25 (1), 2024, 399-418
Jurnal Pendidikan MIPA
e-ISSN: 2685-5488 | p-ISSN: 1411-2531
http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Mathematical Problem-Solving Process Reviewed from Emotional Intelligence through Metacognition: A Literature Review

Reyvall Angling Kusuma[1], Fadila Rahmawati[1], Yanuar Hery Murtianto[1*], & Milagros Baldemor[2]
[1]Department of Mathematics Education, Universitas PGRI Semarang, Indonesia
[2]Don Mariano Marcos Memorial State University, Filipina

Abstract: Mathematical Problem Solving Reviewed from Emotional Intelligence through Metacognition: A Literature Review. Metacognition is an essential part of the math problem-solving process, with emotional intelligence helping to maintain student consistency and focus. **Objectives:** This study aims to provide an overview of research related to the role of metacognition in mathematical problem solving, particularly from the perspective of emotional intelligence, in the period 2013 to 2024. It focuses on how emotional intelligence affects monitoring, evaluating, and controlling cognitive states and regulating students' interpersonal interactions in problem-solving. **Method:** This study used the PRISMA Method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) to select relevant literature. Data analysis was conducted with the help of VOSViewers and Bibliometrix R-Package software, which enabled the mapping of relationships between variables and identifying major trends in research. This study focused on articles that explored metacognition in mathematical problem-solving and the impact of emotional intelligence on this process. **Findings:** The results of this literature review show a 1.21% decrease in metacognition research trends from 2013 to 2024. Metacognition is connected to student variables, cognitive systems, problem-solving strategies, working memory, self-efficacy, active learning, and reflection. The integration of metacognition and emotional intelligence emphasizes their role in mathematics education. **Conclusion:** This study provides insights for further research on mathematics problem-solving regarding emotional intelligence through metacognition. In addition, variables such as active learning, problem-solving skills, math anxiety, student characteristics, and math awareness can be used as research references relevant to the current generation.

Keywords: metacognition, mathematics, problem-solving, emotional quotient.

▪ INTRODUCTION

Students' thinking skills are closely related to information and knowledge management. Meanwhile, the ability to control and regulate one's thinking processes is commonly called metacognition. Metacognition refers to the general human ability to think about their own thinking processes (Masnia et al., 2023; Porumb & Manasia, 2015). Optimizing learning through metacognition creates a productive and competitive learning environment. When students can develop their own thinking processes, they can identify and evaluate their understanding, thereby helping them become more adaptive, independent, and reflective learners in every aspect.

Metacognition consists of the prefixes "meta" and "cognition," first introduced by John Flavell in 1976. "Meta" is a prefix meaning "beyond" or "after" cognition. Adding the prefix "meta" to cognition reflects the idea that metacognition is defined as cognition about cognition, knowledge about knowledge, or thinking about thinking (Anderson, 2008; Mahdavi, 2014; Wellman, 1985). Students' metacognition refers to their knowledge and awareness of their cognitive processes and activities (Mahdavi, 2014). Livingston

Yanuar Hery Murtianto
*Email: yanuarheri@upgris.ac.id

DOI: http://dx.doi.org/10.23960/jpmipa/v25i1.pp399-418
Received: 19 July 2024
Accepted: 20 August 2024
Published: 24 August 2024

(1997), as cited in Prasetyoningrum & Mahmudi (2017), provides a more straightforward definition of metacognition as "thinking about thinking," which means reflecting on one's own thinking processes. It can be interpreted that the process of metacognition involves reflecting on one's own thinking objects or knowing what is known and what is not. Metacognition has two main components: metacognitive knowledge and metacognitive experience or regulation (Kurniawan & Wijayanti, 2022). Metacognitive knowledge is defined as an understanding of thinking processes and awareness of cognitive strategies and processes, enabling individuals to organize and manage their learning activities more effectively. Hamid and Abdullah state that metacognitive knowledge refers to knowledge related to what should be done in specific situations, thus enabling individuals to define their knowledge and thinking accurately (Irdayani et al., 2020). Metacognitive experience is a critical component in controlling cognitive activities and achieving learning goals or problem-solving. Metacognitive experiences allow for concurrent or 'on-line' monitoring during task performance (Brick et al., 2015). They include metacognitive feelings, which 2 inform the individual about task performance in the form of a feeling, such as feelings of 3 difficulty, and tend to be implicit in nature (Brick et al., 2015; Efklides, 2006). According to Schraw and Moshman, the three main components of metacognitive experience are planning, evaluation, and monitoring. These three components are closely related to the problem-solving indicators, according to Polya (1973).

Basic skills that students need to develop include problem-solving abilities. Problem-solving is defined as a cognitive process that focuses on accomplishing an objective for which the students do not primarily know a solution technique (Rahman, 2019). Meanwhile, Mathematical problem-solving has long been seen as an essential aspect of mathematics, teaching mathematics, and learning mathematics (Siagian et al., 2019). A primary goal of mathematics teaching and learning is to develop students' ability to solve complex mathematics problems (Fernandez et al., 1994; Zhou et al., 2019). Based on the description of metacognition and problem-solving above, it can be concluded that metacognition is related to mathematical problem-solving ability. Students with good metacognitive abilities in problem-solving will also positively impact their learning process and achievements (Mayasari et al., 2018; Ormrod, 2006; Özcan, 2014). Metacognitive abilities enable students to recognize, understand, and regulate their thinking processes when encountering mathematical problems. With a better understanding of how they think and learn, students can develop effective strategies for problem-solving and enhance their overall academic performance. This indicates that metacognitive abilities in problem-solving are crucial factors in improving the quality of mathematics learning and students' achievements.

Problem-solving involves high-level thinking where students must apply the knowledge and skills they have learned to solve existing challenges through steps that include understanding the problem, devising a problem-solving plan, implementing the plan, and reviewing (Alfiyah & Siswono, 2014; Anggo, 2011; Damayanti et al., 2020; Kurniawan & Wijayanti, 2022; Polya, 1973; Safitri et al., 2020; Sari et al., 2021). Students must be taught mathematical problem-solving skills to optimize their thinking skills (Kartika & Firmansyah, 2018; Riani et al., 2022). This aligns with the concept of mathematics, which provides a structured framework that uses established rules, ideas, and techniques. Mathematics is a natural science that requires a thinking process to control what is thought and what is done (Safitri et al., 2020).

In addition, emotional intelligence also plays a crucial role in mathematical problem-solving abilities. Emotional intelligence encompasses the ability to self-motivate and persevere through frustration, control impulses, avoid exaggerating pleasure, regulate mood, and manage stress to ensure it does not impair cognitive skills, empathy, and prayer (Goleman, 2002, p. 43). Furthermore, Goleman emphasizes that emotional intelligence is the ability to manage one's emotional life with intelligence, maintaining emotional harmony and appropriate expression through self-awareness, self-control, self-motivation, empathy, and social skills (Goleman, 2002). emotional intelligence (EQ) is an individual's ability to monitor, manage, and effectively use emotions in oneself and others, utilizing skills such as self-awareness, self-control, self-motivation, empathy, and social skills. Emotional intelligence is one of the intelligence that influences a person's cognitive abilities (Nurjamil & Saepulloh, 2023). This is likely due to the fact that the processes involved in emotional intelligence, such as the perception, understanding, and regulation of emotions, require a high degree of self-awareness and self-reflection, which are critical to the effective use of metacognitive strategies (Brackett et al., 2011; Drigas & Papoutsi, 2018; Mayer et al., 2000; Mayer & Salovey, 1993). Students with high emotional intelligence tend to manage their emotions, enabling them to maintain calmness and concentration when facing complex problems. Uncontrolled emotions can hinder one's intelligence. Individuals cannot fully optimize their cognitive potential without the ability to manage emotions. Thus, enhancing emotional intelligence also plays a role in improving cognitive skills because both are interconnected and contribute to achieving success. This suggests a relationship between emotional intelligence and mathematical understanding (Israria & Misu, 2014). Through metacognitive practices, where students actively regulate their thoughts on how they understand and solve mathematical problems, emotional intelligence becomes crucial in enhancing the quality of mathematical problem-solving.

