationship between problem-solving ability and learning and daily life demonstrates how important it is for every student to possess this skill.

The application of problem-solving abilities in mathematics learning has become a major focus for educators and researchers, both locally and internationally (Wahyuni et al., 2024). In response to the importance of problem-solving abilities in mathematics education, researchers at both local and international levels have been actively conducting studies to identify trends and patterns in the development of these skills. One method used in research is bibliometric analysis. Bibliometrics is a method used to explore scientific publications through citation analysis, commonly used in library science and other fields (Rohanda & Winoto, 2019). According to Winardi et al. (2022), bibliometrics is the study of writing and its mathematical analysis. From these views, it can be concluded that bibliometric analysis is the study of scientific literature in publications to analyse authorship and references.

Based on the explanation above, the author is interested in conducting a bibliometric analysis to examine research trends and patterns in mathematical problem-solving abilities. Through this research, it is expected that current research trends and emerging keywords can be interpreted, serving as a reference and recommendation for future studies involving problem-solving abilities in the context of mathematics learning.

2. Methods

The bibliometric analysis research method is used to answer research questions by looking at its development and literature (Hakim, 2020). The mapping of mathematical problem-solving ability metadata is taken from reputable and accredited journals obtained from the Google Scholar site as many as 994 journals from 2015 to 2024. The stages in bibliometric analysis are carried out with the first step, namely, collecting articles related to mathematical problem-solving abilities using Publish or Perish (PoP).

Then the data is processed and analyzed at the same time using Microsoft Excel to obtain tables and graphs. Furthermore, for visualization of article data in the form of a network and VOS Viewer is used. An explanation of the stages of bibliometric analysis can be seen in the following description. First, the keyword analysis of mathematical problem-solving abilities on function material is entered in the Pop software with the year settings 2015-2024 and a maximum of 1000 results. The database selected and used to search for related research articles is Google Scholar for reasons of ease of search and access. The results are as shown in Figure 1.

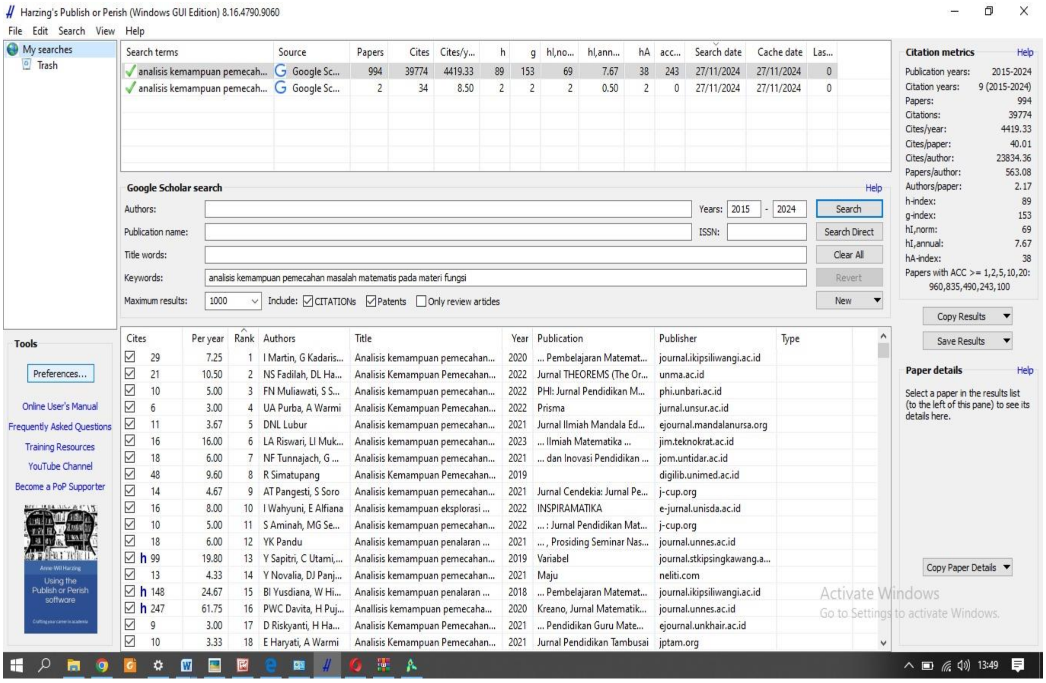

Figure 1. Google Scholar Database Search

Based on Figure 1, the maximum search allowed in Google Scholar is 1000. From Figure 1, information is obtained about citation marks that describe quantitative data which is completely shown in Table 1.

