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Trends in Mathematical Problem-Solving Skills in Mathematics Learning

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Article Info	Abstract

Mathematical problem-solving skills is an essential skill that students must possess because it supports their understanding of mathematical concepts, the application of knowledge in daily life, and the development of higher-order thinking skills such as critical and analytical thinking. However, various studies show that this ability is still considered low, necessitating a systematic and comprehensive research mapping. This study aims to identify trends in research on mathematical problem-solving abilities in mathematics learning from 2021 to 2025. The method used is a Systematic Literature Review based on the PRISMA 2020 protocol, utilising the Scopus database. The analysis was conducted with the assistance of VOSviewer to visualise keyword connections, research theme clusters, and publication patterns. The study results show an increase in the number of publications year after year, peaking in 2025. A qualitative research approach dominates, while the most frequently used instrument is a test sheet. The most researched educational level is high school, followed by middle school and teachers. Frequently occurring keywords include problem-solving, problem-based learning, and technology as the main focus. The latest trend points toward utilising authentic problem-based learning technologies and strategies to enhance mathematical problem-solving abilities. This finding confirms that mathematical problem-solving ability is an important complex skill.

Introduction

One of the abilities that students must possess is mathematical problem-solving skills. Mathematical problem-solving skills is crucial in mathematics learning because it is widely applied in other fields of study and in daily life (Ukobizaba, Nizeyimana, & Mukuka, 2021; Nauli, Harisman, Armiati, & Yerizon, 2024; Leonardo & Ortega-Dela Cruz, 2024). Mathematical problem-solving skills help students acquire the knowledge and skills needed to formulate, approach, and solve problems based on what they have learnt (NCTM, 2000). Mathematical problem-solving skills can help students gain knowledge and skills and formulate and solve everyday life problems according to what they have learnt in school (Mursalin & Saputra, 2023; Izzati & Utami, 2024). When mathematical problem-solving abilities are low, it can hinder analytical and critical thinking skills and affect students' learning motivation (Nagy & Saeed, 2022). According to (Anwar & Rahmawati, 2017) in their research, students are considered capable of solving problems if they can solve mathematical problems using 4 stages: 1) understanding all the words in the problem, 2) creating a problem-solving strategy, 3) applying the chosen strategy so that the problem can be solved, and 4) reviewing the entire problem-solving process.

The importance of mathematical problem-solving skills is a concern for educators to create quality mathematics learning. Educators face the challenge of creating an interactive learning environment and supporting students in developing mathematical problem-solving skills, which need to be encouraged using various learning strategies, media, and techniques. In this regard, educators must be able to design collaborative learning activities that allow students to share ideas and discuss ways to solve mathematical problems (Subba et al., 2025). By providing learning that is relevant to real, complex, and diverse contexts, students are able to connect mathematical concepts to real-life situations, enabling them to understand problems through problem-solving skills (Asempapa, 2022 Leonardo & Ortega-Dela Cruz, 2024).

Studies on mathematical problem-solving abilities have been conducted extensively by various researchers, but the mapping has not been comprehensively organised and systematic. This condition impacts the lack of a strong conceptual foundation and scientific framework for subsequent research in developing and directing studies related to this capability more deeply. Many previous studies have addressed mathematical problem-solving abilities. However, few studies have systematically outlined the development of this research using literature reviews or scientific references drawn from the Scopus database. Several previous studies have investigated how mathematical problem-solving abilities can be used to solve problems, such as research by (Widodo et al., 2025; Wanabuliandari, Wardono, Susilo, Bintoro, & Mariani, 2025; Almubarak et al., 2025).

Therefore, further initiatives are needed to develop more focused, systematic, and directed studies in order to enrich understanding and development in this field. Through a content analysis approach to a number of articles published in internationally reputable journals indexed by Scopus, with a publication time range from 2021 to 2025, this study aims to gather, summarise, and map important information from various studies that examine mathematical problem-solving abilities in the context of mathematics learning. This research aims to answer the following questions: 1) how is the trend in the number of studies on mathematical problem-solving from year to year? 2) What type of research is frequently used in studies on mathematical problem-solving skills? 3) What

instruments are used in studies on mathematical problem-solving skills? 4) What level of education is most often involved in research related to mathematical problem-solving skills? 5) Which country conducts the most research to observe the development of mathematical representation? and 6) What keywords did the researcher use to investigate mathematical problem-solving skills?