Based on the discussion above, the researcher has formulated several vital questions: How has the trend in metacognition research in mathematics evolved over the decade from 2013 to 2024? What is the relationship between metacognition of mathematics and problem-solving when viewed through emotional intelligence? Additionally, what other variables are currently trending in research on metacognition of mathematics?

This literature review examines the overview and publications related to metacognition of mathematics over a decade from 2013 to 2024. It will illustrate the research trends in metacognition, highlighting various variables that have been studied and exploring opportunities for new research on metacognition with other variables. The study also provides insights into the relationship between mathematical problem-solving processes viewed through the lens of emotional intelligence via metacognition.

▪ METHOD

Research Design

This study uses a literature review approach with bibliometrix analysis design to evaluate research trends related to metacognition in mathematics problem-solving through emotional intelligence from 2013 to 2024. Bibliometric analysis was performed following the methodology outlined in (Donthu et al., 2021) using the Bibliometrix package in R (Aria & Cuccurullo, 2017). Bibliometrix is an open-source tool for performing bibliometric and scientometric analyses using the R programming environment. It provides tools for quantitative research in bibliometrics, allowing researchers to conduct science mapping and statistical analyses (Aria & Cuccurullo, 2017). This design was chosen because it will enable researchers to identify patterns, categorize, and analyze various variables related to the topic under study, thus providing a comprehensive view of the development of literature in this field. In addition, VOSviewer (version 1.6.19) (van Eck & Waltman, 2010) was also used to construct and visualize bibliometric networks, which facilitates visualization and mapping of research networks.

Search Strategy

This study's literature search was conducted in English using the Scopus academic database. Scopus was chosen due to its comprehensive coverage, indexing over 14,000 titles in Science, Technology, and Medicine (STM) and social sciences from 4,000 publishers, making it the largest indexing and abstraction database (Burnham, 2006). Scopus covers publications from 1788 to 2019, covering literature from different regions, including Europe and Asia-Pacific, in English and non-English (Burnham, 2006; Kaas et al., 2018). Scopus also covers various disciplines and considers various bibliometric indicators, citation information, abstracts, keywords, funding details, and references for each article.

The literature search strategy was conducted using the Scopus database. The keywords used in the search included "Metacognition of Mathematics" and "Emotional Intelligence & Mathematics." The search used the title, abstract, and keywords of articles published from 2013 to 2024. A total of 416 documents from 240 sources of pertinent scientific literature and 78 documents from 66 sources of pertinent scientific literature were obtained from this search.

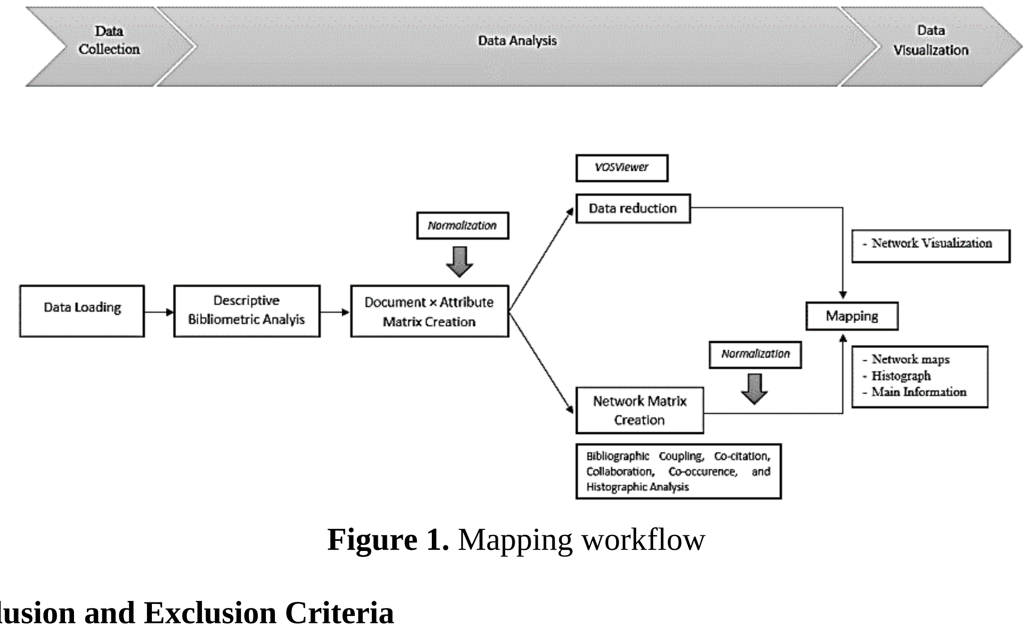

Figure 1. Mapping workflow

Inclusion and Exclusion Criteria

Inclusion criteria in this study include (1) Articles published in Scopus-indexed journals, (2) Articles relevant to the topic of metacognition and emotional intelligence in the context of mathematical problem solving, (3) Articles published between 2013 and 2024, and (4) Articles available in full text. Exclusion criteria included (1) Articles that were not available in full text, (2) Articles that were not written in English or Indonesian, and (3) Articles that were not relevant to the research topic despite appearing in the initial search results.

Data Analysis

The data obtained from the literature search was analyzed using bibliometrix analysis method assisted by VOSviewer and Bibliometrix R-Package software. This analysis includes the evaluation of co-citation, keyword co-occurrence, and bibliographic coupling. VOSviewer was used to visualize the bibliometrix network, including analysis of relationships between authors, institutions, and countries collaborating in this study. In addition, thematic analysis was also conducted to identify the main topics in the literature related to metacognition and mathematical problem-solving (van Eck & Waltman, 2023). Network visualization and topic density are detailed (van Eck & Waltman, 2014).

By integrating Bibliometrix and VOSviewer, we simplified the bibliometric analysis process and produced an attractive visual representation of the collected data. We used VOSviewer to reduce the data related to "mathematical metacognition" and "emotional intelligence & mathematics" by selecting keywords relevant to the research title. The data reduction results, displayed in Table 1 and Table 2, were then further analyzed using VOSviewer software.

Table 1. Selected keyword metacognition in VOSviewers

Include Keyword	Reduce Keyword
Metacognition	Human
Mathematics	Humans
Students	Male
Problem-Solving	Female
Cognitive systems	Learning
Education	Child
Cognition	Article
Psychology	Human experiment
Controlled study	Adolescent
Decision making	Adult
Skill	Teaching
Student	Physiology
Mathematics education	Major clinical study
Motivation	Judgment
Mathematical problem solving	Academic achievement
Mathematical phenomena	Preschool child
Self-control	Priority journal
Self-control	Executive function
Metacognitive	Learning disorder
Working memory	Arithmetic
Self-regulated Learning	Reading
Stem (science, technology, engineering, and mathematics)	Learning systems

Metacognitive monitoring	Young adult
Mathematics learning	Mathematical concepts
Mathematical problems	Comprehension
Self-regulation	Language
Knowledge	Calibration
Metacognitive awareness	Clinical article
Metacognition skills	Monitoring
Problem-based learning	Questionnaire
Cognitive process	Research subjects
Confidence	Achievement
Academic performance	Teacher
Problem-solving	Computer-aided instruction
Metacognitive knowledge	E-learning
Stem	Technology
Self-assessment	Junior high schools
Metacognitive skills	Creativity
Mathematics anxiety	Education computing
Self-efficacy	Artificial intelligence
Reflection	Data collection
Metacognitive strategies	Qualitative research
Active learning	Surveys
	Writing
	Engineering education
	Qualitative approach
	Learning strategies
	Scaffolds
	Assessment
	Gender differences
	Mathematics achievement
	Mathematics teachers
	Number sense