Table 1 - Citation Marks

Results	Explanation
Keywords	Analysis of Mathematical Problem-Solving Ability on Function Material
Year of Publication	2015-2024
Year of Citation	9(2015-2024)
Article	994
Number of Citations	39774
Citations of each year	4419.33
Citation of each article	40.01
Author of each article	2.17
H Index	89
G Index	153
Individual H Index	89
H index of each year	7.67
hA Index	38

From Figure 1, the data is stored in several required formats such as CSV and RIS where CSV is used to process table and graphic data, while RIS is used to be processed in the form of networks and maps using VOS Viewer software.

VOS Viewer software is used to analyze the development map of scientific publications on mathematical problem-solving abilities. The output form of data processing is network visualisation, overlay visualisation, and density visualisation. The network visualisation map is used to see the relationship and cluster of research themes related to keywords. Overlay visualisation is used to identify the year in which the related research theme was conducted. Meanwhile, density visualisation is used to analyse research themes that are saturated and still rarely studied.

3. Results and Discussion

3.1 Results

VOS Viewer software is used to analyse the development map of scientific publications on mathematical problem solving abilities. The output form of data processing is network visualisation, overlay visualisation, and density visualisation. The network visualisation map is used to see the relationships and clusters of research themes related to keywords. Overlay visualisation is used to identify the year in which the related research theme was conducted. Meanwhile, density visualisation is used to analyse research themes that are saturated and still rarely studied.

Table 2 - Number of Publications of Each Year

Year	Number of Publications	Percentage
2015	36	4%
2016	71	7%
2017	98	10%
2018	140	14%
2019	157	16%
2020	177	18%
2021	152	15%
2022	120	12%
2023	22	2%
2024	21	2%
Total	994	100%

Based on table 2 above, in 2015 there were 36 (4) publications, in 2016 there were 71 (7) publications, in 2017 there were 98 (10) publications, in 2018 there were 140 (14) publications, in 2019 there were 157 (16) publications, in 2020 there were 177 (18) publications, in 2021 there were 152 (15) publications, in 2022 there were 120 (12) publications, in 2023 there were 22 (2%) publications and in 2024 there were 21 (2%) publications. This shows that from 2015 to 2020 the number of scientific publications increased by 14%, but from 2020 to 2024 the number of scientific publications regarding the keyword "Analysis of Problem Solving Ability in Function Material" decreased by 16% which can be seen in Figure 2.

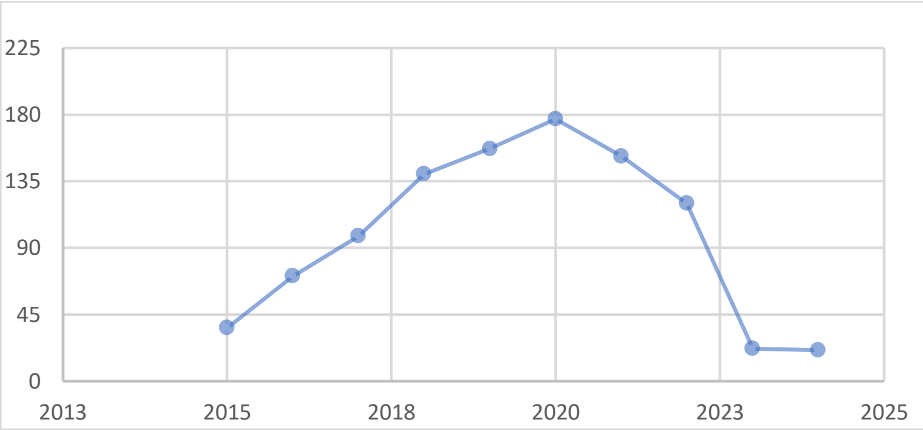

Figure 2. Development of Scientific Publications from 2015-2024

Mapping the development of scientific publications using a binary calculation method with a minimum number of word displays of 10 out of 4604 words, and only 43 meet the upper threshold, while 26 words are selected. In the visualisation, there are nodes (circles) to indicate the author, while edges (networks) indicate the relationship between authors. The distance of the circles associated with the network indicates that the larger the circle, the more variables are studied simultaneously (Aribowo, 2019).