Method

Through systematic steps and adherence to standard procedures in the Systematic Literature Review (SLR) method, the research question formulated above will be structured and elaborated upon. This process includes several steps: first, determining the main keywords for retrieving articles, which is "mathematical problem-solving skills "; second, determining the type of document to be retrieved, which is journals from the Scopus database; third, selecting accessible journals, limiting the publication stage to only the final version, limiting the document type to articles, limiting the subject area to mathematics, limiting the article publication period to 2021-2025, limiting the language used to English only, and limiting the keyword type; fourth, determining the type of file to be reviewed, which is RIS files; fifth, selecting a reference management application, which is Mendeley; sixth, using the VOSviewer application; and finally, analysing articles with VOSviewer features to visualise the network between keywords
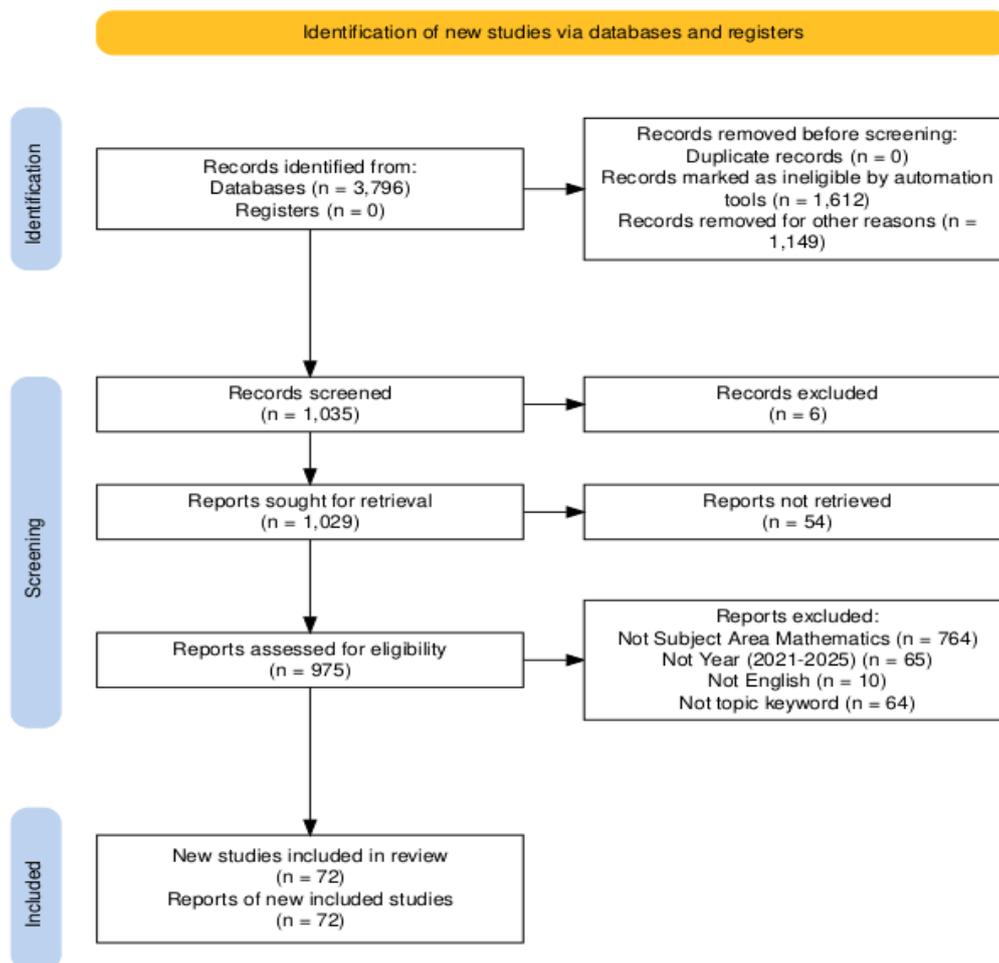

Chart 1. Stages of Article Retrieval

This research was conducted based on the stages of the PRISMA 2020 protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which includes the steps of identifying, screening, and selecting articles from Scopus as the main database (Page et al., 2021). The identification stage is related to the initial stage of article retrieval. This stage is carried out by registering an account in the premium Scopus database and entering the term "mathematical problem-solving abilities" in the article search column in Scopus. At this stage, 3796 articles were found. Then, through selection by limiting documents that are not journal types, 1612 findings were obtained; limiting inaccessible journals yielded 1149 findings. The screening stage involved filtering the remaining 1035 documents by determining the number of articles recorded from the Scopus database. At this stage, this was done by filtering publication journals that were not final, resulting in 6 articles; documents that were not articles were found to be 54 documents; then, these were aligned with the chosen study topic by filtering subject areas that were not mathematics, resulting in 764 articles; those not included in the 2021-2025 range were found to be 65 articles; those not in English were 10 articles; those not included in the keywords were 64 articles. The final stage was the inclusion stage, where 72 articles were strictly verified and validated.