Table 2. Selected keyword emotional intelligence and mathematics in VOSviewers

Include Keyword	**Reduce Keyword**
Emotional Intelligence	Teaching
Mathematics	Education computing
Students	Male
Academic achievement	Female
Student	Article
Education	Adolescent
School	Physiology
Primary education	
Human	
Humans	
Child	

- **RESULT AND DISSCUSSION**

Four hundred and ninety-four (494) studies were collected through a search on Scopus. Only Scopus was chosen because of its broad scope, indexing over 14,000 titles in Science, Technology, and Medicine (STM) and social sciences from 4,000 publishers, making it the largest indexing and abstraction database (Burnham, 2006). Of the 494 research articles collected, there were two keywords: 416 articles "Metacognition of Mathematics" and 78 articles "Emotional Intelligence and Mathematics". Then, the final stage was "data visualization," shown in Figure 1. From the results of bibliometrix and VOSviewer analysis, several themes were obtained, namely: (1) Overview of metacognition within bibliometrix analysis, (2) Trends of metacognition topics, (3) Co-Citation Network, (4) Countries' Collaboration World Map Metacognition of Mathematics, (5) Network Visualization VOSViewer on Metacognition of Mathematics, (6) Emotional Intelligence & Mathematics in VOSViewers.

Theme 1 : Overview of Metacognition Within Bibliometrix Analysis

The Overview presents a summary of the results of the bibliometrix analysis, including the number of publications, authors, and journals involved, as well as key statistics such as publications per year and citation distribution. It also identifies research trends and patterns and provides data visualizations to understand research dynamics and relationships between data elements easily.

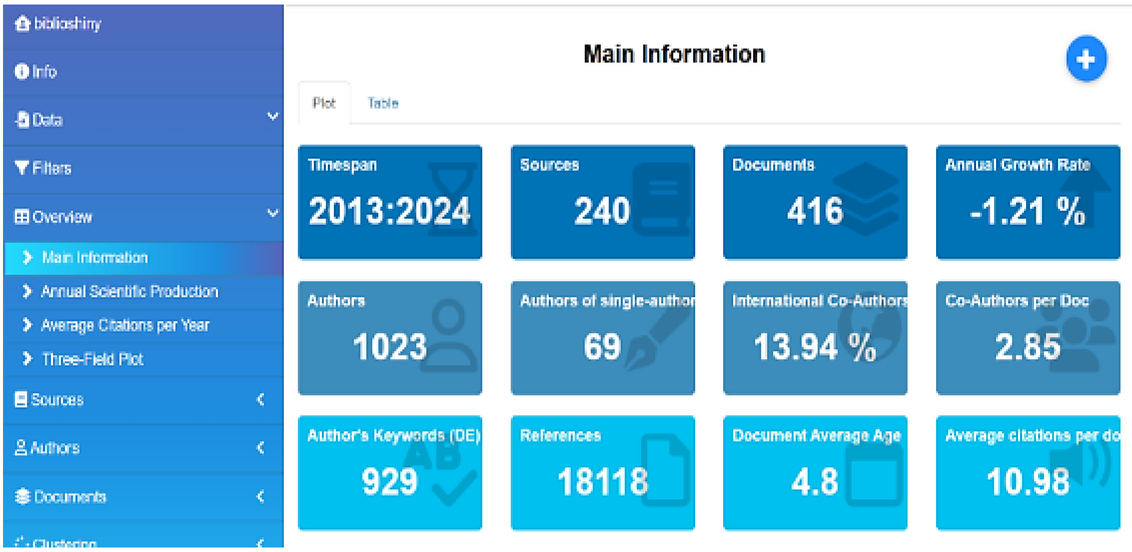

Figure 2. Main information

Figure 2 shows the information related to articles focusing on metacognition of mathematics. We can observe that over the past decade, from 2013 to 2024, 416 articles were published in Scopus from 240 sources with 1023 authors. Additionally, it reveals that metacognition of mathematics has drawn the attention of various international researchers, with 13.94% of all articles involving international collaborations.

The data shows that each article on average involves 2.85 co-authors, indicating significant teamwork in advancing knowledge in this field. Furthermore, 929 author keywords (DE) were used to identify critical mathematics metacognition-related topics, demonstrating the diversity and complexity of research approaches. The references cited in this literature reach 18118, confirming a broad scientific foundation used to support development and analysis in this topic. With an average document age of 4.8 years, this bibliometric analysis highlights the contemporaneity of the literature supporting research on metacognition of mathematics, indicating that this topic remains relevant and evolving despite a slight annual growth rate decline of 1.21%.

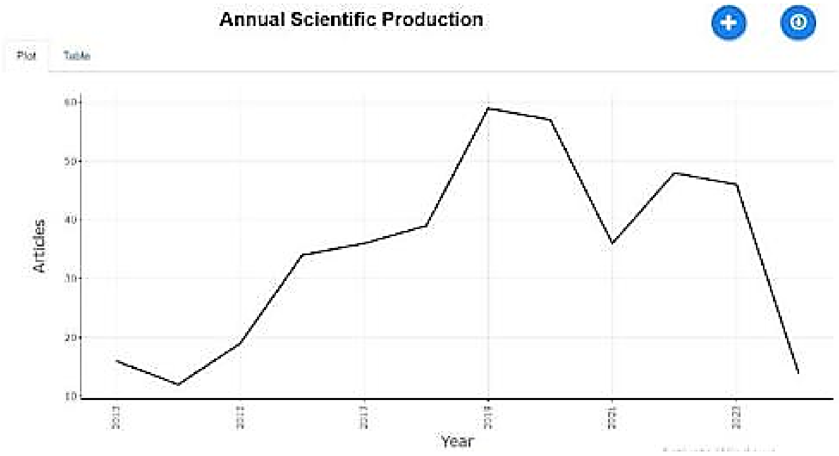

Figure 3. Annual scientific production

Figure 3 presents data on articles about metacognition of mathematics published per year. The graph above shows that publications on metacognition of mathematics experienced a significant increase from 2014 to 2019. This could be attributed to the growing recognition of the importance of metacognition in learning processes and cognitive development. 2021, there was a sharp decline in the number of publications, dropping from 57 in 2020 to 36 in 2021. This decline is likely due to the initial impact of the COVID-19 pandemic, which disrupted many aspects of life, including academic research. The global prevalence and burden of mental health issues, exacerbated by the COVID-19 pandemic, have raised significant concerns about the potential impact on metacognition (Santomauro et al., 2021). However, in 2022, the trend of metacognition in mathematics saw an increase again, although not as substantial as in 2019. It can be concluded that the research trend on metacognition of mathematics has experienced a shift in interest. Researchers need to understand and analyze research trends in the field of metacognition as a basis for planning future research endeavors.

The graph above shows the average citations per year. The average citations peaked in 2014, with about five citations per year on average for publications that existed in that year. After the peak in 2014, there was a sharp decline in average citations until around 2016. From 2016 to 2019, there were fluctuations in average citations, with slight increases in some years but no return to the peak in 2014. After 2019, the graph shows a continuing downward trend until 2024, with very low average citations at the end of this period.