Finally, the density visualisation depicts the concentration of research on certain variables based on colour intensity, representing the extent to which these variables have been studied. Variables like “problem solving” and “ability” show high density, indicating a substantial amount of prior research, whereas others, such as “critical thinking ability,” “PBL,” and “development” are located in blue areas, suggesting opportunities for further exploration and innovation. These findings provide a foundation for future research directions that have the potential to enrich both literature and practice in mathematics education.

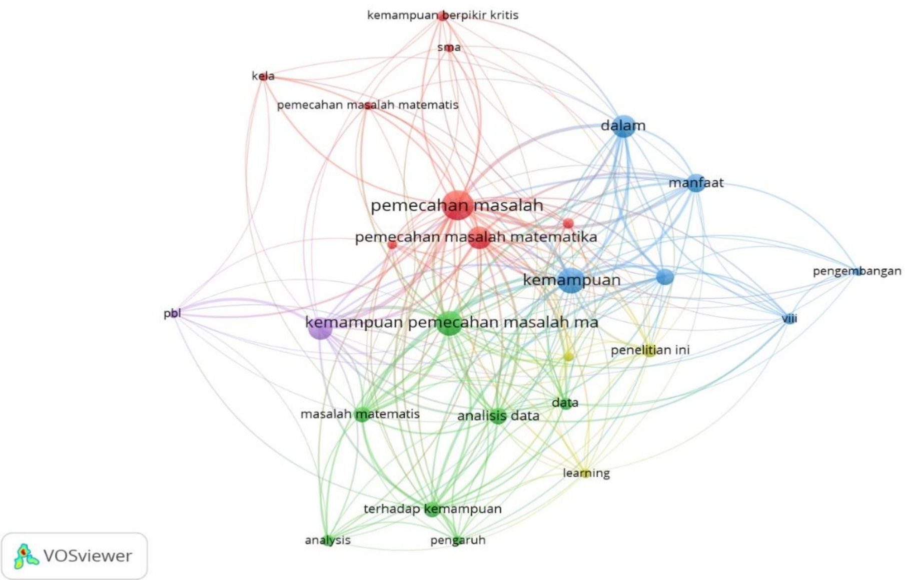

Figure 3. Network Visualisation VOS Viewer

Figure 3 presents the relationship between terms visualised through a connected network (Taufiq et al., 2023). Based on Figure 3, the centre of research related to mathematical problem-solving abilities in functional material is problem-solving, where there are 5 clusters or groups marked with red in group 1, green in group 2, blue in group 3, yellow in group 4, and purple in group 5. The results of network visualisation using VOS Viewer show the relationship between variables/themes consisting of 21 variables, where 6 variables are in cluster 1, 7 variables are in cluster 2, 5 variables are in cluster 3, 2 variables are in cluster 4, and 1 variable is in cluster 5. For example, in cluster 1, the problem-solving variable is related to the variables of mathematical problem-solving, ability, mathematical problem solving, critical thinking skills, problem-solving abilities, benefits, class, and high school. This means that research on problem-solving is closely related to these variables, but some variables are still rarely studied, such as PBL, influence, development and learning.