Results

Trend in the Number of Studies on Mathematical Problem Solving Year by Year

The trend in studies on mathematical problem-solving, in the form of published articles appearing between 2021 and 2025 in various Scopus-indexed journals, reflects the intensity of research conducted during that period. Based on the graph shown in Figure 1, it can be seen that the peak number of publications occurred in 2025 during that period. The pattern of increasing article numbers reflects significant growth in researchers' interest in studying and developing this topic. Meanwhile, the fewest publications occurred in 2022 and 2023. This is happening because, according to Clarivate/Web of Science data, the number of indexed global scientific articles is decreasing. The number of indexed scientific articles published decreased between 2022 and 2023. One of the main reasons for the decline in global publications is the decrease in research output in several major countries, particularly China and India.
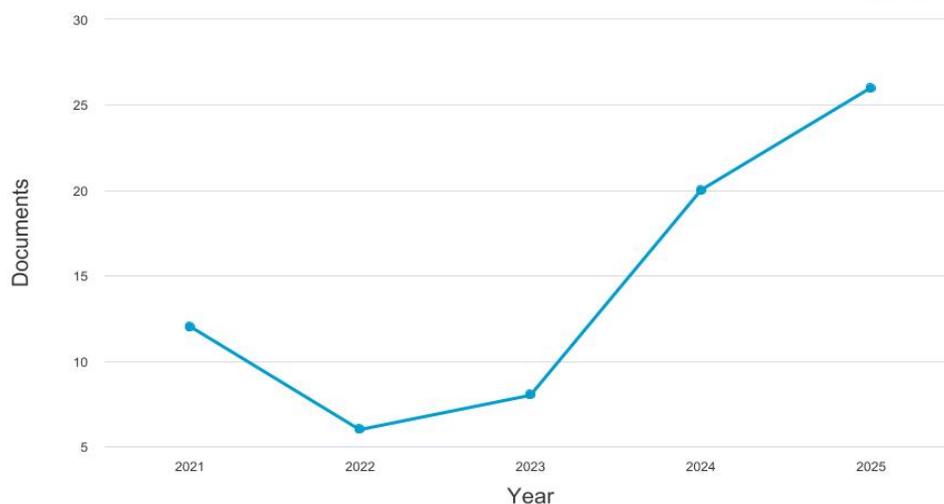

Figure 1. Trend in the Development of the Number of Research with Mathematical Problem Solving Skills as the Main Focus in Scopus over 5 Years

In the studies conducted, the average analysis focused on aspects related to mathematical problem-solving, and the fact remains that mathematical problem-solving abilities are still low, accompanied by the identification of difficulties related to mathematical problem-solving abilities (Bulkova, Medova, & Cererkova, 2020; Pongsakdi et al., 2020; Putri, Zulkardi, & Riskanita, 2022; Fonseca, 2021). Following the analysis of difficulties and aspects related to mathematical problem-solving abilities, several studies investigated the influence of various teaching models, such as contextual learning, problem-based learning, and collaborative discussion-based learning, to determine the cause-and-effect relationship with mathematical problem-solving skills (Ukobizaba, Nizeyimana, & Mukuka, 2021; Suparatulatorn, Jun-On, Hong, Intaros, & Suwannaut, 2023; Meriza, Hiltrimartin, & Hartono, 2024). Subsequently, several researchers made efforts to improve mathematical problem-solving abilities, including developing mathematical instruments, interactive learning, and using technology (Cirneanu & Moldoveanu, 2024; Susanti, Wulandari, Hapizah, Isrokatun, & Simarmata, 2025; Barbosa & Vale, 2025).