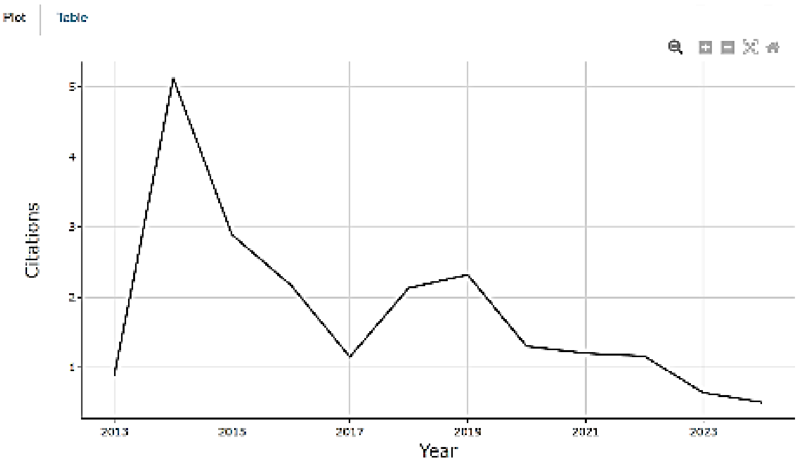

Figure 4. Average citations per year

Theme 2. Tren Topic Metacognition

Topic trends in bibliometrix show patterns and changes in research focus through the analysis of bibliometric data, such as publications, citations, and keywords. By analyzing this data, bibliometrix helps identify how research interests evolve over time, illustrates the relationship between authors and topics, and maps changes in research focus and collaboration. As shown in figure 5.

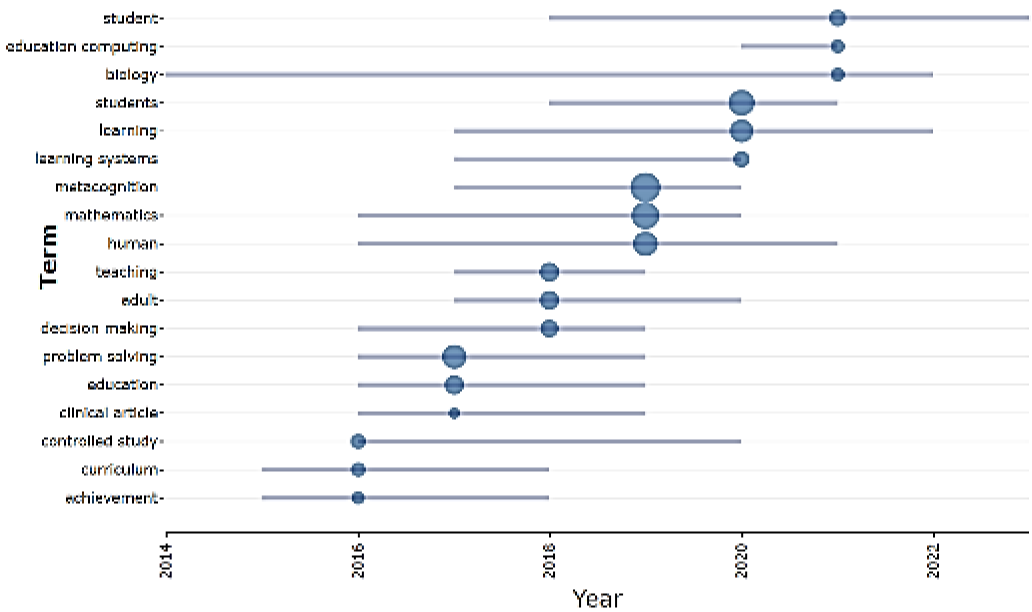

Figure 5. Tren topic metacognition

Figure 5. shows the trend of research topics related to metacognition in the context of mathematics from 2014 to 2022. The graph shows that the topics of "metacognition" and "mathematics" started to receive increased attention around 2016 and continued to grow until 2022. This topic is often associated with other terms such as "learning systems," "problem-solving," and "decision making," indicating that research on

metacognition in mathematics not only focuses on individual reflective abilities but also the application of strategies in problem-solving and decision-making. This signifies the importance of metacognition in helping students understand and master mathematical concepts through a more strategic and reflective approach. These findings reflect a trend of increasing attention to how metacognition can influence the effectiveness of mathematics learning and student learning outcomes.

Theme 3. Co-Citation Network

A co-citation network is an analytical tool in bibliometrix that maps the relationship between publications based on how often they are co-cited. In this network, frequently co-referenced publications are connected by lines, with the nodes representing the publications. This analysis helps identify clusters of related research, influential works, and knowledge structures within a field, as well as visualize the interconnectedness of ideas and concepts in the scientific literature. As shown in figure 6.

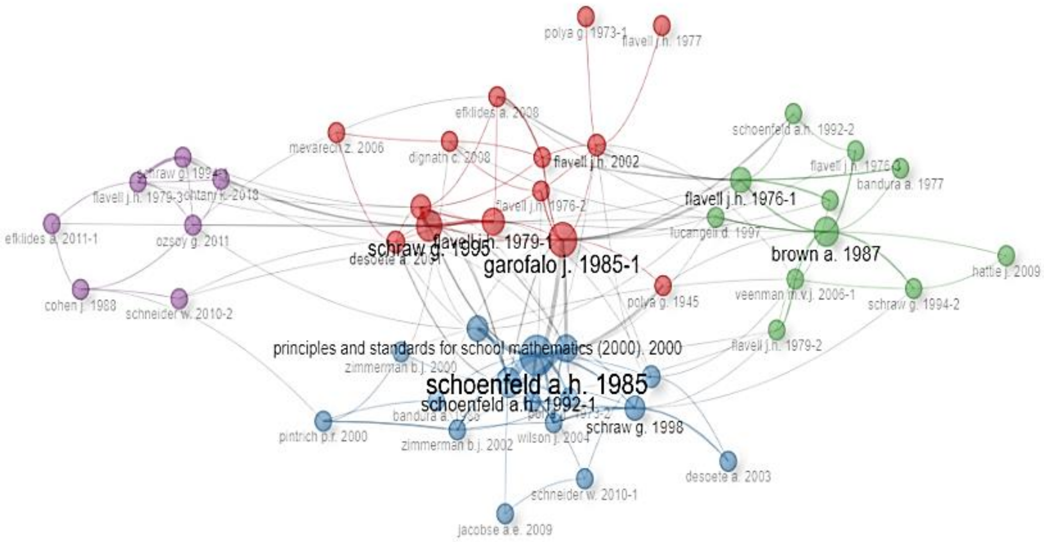

Figure 6. Co-citation of cited authors from 416 Scopus search results for metacognition of mathematics. Fractional counting was selected, meaning that publications with a long reference list (e.g., review articles) play a less critical role in constructing a co-citation network

The co-citation network of authors cited in mathematical metacognition is shown in Figure 6. R-Studio selected 48 nodes with the highest total strength and categorized them into 4 clusters. The first cluster (red) includes 14 nodes, the second cluster (blue) consists of 16 nodes, the third cluster (green) contains 11 nodes, and the fourth cluster (purple) includes seven nodes. Increasing the number of clusters in a co-citation network indicates a more complex and diverse range of topics or groups of documents identified in academic literature. Generally, an increase in the number of clusters can indicate greater diversification in topics or sub-fields related to specific research on metacognition of mathematics. This may reflect various approaches or perspectives in understanding the metacognition of mathematics and the diversity of contributions and perspectives from different authors or research groups. For example, Flavell J.H. 1979-1 is a node in the co-citation network representing scholarly work frequently cited with other works in academic literature, categorized within the first cluster (red). This indicates that Flavell J.H.'s work is often cited alongside works within the same group or topic. Another example is Ohtani K. 2018, included in the co-citation network's fourth cluster (purple). This suggests that Ohtani K.'s work is frequently cited with other works grouped within this cluster, indicating a close relationship in a specific topic or theme related to the metacognition of mathematics. Understanding these nodes and their clustering in the co-citation network helps identify communities of researchers or particular topics that are prominent in academic literature, providing insights into the interconnectedness and influence of specific works in the field of research.