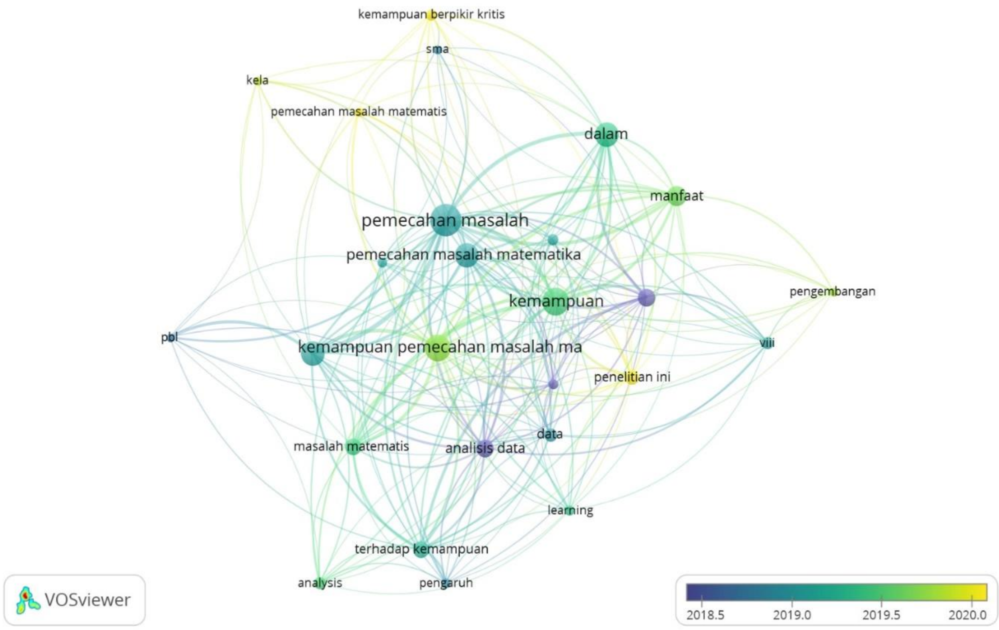

Figure 4. Overlay Visualisation VOS Viewer

Figure 4, according to Taufiq et al (2023) displays an overlapping visualization in research on mathematical problem-solving abilities in function material. This visualization shows the novelty of research related to related terms. The results of the overlay visualization in Figure 4 using VOS Viewer show that problem-solving variables were widely published between 2018-2019 which were closely related to mathematical problem-solving abilities in function material. The results of the overlay visualization also show that in 2018-2020 the problem-solving variable was the center of research. Meanwhile, the results in 2021-2024 discussed include critical thinking skills, development, class, mathematical problem solving, and this research. The color difference for each year indicates the range of publication years. The network with purple indicates the oldest publication year, the network with yellow indicates the latest publication year (Indriyanti et al., 2023).

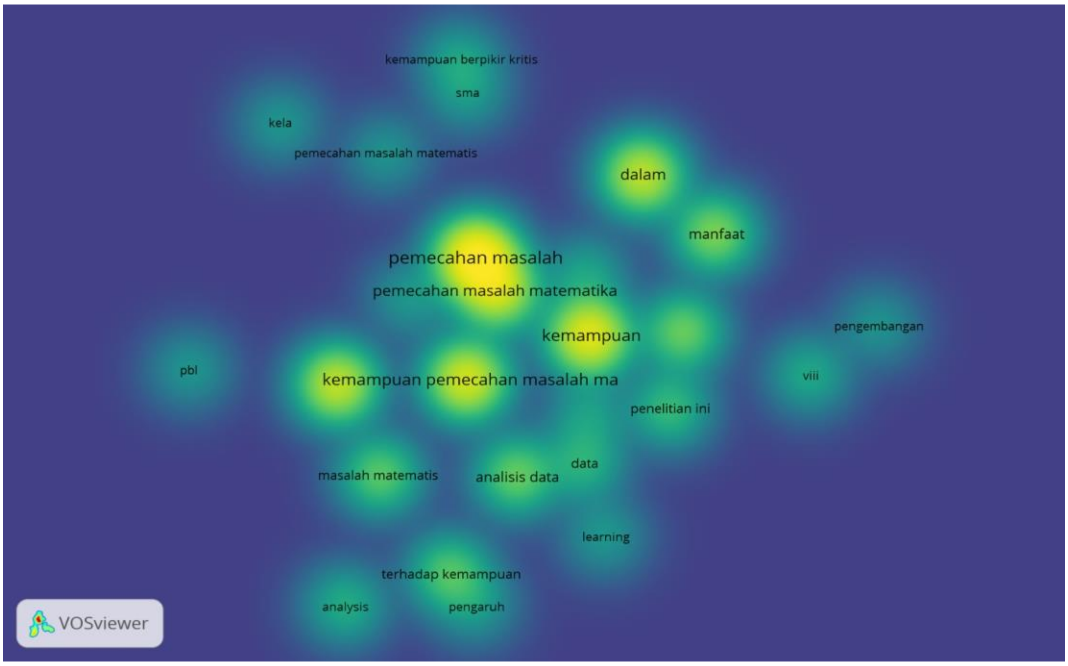

Figure 5. Density Visualisation VOS Viewer

Figure 5 illustrates the results of the density visualisation conducted using VOS Viewer, which maps the distribution of research topics related to mathematical problem-solving ability within the function topic. This visualisation utilises a colour spectrum, primarily yellow, green, and blue, to indicate the intensity or frequency of research activity on specific variables. Following the framework by Tupan et al. (2018), yellow regions represent high-density areas where variables have been extensively studied, suggesting strong scholarly interest and well-established relationships between these topics. For instance, variables such as "problem solving" and "ability" fall within this category, demonstrating their central role in current mathematics education research.