Research Methodology

The selection of research methods and designs is an essential component that significantly determines the direction, analytical approach, and breadth of scope of a scientific study, particularly in the field of mathematics education.
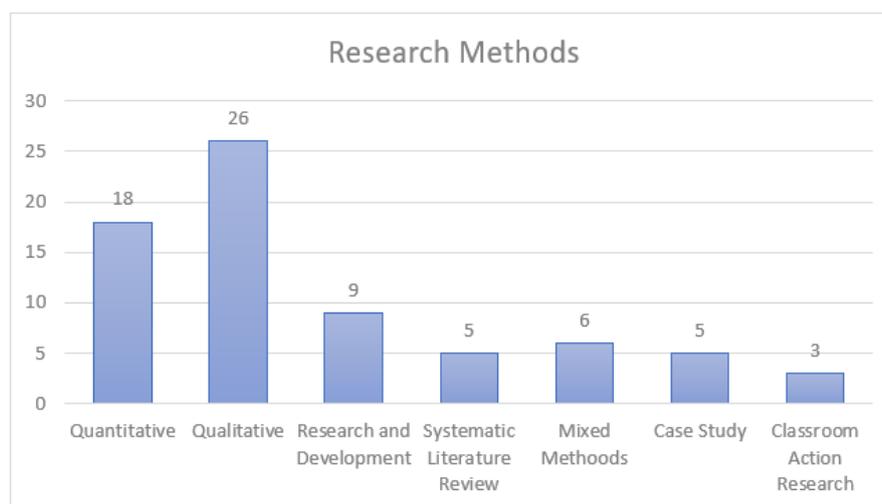

Figure 2. Distribution Of Research with Mathematical Problem Solving Skills as the Main Focus on Research Methods

Based on the visual data presented in Figure 2, it is known that the qualitative approach is the most widely used research design by researchers in exploring students' mathematical problem-solving abilities. As research conducted by (Sulistyaningsih & Purnomo, 2021; Putri et al., 2022; Sari, Rosjanuardi, Isharyadi, & Nurhayati, 2024) shows, this is because solving mathematical problems involves complex thinking processes, and researchers tend to explore students' strategies, logical reasoning, and ways of thinking in depth. A qualitative approach is suitable for this because it can understand phenomena from the participants' perspective and capture experiences and meanings that cannot be measured with numbers (Oranga & Matere, 2023).The second preferred approach is quantitative, which is used to test hypotheses and theories and examine patterns and causal relationships between

variables related to mathematical problem-solving skills. As research conducted by (Kusuma, Ruchjana, Widodo, & Dwipriyoko, 2024; Fitria, Susilana, Priatna, & Rusman, 2025) shows. Other research methods such as R&D, mixed methods, SLR, case studies, and action research are rarely used, but that doesn't mean these types of research are unsuitable for measuring mathematical problem-solving abilities. Although its frequency is still considered low, this research method remains highly relevant and has great potential for applying, developing, and mapping mathematical problem-solving abilities in mathematics education. This can serve as a basis for developing more complex research, which would certainly be difficult to do using qualitative methods.

Data Collection

Instruments are used as a tool to support the data collection process for assessing students' mathematical problem-solving abilities. Various types of instruments have been developed in previous studies. Based on the graph in Figure 3, it can be seen that tests or test sheets are the most widely used instrument for obtaining data related to problem-solving abilities. This is because tests or test sheets are considered effective, as they can directly, objectively, and systematically measure mathematical problem-solving abilities, as well as display students' thinking processes and solution outcomes through questions designed based on problem-solving indicators. Research has shown that instruments using test sheets can effectively measure mathematical problem-solving abilities (Subba et al., 2025; Aripin et al., 2025;Marin Ballon et al., 2024). Furthermore, the use of a questionnaire sheet is also a widely chosen instrument by researchers, as demonstrated by researchers (Geteregechi, 2025; Méndez-Romero et al., 2021). In addition, the instruments used were observation sheets, screening forms, and interview sheets, although some researchers did not mention the instruments they used. This finding indicates that the accuracy of instrument selection is crucial in determining the quality and relevance of the data obtained in research on mathematical problem-solving abilities.