Theme 4. Countries' Collaboration World Map Metacognition of Mathematics

The World Country Collaboration Map in the context of research on metacognition in mathematics illustrates how different countries work together to study and develop knowledge in this area. The map shows the international network of collaborations between countries contributing to the study of metacognition in mathematics, with lines connecting countries based on the number and intensity of their collaborations. Through this map, it is possible to identify countries leading the way in mathematics metacognition research and how knowledge and innovations in this field are shared worldwide. By understanding global collaboration patterns, researchers can see how ideas and approaches in mathematical metacognition spread and develop internationally, as well as identify potential partnerships and opportunities for further research.

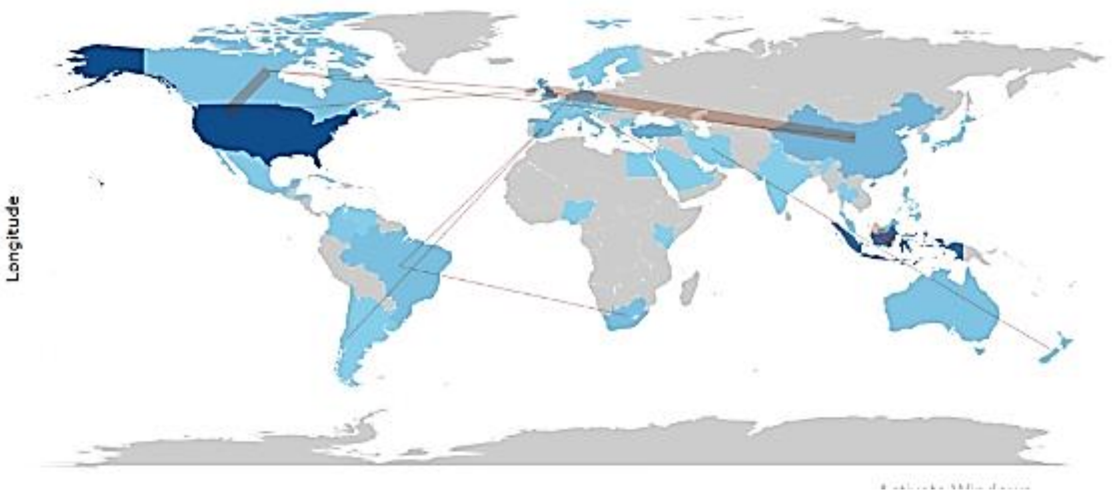

Figure 7. Total citations per country

Figure 7 depicts the collaboration network among 48 productive countries in research on metacognition of mathematics from 416 Scopus search results. The thickness between the two countries indicates the strength of collaboration between them. The nodes' size also represents each country's contribution (larger nodes indicate higher contribution in terms of co-authorship collaboration). Items with the same color indicate their relatedness (i.e., within the same cluster). In the figure, there are connecting lines between countries, which represent the frequency of collaboration. The line's thickness indicates whether the collaboration frequency is high or low. If the frequency of collaboration between two countries in the context of research on "metacognition of mathematics" the line is thick, then the frequency of collaboration is high; for example, "Indonesia to Malaysia with high frequency" indicates that there are many documents or studies where researchers or institutions from both countries are actively collaborating in research on metacognition of mathematics. This pattern also applies to other countries.

Theme 5. Network Visualization VOSViewer on Metacognition of Mathematics

Network Visualization using VOSviewer provides a comprehensive visual overview of the structure of metacognition research in mathematics. VOSviewer facilitates the mapping of collaboration networks between researchers, institutions, and countries, displaying how they are connected through joint publications. In addition, the tool illustrates relationships between keywords, identifying how key terms in metacognition research are interconnected, which helps in finding key themes and concepts. VOSviewer also enables citation network analysis to identify important works and key trends in the field. By grouping articles and authors based on similar themes, the tool provides an understanding of the research structure and emerging areas. Overall, VOSviewer helps understand mathematical metacognition research dynamics by uncovering patterns, relationships, and emerging trends in the scientific literature.

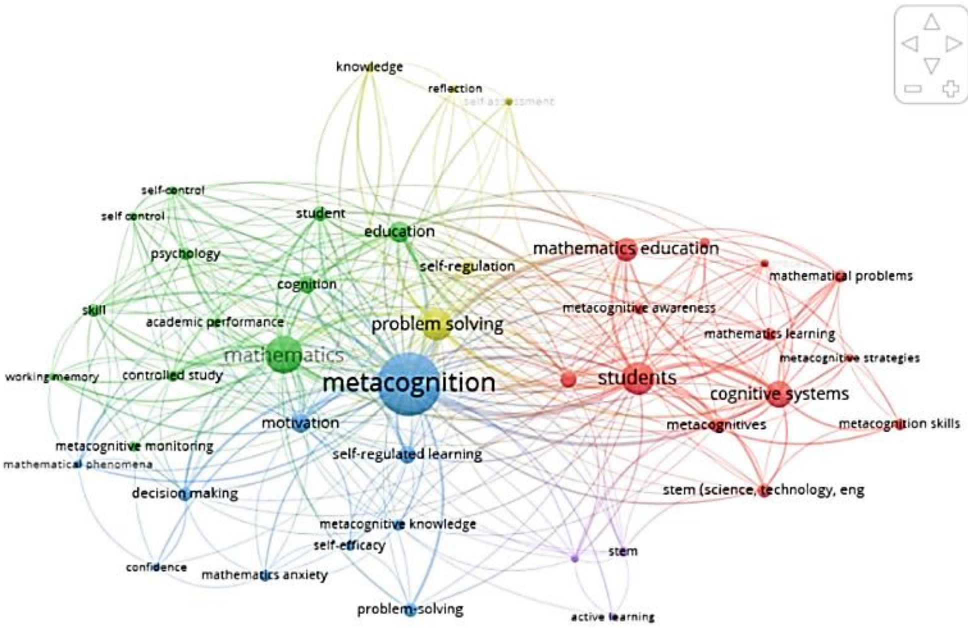

Figure 8. Network visualization VOSViewers

Figure 8 depicts the main themes with related research variables in articles on metacognition of mathematics between 2013 and 2024. Five clusters categorize metacognitive variables based on interconnected terms highlighted in blue, red, yellow, green, and purple. The clusters of keywords are depicted based on their frequency of co-occurrence in articles or literature, reflecting common topics or themes in the context of research on metacognition of mathematics. For example, in the first cluster (Blue), keywords such as "metacognition," "motivation," "problem-solving," "metacognitive knowledge," etc., are grouped. Keywords within the same cluster indicate their frequent appearance together in articles or research on metacognition of mathematics. For instance, "metacognition" and "problem-solving" are often closely associated with understanding how metacognition influences students' abilities to solve mathematical problems, as explored in studies such as those conducted by (Rusmini et al., 2020) “Analysis of the role of metacognition based on process complex problem solving against the mathematical understanding of statistics in the era pandemic COVID-19”, (Cozza & Oreshkina, 2013) "Cross-Cultural Study of Cognitive and Metacognitive Processes During Math Problem Solving," etc.

Using clustering systems, researchers can observe how different concepts are interconnected and how these relationships evolve in academic literature. For example, an increased association between "self-regulation" and "problem-solving" may indicate that research is exploring more deeply how students' self-regulation affects their abilities in solving mathematical problems, or there might be new approaches to understanding the relationship between these two concepts.

In the figure, there are also data points representing variables of different sizes; the more significant the variable point, the more frequently it is used. Thus, we can infer that variables such as "student," "mathematics," "cognitive systems," and "problem-solving" are commonly utilized by researchers in studying metacognition of mathematics.