3.2 Discussion

This discussion focuses on the results of network visualisation analysis using the VOS Viewer software to identify patterns and relationships among variables in research related to mathematical problem-solving abilities, particularly in the topic of functions. The presented network visualisation illustrates how various variables are interconnected and form thematic clusters that reflect current research focuses. Through this mapping, core variables as well as underexplored aspects become apparent, opening opportunities for further research development.

Furthermore, the overlay visualisation provides a temporal overview of the research progression in this field, highlighting trends and the emergence of new topics over the years. Variables such as problem-solving ability occupied a central position during the period of 2018 to 2020, while more recent studies from 2021 to 2024 have begun to emphasise critical aspects such as critical thinking skills, material development, and classroom learning contexts. This shift in focus indicates the maturation and broadening scope of research in mathematics education.

The presence of green regions indicates moderate research attention, implying that these topics have been explored but still hold potential for further investigation. Meanwhile, blue regions signify low-density areas, revealing variables that remain underexplored. Such findings highlight research gaps and novel opportunities for scholars to contribute new insights, particularly regarding variables like "critical thinking ability," "PBL (problem-based learning)," and "development," which appear in these blue zones. This aligns with recent studies emphasising the need to broaden research beyond traditional problem-solving skills to incorporate affective and contextual factors influencing student learning (Widodo et al., 2022; Arifin & Setiawan, 2023).

Moreover, the differentiation of colour intensities underscores the evolving nature of mathematics education research. For example, Li and Zhang (2021) point out that integrating innovative pedagogical strategies, such as digital tools and collaborative learning models, has become increasingly relevant in addressing these less-studied variables. Similarly, research by Sari et al. (2023) supports the notion that critical thinking and problem-based learning methodologies are crucial for improving students' mathematical competencies but require further empirical validation in diverse educational contexts (Rahayu et al., 2024; Fadilah et al., 2024; Madya et al., 2025; Santika et al., 2025; Cahyani et al., 2024).

In addition, the low-density areas identified in the density visualisation resonate with global educational priorities focusing on 21st-century skills and STEM education integration (Nurhadi et al., 2020; Pratiwi & Santosa, 2024). These emerging areas call for a multidisciplinary approach combining cognitive, emotional, and social dimensions, which current studies have only partially addressed. Therefore, the density visualisation not only maps the present research landscape but also signals key directions for future studies to enrich mathematics education theory and practice.

Variables located in yellow-colored areas with high density include "problem solving," "mathematical problem solving," "in," "ability," and "problem-solving ability." These have been widely studied, indicating that they are central variables or core focuses in the network and have interrelated topics. Variables in yellow-green areas include "mathematical problems," "data analysis," "on ability," "influence," and "benefit." Meanwhile, variables in blue-colored areas indicating low density include "critical thinking ability," "high school," "mathematical problem solving," "PBL," "development," "eighth grade," "analysis," and "learning."

Based on the interpretation of Figure 5, the variable "mathematical problem solving" appears in a blue-colored area, which implies that this variable has not yet been extensively researched. This indicates an opportunity for innovation and future research development. Other variables that also appear in blue-colored areas and have potential for further exploration include "critical thinking ability," "high school," "PBL," "development," "eighth grade," "analysis," and "learning," all of which suggest novelty and research opportunities.

4. Conclusions

Based on the findings and discussions, it was found that the number of scientific publications on Google Scholar from 2015 to 2024 that are related to mathematical problem-solving ability in the function topic totaled 994 articles. The highest number of publications occurred in 2020, with 177 articles, while the lowest was in 2024, with only 21 articles, based on analysis using the VOSviewer software. The network visualization results revealed relationships between variables/themes consisting of 21 variables: 6 variables in cluster 1, 7 in cluster 2, 5 in cluster 3, 2 in cluster 4, and 1 in cluster 5. The results of the overlay visualization and density visualization show that the variable "problem solving" was widely published between 2018 and 2019 and is closely related to mathematical problem-solving ability in the function topic. The overlay visualization also shows that in 2018–2020, "problem solving" was the central focus of research. In contrast, during 2021–2024, the focus shifted to include "critical thinking ability," "development," "class," "mathematical problem solving," and "this research." Variables related to mathematical problem-solving ability in the function topic that have potential and novelty for future research include: “critical thinking ability,” “high school,” “mathematical problem solving,” “PBL,” “development,” “eighth grade,” “analysis,” and “learning,” because these have not yet been widely studied. Therefore, the results indicate that there are novel areas that can be further developed by researchers.

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Conflict of Interest
The authors declare no conflicts of interest.

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