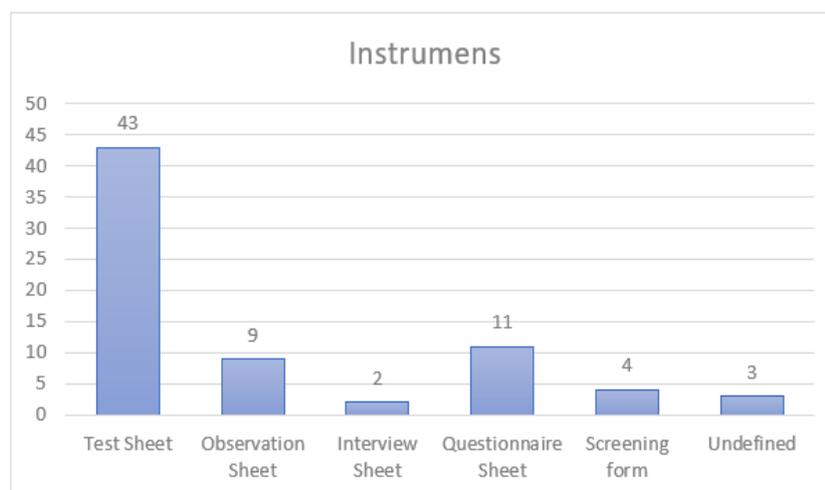
Figure 3. Distribution of Data Collection Instrument for Measuring Mathematical Problem Solving Skills

Participants in the Study

Research participants are individuals or groups involved in the data collection process, whether as subjects or

respondents. In educational research, participants generally include students, educators, or other parties who contribute data as data sources. In addition to being data sources, research participants also receive the treatment or intervention provided by the researcher. Participants also represent specific characteristics of the study population.
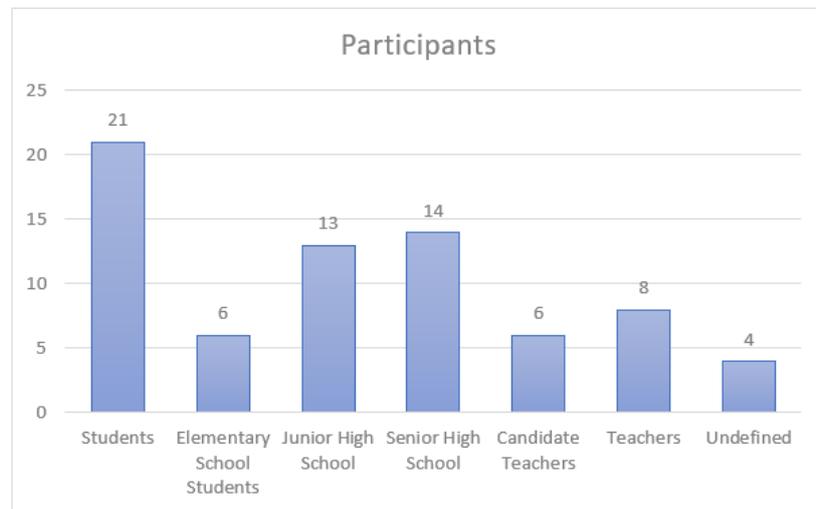

Figure 4. Participants

Figure 4 shows that the majority of participants used in the study of mathematical problem-solving skills were students. This is because students are an important aspect of learning engagement and are the main target for assessing mathematical problem-solving skills .However, the word "student" is less clear because the researcher did not specify the level or grade of education used. Furthermore, the participants most frequently used in research on mathematical problem-solving abilities are high school students, followed by middle school students. This indicates that participants at these grade levels are the ones who should be more focused on being studied in the field of mathematical problem-solving abilities. As stated in research conducted by (Hiltrimartin & Pratiwi, 2025;'ulya, Sugiman, & Rosnawati, 2024; Nauli et al., 2024) participants at that grade level still have poor mathematical problem-solving abilities. A large number of participants were also teachers, similar to the research conducted by (Chinofunga et al., 2025). Teachers are heavily involved because of their central role in developing mathematical problem-solving abilities through the selection of teaching methods, media, and strategies. Teacher involvement allows researchers to understand their strategies, perspectives, and experiences in teaching problem-solving in the classroom. By involving a heterogeneous group of participants, the research is expected to generate broader and more implementable insights that can then support the improvement of learning practices in the world of education (Anwar, Rahmawati, & Wulandari, 2025).

State-Based Documents

Based on the graph in Figure 5, it shows a comparison of the number of documents from 10 countries or regions, including several countries or regions that have researched mathematical problem-solving abilities. From this data, it can be seen that Indonesia holds the top position with the highest number of documents. This is because the problem-solving abilities of participants in Indonesia are considered low. The next countries are Spain, the