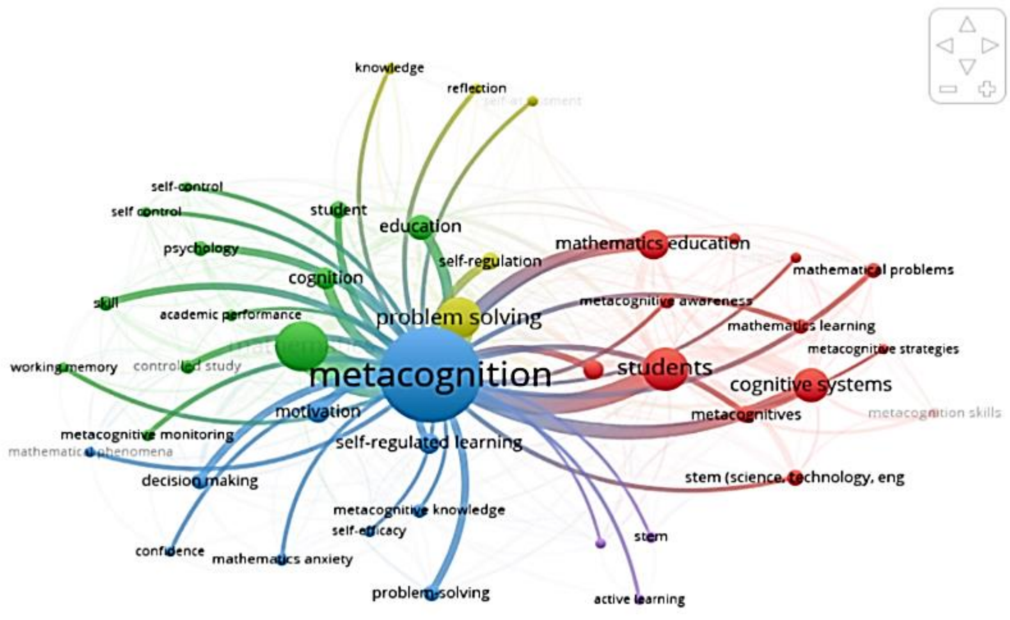

Figure 9. Metacognition on network visualization VOSViewers

In Figure 9, variables that researchers have used in studies of metacognition of mathematics are presented. The proximity and thickness of the lines connecting two variables indicate how frequently they appear together. Metacognition is connected to variables such as student, a cognitive system, problem-solving, working memory, self-efficacy, active learning, reflection, etc. It can be observed that researchers quite commonly use variables like metacognition and problem-solving. The relationship between metacognition and problem-solving is reciprocal, as acquiring and applying metacognitive strategies can enhance an individual's problem-solving capabilities. In contrast, successful problem-solving experiences can, in turn, further develop and refine one's metacognitive skills (Doulik et al., 2015). Therefore, metacognition of mathematics is related to the process of problem-solving.

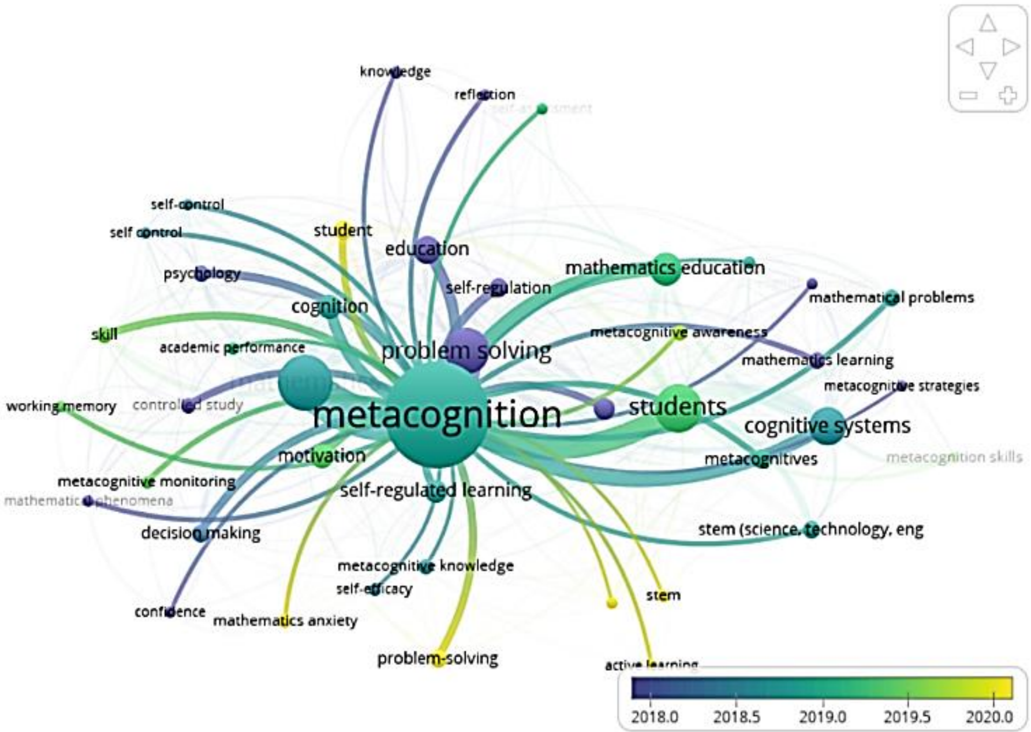

Figure 10. Metacognition on overlay visualization VOSViewers

In Figure 10, overlay visualization depicts research in metacognition. The different colors of the variable points indicate how long ago the articles were published; darker colors represent variables that have been used for a more extended period. The figure highlights newer variables related to metacognition in 2020 in yellow, including active learning, problem-solving, mathematics anxiety, students, and mathematics awareness. These variables signify renewed research themes in the metacognition of mathematics.

Theme 6. Emotional Intelligence & Mathematics in VOSViewers

Emotional Intelligence & Mathematics in VOSviewer refers to the network analysis linking the concept of emotional intelligence with mathematics, which is done using the VOSviewer tool. The visualization generated by VOSviewer helps understand how emotional intelligence concepts relate to mathematics. The network map shows how research on the influence of emotional intelligence on mathematical understanding is spread in the literature, as shown in Figure 11. By studying this visualization, researchers can identify significant trends in research on emotional intelligence and mathematics, including areas that have been extensively researched and gaps that may exist in the literature. It also helps identify research clusters or sub-fields that combine these two topics.

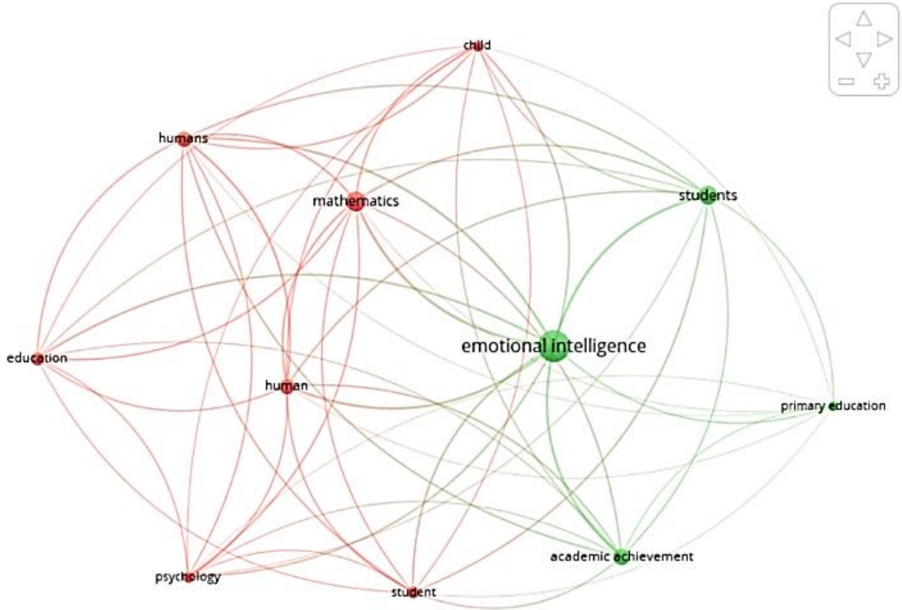

Figure 11. Network visualization VOSViewers of emotional intelligence & mathematics

Figure 11 shows a visual network representation of emotional intelligence and mathematics over the past decade. In the last ten years, 79 newly published articles on emotional intelligence and mathematics in Scopus have been published. Variables associated with emotional intelligence include mathematics, human, student, academic primary education, students, child, humans, education, psychology, and human.