United States, Europe, Australia, Chile, Iran, Mexico, South Africa, and Thailand. From that data, it shows that several countries contributed to discussing research in the field of mathematical problem-solving abilities.
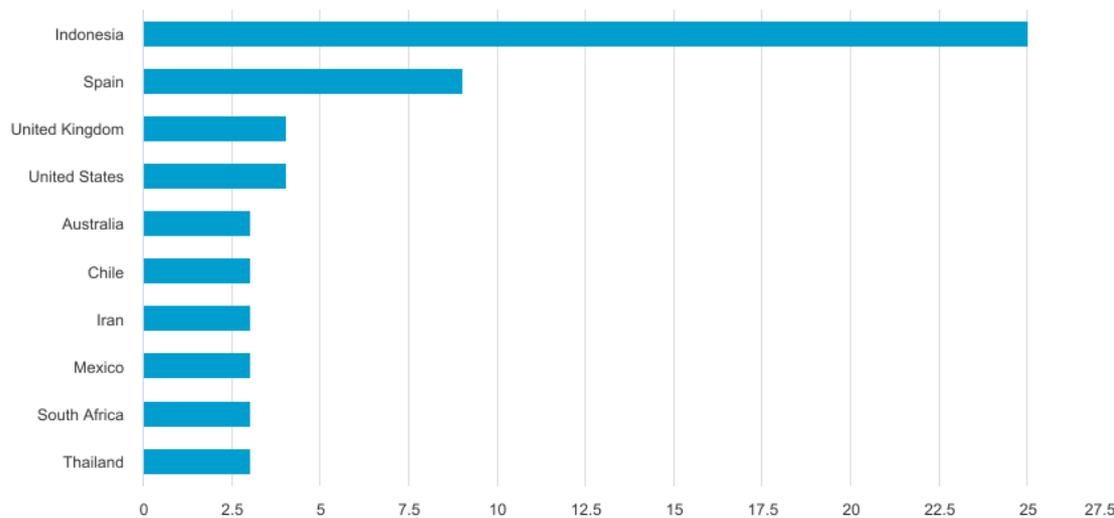

Figure 5. Distribution of Research Document Counts by Country

The graph presented in Figure 5 can serve as a data source for researchers and educators in analysing problems and patterns and understanding how other countries contribute to mathematical problem-solving skills, thus enabling them to address various issues and challenges in this field.

Keywords in the Research

Keywords in research serve as the core representation of the problem and variables being studied, making it easier for readers, other researchers, and journal indexers to find and categorise relevant research. Keyword selection should reflect the main concepts, theories, and research focus to increase visibility in scientific database searches. In other words, keywords become an important tool for connecting research with related literature, clarifying the scope of the study, and supporting topic cohesion within the same field of science. The visualisation of the keyword network from VOSviewer in Figure 6 shows that research on mathematical problem-solving skills is connected to various domains within mathematics education.

In Figure 6, the visualisation of the keyword network from VOSviewer shows that research on mathematical problem-solving abilities is connected to many fields within mathematics education. The keyword "problem-solving" appears to be the main hub, as it frequently appears alongside other keywords such as "problem-based learning", "technology", "mathematics", and "metacognition". This indicates that problem-solving skills is not only independent but also closely related to the use of technology, the application of problem-based learning, and the development of higher-order thinking skills. The red cluster indicates a connection to "mathematical modelling", "word problems", and "curriculum design", meaning that problem-solving research is often contextualised through word problems, mathematical modelling, and curriculum design. This suggests that research in this field is largely built upon the context of mathematical modelling and the development of teaching materials. The green cluster connects this topic with "mathematics education", "ethnomathematics", "geogebra",

and "digital technology", indicating the development of research that incorporates digital technology and cultural contexts into learning. While the blue and purple clusters point to topics such as "algebraic thinking", "generalisation", "STEM", and "augmented reality", indicating that problem-solving is also being studied in the context of algebraic thinking and the use of cutting-edge technology. Overall, this map shows that mathematical problem-solving skills are developing as a broad topic, encompassing various modern learning approaches, technology integration, cultural contexts, and 21st-century skill needs.
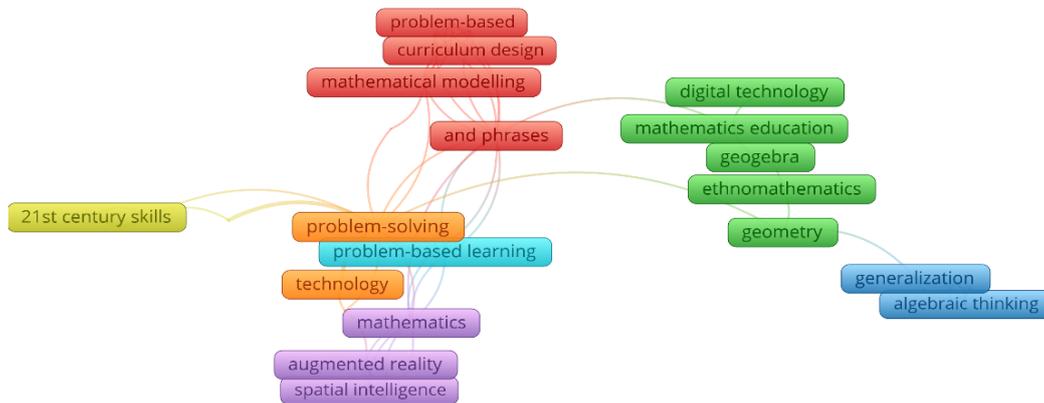