Meta-Theme. Mathematical Problem-Solving Process Reviewed from Emotional Intelligence through Metacognition

The analysis results conducted through VOSviewers and Bibliometrix R-Package show a comprehensive picture of the development of metacognition research in mathematics. Based on the findings obtained, it was found that the trend of metacognition research in mathematics continued to increase from 2013 to 2019 and experienced a significant decline from 2020 to 2021. Still, the trend of metacognition in mathematics again attracted the attention of researchers in 2022; overall, according to Figure 2, the trend of metacognition in mathematics decreased by 1.21%. Articles on Scopus show that many researchers agree that metacognition in mathematics affects the problem-solving process, this can be seen in Figure 8 and Figure 9, where the variables of metacognition and problem-solving are often used together in research, thus showing a close relationship between understanding the thinking process (metacognition) and the practical ability to solve mathematical problems (problem-solving). Further research can deepen the understanding of how the interaction between these two concepts affects the quality of mathematics learning at various levels of education. One factor that has been found to play a crucial role in mathematical problem-solving is metacognition, which refers to an individual's awareness and regulation of their own cognitive processes. Metacognition allows students to monitor their understanding, identify weaknesses, and adaptively employ appropriate problem-solving strategies (Jiang et al., 2021). This research integrates two main concepts: metacognition, which involves self-awareness of thinking processes, and emotional intelligence, which includes the management of emotions and motivation. Both concepts are crucial for effective mathematics learning in problem-solving contexts.

The variables that are the latest research trends shown in Figure 10, including active learning, problem-solving, mathematics anxiety, student, and mathematics awareness, are included in the renewal of research on the theme of metacognition in mathematics. These trends indicate a greater focus of researchers on approaches that actively engage learners in the learning process and provide new insights into how to overcome mathematics anxiety and develop metacognitive awareness in the context of mathematics. Furthermore, Figure 11 highlights the relationship between emotional intelligence and mathematics learning. The findings show that variables related to emotional intelligence such as emotional intelligence and psychology often appear in the context of mathematics learning, indicating the importance of considering non-cognitive aspects in mathematics education. This emphasis on non-cognitive aspects is enlightening and encourages a more holistic approach to mathematics education. Moreover, both metacognition and emotional intelligence have been associated with various positive outcomes, including academic achievement, social competence, and workplace success (Brackett et al., 2011; Mayer et al., 2000; Mayer & Salovey, 1993; Nkeobuna Nnah Ugoani., 2021). It can be concluded that there is a connection between the process of solving mathematical problems in terms of emotional intelligence through metacognition. This indicates that further research in this connection can provide new insights on how to improve mathematics teaching by paying attention to the emotional aspects of students.

▪ CONCLUSION

Based on the analysis using VOSviewers and Bibliometrix R-Package, research on metacognition of mathematics has shown a decline of 1.21% over the decade from 2013 to 2024. Nevertheless, researchers have widely recognized the importance of metacognition in mathematical problem-solving processes. Studies indicate that variables of metacognition and problem-solving are frequently used together, suggesting a close relationship between understanding cognitive processes (metacognition) and practical abilities to solve mathematical problems. This study also emphasizes the integration between metacognition and emotional intelligence in the context of mathematics learning. Findings that emotional intelligence variables such as emotional intelligence and psychology often appear in the literature on mathematics education highlight the need to consider non-cognitive aspects in mathematics teaching strategies. Previous research has shown that metacognition and emotional intelligence positively contribute to academic achievement, social competence, and workplace success. Therefore, the findings of this study can serve as a reference for other researchers to conduct related research based on the analysis by the researchers. Additionally, opportunities for other variables related to metacognition as references for other researchers, which have not been extensively explored by previous researchers but are relevant to current generational trends, include active learning, problem-solving, mathematics anxiety, student, and mathematics awareness.

▪ REFERENCES

Alfiyah, N., & Siswono, T. Y. E. (2014). *Identifikasi kesulitan metakognisi siswa dalam memecahkan masalah matematika* [identification of students' metacognition difficulties in solving mathematics problems]. MATHEdunesa, 3(2), 131–138.

Anderson, N. J. (2008). Metacognition and good language Learners. In C. Griffith, Lessons from Good Language Learners, pp. 99-109. Cambridge, Cambridge University Press.

Anggo, M. (2011). *Pemecahan masalah matematika kontekstual untuk meningkatkan kemampuan metakognisi siswa* [contextualized mathematics problem solving to improve students' metacognition skills]. Edumatika, 1(2), 35–42. https://online-journal.unja.ac.id/index.php/edumatica/article/view/182

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Brackett, M. A., Rivers, S. E., & Salovey, P. (2011). Emotional intelligence: Implications for personal, social, academic, and workplace success. Social and Personality Psychology Compass, 5(1), 88–103. https://doi.org/10.1111/j.1751-9004.2010.00334.x

Brick, N., MacIntyre, T., & Campbell, M. (2015). Metacognitive processes in the self-regulation of performance in elite endurance runners. Psychology of Sport and Exercise, pp. 19, 1–9. https://doi.org/10.1016/j.psychsport.2015.02.003

Burnham, J. F. (2006). Scopus database: A review. Biomedical Digital Libraries, 3, 1–8. https://doi.org/10.1186/1742-5581-3-1

Cozza, B., & Oreshkina, M. (2013). Cross-cultural study of cognitive and metacognitive processes during math problem solving. School Science and Mathematics, 113(6), 275–284. https://doi.org/10.1111/ssm.12027

Damayanti, R., Sunardi, Yuliati, N., Karimah, R., & Albab, A. U. (2020). Students' metacognitive ability in solving quadrilateral problems based on adversity quotient. Journal of Physics: Conference Series, 1538(1). https://doi.org/10.1088/1742-6596/1538/1/012077

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133(March), pp. 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Doulik, P., Skoda, J., & Rican, J. (2015). Metacognitive strategies: asset to efficient learning and education. Slavonic Pedagogical Studies Journal, 4(1), 62–81. https://doi.org/10.18355/pg.2015.4.1.62-81

Drigas, A. S., & Papoutsi, C. (2018). A new layered model on emotional intelligence. Behavioral Sciences, 8(5), 1–17. https://doi.org/10.3390/bs8050045

Efklides, A. (2006). Metacognition and affect: What can metacognitive experiences tell us about the learning process? Educational Research Review, 1(1), 3–14. https://doi.org/10.1016/j.edurev.2005.11.001

Fernandez, M. L., Hadaway, N., & Wilson, J. W. (1994). Problem-solving: Managing it all. Mathematics Teacher, 87(3), 195–199.

Goleman, D., Boyatzis, R., & McKee, A. (2002). The emotional reality of teams. Journal of Organizational Excellence, 21(2), 55–65. https://doi.org/10.1002/npr.10020

Irdayani Hamid, Helmi Abdullah, K. (2020). *Pengembangan tes pengetahuan metakognitif berbasis fisika dengan model two-tier multiple choice* [development of physics-based metacognitive knowledge test with two-tier multiple choice model]. 110–113.

Israria, W. O., & Misu, L. (2014). *Pengaruh kecerdasana emosional terhadap pemahaman matematis pada siswa kelas VIII Di SMP Negeri 5 Kendari* [the effect of emotional intelligence on mathematical understanding in class VIII Students at SMP Negeri 5 Kendari]. 2(3), 145–164.