Figure 6. Keywork Network used in Research related to Mathematical Problem Solving Skills

Besides the interconnectedness of these keywords, this data is also supported by the density or intensity of keyword occurrences within the research used, as presented in Figure 7.

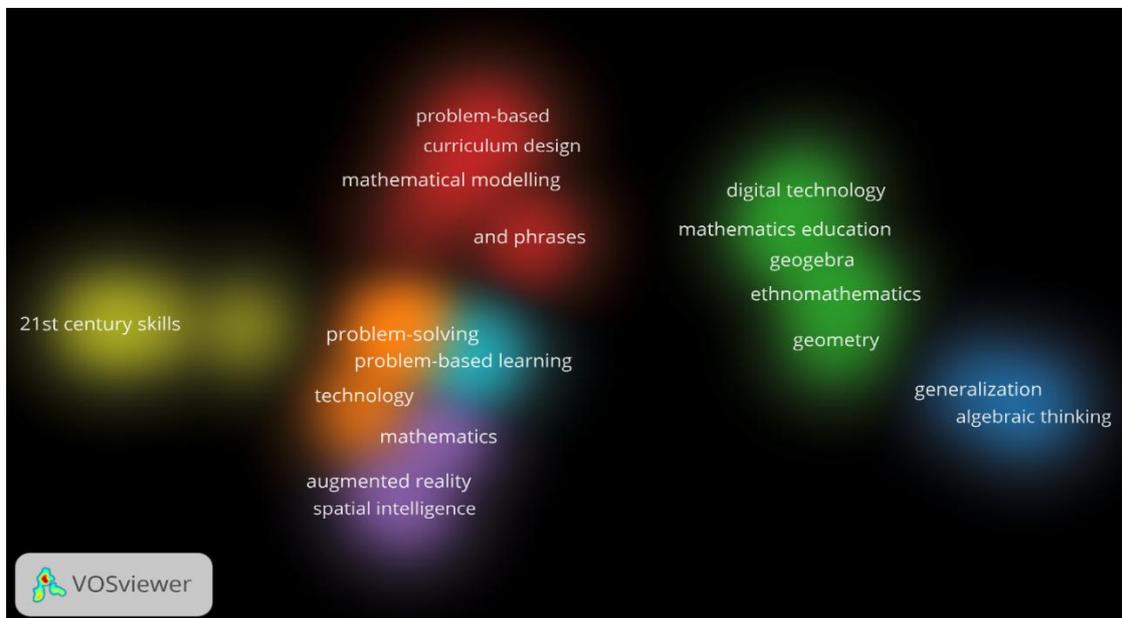Figure 7. Keywork Density used in Research related to Mathematical Problem Solving Skills

The size variation indicates the frequency of research used; the larger the size, the more often the topic is researched, and the smaller the size, the less common it is to be researched. Therefore, this analysis can help identify areas that have not been frequently researched. By knowing the frequency of research on these keywords,

researchers can develop further studies to address issues related to the topic in more detail.