Jiang, Y., Gong, T., Saldivia, L. E., Cayton-Hodges, G., & Agard, C. (2021). Using process data to understand problem-solving strategies and processes for drag-and-drop items in a large-scale mathematics assessment. Large-Scale Assessments in Education, 9(1). https://doi.org/10.1186/s40536-021-00095-4

Kaas, R., Laeven, R., Lin, S., Tang, Q., Willmot, G., & Yang, H. (2018). IME's Editorial Board. Insurance: Mathematics and Economics, p. 78, A1–A3. https://doi.org/10.1016/j.insmatheco.2017.08.008

Kartika, H., & Firmansyah, D. (2018). *Peran kesadaran metakognitif terhadap kemampuan pemecahan masalah matematis* [the role of metacognitive awareness on mathematical problem solving ability]. Theorems (The Original Research of Mathematics), 3, 1–6.

Kurniawan, P., & Wijayanti, P. (2022). *Profil metakognisi siswa sma dalam memecahkan masalah matematika materi fungsi komposisi dan fungsi invers ditinjau dari kemampuan siswa* [metacognition profile of senior high school students in solving mathematical problems on composition function and inverse function material based on student ability]. MATHEdunesa, 11(3), 644–656. https://doi.org/10.26740/mathedunesa.v11n3.p644-656

Livingston, J. A. (1997). Metacognition: an overview. Psychology, pp. 13, 259–266. http://gse.buffalo.edu/fas/shuell/CEP564/Metacog.htm

Mahdavi, M. (2014). An overview: Metacognition in education. International Journal of Multidisciplinary and Current Research, 2(6), 529–535. http://ijmcr.com

Masnia, Waluya, S. B., Dewi, N. R., & Sohilait, E. (2023). *Proses berpikir aljabar berdasarkan metakognisi* [algebraic thinking process based on metacognition]. FIBONACCI: Jurnal Pendidikan Matematika dan Matematika, 9(1), 89–94.

Mayasari, D., Utomo, D. P., & Cholily, Y. M. (2018). *Analysis metakognisi siswa dalam memecahkan masalah matematika ditinjau dari tipe kepribadian hippocrates* [analysis of students' metacognition in solving mathematics problems given hypocrites personality type]. Jurnal Kajian Pembelajaran Matematika, 2(1), 10. http://journal2.um.ac.id/index.php/jkpm

Mayer, J. D., & Salovey, P. (1993). The intelligence of emotional intelligence. Intelligence, 17(4), 433–442. https://doi.org/10.1016/0160-2896(93)90010-3

Mayer, J. D., Salovey, P., & Caruso, D. (2000). Models of emotional intelligence [modelos de la inteligencia emocional]. Handbook of Intelligence, 396–420.

Nkeobuna Nnah Ugoani, J. (2021). Emotional intelligence and its impact on effective human resource management. International Journal of Economics and Financial Research, 7(71), 5–13. https://doi.org/10.32861/ijefr.71.5.13

Nurjamil, D., & Saepulloh, A. (2023). *Pengembangan bahan ajar matematika beroerientasi high order thinking skill (hots) matematika yang memfasilitasi kecerdasan emosional dan kecerdasan spritual* [development of high order thinking skill (hots) oriented mathematics teaching materials that facilitate emotional intelligence and spiritual intelligence]. Jurnal THEOREMS (The Original Research of Mathematics), 7(2), 286. https://doi.org/10.31949/th.v7i2.4452

Ormrod, J. E. (2006). Essentials of educational psychology. Essex: Pearson Merrill Prentice Hall.

Özcan, Z. Ç. (2014). Assessment of metacognition in mathematics: which one of two methods is a better predictor of mathematics achievement? International Online Journal of Educational Sciences, 6(1), 49–57. https://doi.org/10.15345/iojes.2014.01.006

Pólya, G. (1945/1973). How to solve it. Princeton, NJ: Princeton University.

Porumb, I., & Manasia, L. (2015). A Clusterial conceptualization of metacognition in students. Educatia in Societatea Contemporana.Aplicatii, May, 33--44.

Prasetyoningrum, F. D., & Mahmudi, A. (2017). *Pengaruh strategi metakognitif terhadap kemampuan pemecahan masalah matematis siswa kelas VIII di SMP Negeri 6 Yogyakarta* [The effect of metacognitive strategies on mathematical problem solving skills of grade VIII students at SMP Negeri 6 Yogyakarta]. Jurnal Pendidikan Matematika, 6(4), 19–27.

Rahman, M. (2019). 21st Century skill " problem solving ": defining the concept. 2(1).

Riani, Asyril, & Untu, Z. (2022). *Metakognisi siswa dalam memecahkan masalah matematika* [students' metacognition in solving math problems]. Primatika, 51–60.

Rusmini, R., Harahap, F. S. W., & Guntoro, F. R. (2020). Analysis of the role of metacognition based on complex problem-solving processes against the mathematical understanding of statistics in the era of the COVID-19 pandemic. Journal of Physics: Conference Series, 1663(1). https://doi.org/10.1088/1742-6596/1663/1/012039

Safitri, P. T., Yasintasari, E., Putri, S. A., & Hasanah, U. (2020). *Analisis kemampuan metakognisi siswa dalam memecahkan masalah matematika model pisa* [analysis of students' metacognition ability in solving pisa model mathematics problems]. Journal of Medives : Journal of Mathematics Education IKIP Veteran Semarang, 4(1), 11. https://doi.org/10.31331/medivesveteran.v4i1.941

Santomauro, D. F., Mantilla Herrera, A. M., Shadid, J., Zheng, P., Ashbaugh, C., Pigott, D. M., Abbafati, C., Adolph, C., Amlag, J. O., Aravkin, A. Y., Bang-Jensen, B. L., Bertolacci, G. J., Bloom, S. S., Castellano, R., Castro, E., Chakrabarti, S., Chattopadhyay, J., Cogen, R. M., Collins, J. K., … Ferrari, A. J. (2021). Global prevalence and burden of depressive and anxiety disorders in 204 countries and territories in 2020 due to the COVID-19 pandemic. The Lancet, 398(10312), 1700–1712. https://doi.org/10.1016/S0140-6736(21)02143-7

Sari, N. I., Amrullah, A., Azmi, S., & Sarjana, K. (2021). *Analisis tingkat metakognisi peserta didik dalam memecahkan masalah matematika* [analysis of students' metacognition level in solving mathematics problems]. Griya Journal of Mathematics Education and Application, 1(1), 36–43. https://doi.org/10.29303/griya.v1i1.10

Siagian, M. V, Saragih, S., & Sinaga, B. (2019). Development of learning materials oriented on problem-based learning model to improve students ' mathematical problem solving and metacognition ability. 14(2), 331–340.

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

van Eck, N. J., & Waltman, L. (2014). Visualizing bibliometric networks. In Measuring Scholarly Impact. https://doi.org/10.1007/978-3-319-10377-8_13

van Eck, N. J., & Waltman, L. (2023). VOSviewer Manual version 1-6-19. Leiden: Univeristeit Leiden, January, 54. http://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.1.pdf

Wellman, H. (1985). The origins of metacognition. In D. L. Forrest-Pressley, G. E. MacKinnon, and T. G. Waller, Metacognition, Cognition, and Human Performance, volume 1, Theoretical Perspectives, pp. 1–31. Academic Press, Inc

Zhou, D., Du, X., Hau, K., Luo, H., Feng, P., & Liu, J. (2019). Teacher-student relationship and mathematical problem-solving ability : mediating roles of self-efficacy and mathematical anxiety. Educational Psychology, 0(0), 1–17. https://doi.org/10.1080/01443410.2019.1696947