Next, Figure 8 shows a visualisation of these keywords, depicting a thematic map of research on mathematical problem-solving abilities based on publication year (2021–2025). The colour of each node represents the average year the keyword appeared.
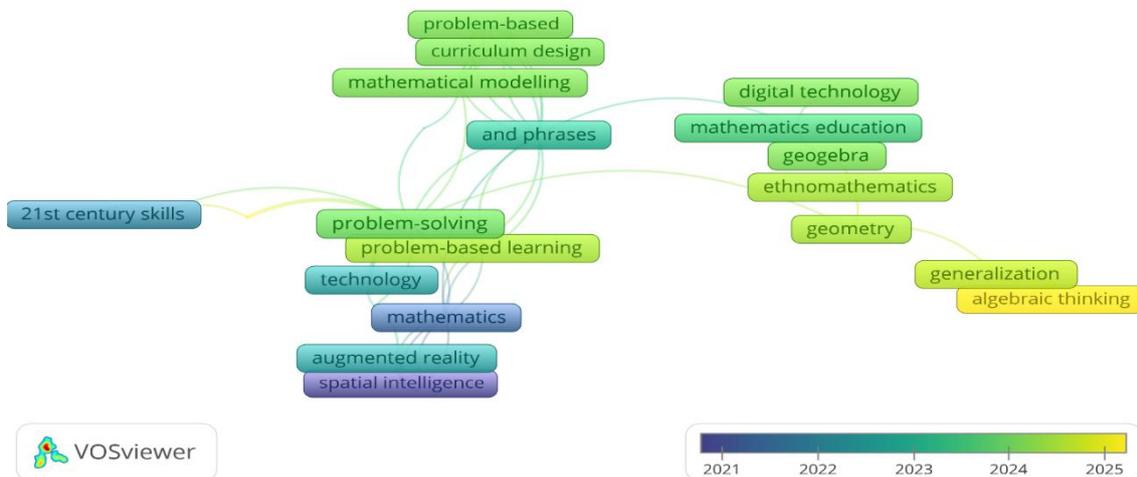

Figure 8. Trend of the Distribution of the Researched Keywords

Figure 8 shows that the keyword "problem-solving" is at the centre of the network, indicating that this topic is a primary focus and often appears alongside various other terms. On the left side, older keywords such as '21st-century skills', 'technology', and 'mathematics' indicate that in the early years of problem-solving studies, it was often associated with 21st-century skills that focused on teacher and student teams, how teachers modelled and taught, and the strategies used to prepare students in developing mathematical problem-solving skiils (Suh et al., 2021). The use of basic technology, as well as mathematics learning in general. Entering the green zone, research began to develop toward "problem-based learning" (PBL), which is a valuable approach for improving problem-solving skills, attitudes toward mathematics, and study habits (Leonardo & Ortega-Dela Cruz, 2024), "digital technology", and "ethnomathematics", indicating a shift in focus toward contextual learning approaches, cultural integration, and the utilisation of digital technology. The use of local culture-orientated technology is practical for use in mathematics learning (Sugiharti et al., 2025). Then, yellow-coloured keywords like "generalisation" and "algebraic thinking" are visible, indicating that in recent years (2024–2025), problem-solving research tends to focus on strengthening algebraic reasoning and the process of generalising concepts. Additionally, keywords such as '21st-century skills', 'spatial intelligence', and 'GeoGebra' emerged, indicating the integration of visual and manipulative technologies as a new trend in supporting problem-solving abilities.

Conclusion

Based on a trend analysis of studies on mathematical problem-solving abilities in mathematics learning, sourced from Scopus-indexed journal articles from 2021 to 2025. The results of this study indicate that:

1. Research on mathematical problem-solving abilities experienced a significant increase during the period

2021–2025. The study results show an increase in the number of publications year by year, peaking in 2025. This pattern of increasing article numbers reflects significant growth in researchers' interest in studying and developing this topic. The fewest publications occurred in 2022 and 2023. Overall, these studies indicate that research on mathematical problem-solving abilities primarily focuses on problem-based learning approaches, technology integration, and mathematical modelling but is also continuously evolving toward innovative technologies, algebraic skills, and cultural contexts in mathematics education.

2. Qualitative research designs dominate the studies, which is because solving mathematical problems involves complex thinking processes, and researchers tend to deeply explore students' strategies, logical reasoning, and ways of thinking.

3. The instrument frequently used in research on mathematical problem-solving skills is a test sheet. Tests or test sheets are considered effective because they can directly, objectively, and systematically measure mathematical problem-solving skills, as well as reveal students' thinking processes and solution outcomes through problems designed based on problem-solving indicators.

4. The most frequently researched level is high school, followed by junior high school and teachers.

5. Indonesia holds the top position for conducting the most research on mathematical problem-solving abilities over the past 5 years.

6. Keyword analysis shows that issues such as problem-solving, problem-based learning, and technology are at the core of the discussion. The latest trends point toward using technology to enhance mathematical problem-solving abilities and problem-based learning strategies, utilising authentic problems in mathematics education. Mathematical problem-solving skills is a complex skill that requires more than just procedural mastery, necessitating support from media and innovative learning strategies. Research needs to focus on using technology and collaborative, contextual learning models to improve students' problem-solving abilities

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