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Mathematical Abilities of Elementary School Students: a Bibliometric Analysis

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ABSTRACT

This study aims to investigate the research trends on the mathematical abilities of elementary school students. The analysis focuses on research articles in the field of mathematics education in elementary schools based on the Scopus database from 2003 to 2022. The obtained data is then inputted into the VOSviewer application to obtain a data distribution based on a co-occurrence map. The co-occurrence map is created based on the text data of the mathematics education articles in elementary schools obtained from the Scopus database and analyzed using bibliometric criteria that reveal the structure and characteristics of elementary school students. This study provides evidence of the research trends on the mathematical education of elementary school students based on the mapping of data that emerges in the Scopus database. These research trends are expected to assist researchers in obtaining information on which areas are more needed to plan their future research related to the mathematical abilities of elementary school students.

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1. INTRODUCTION

Mathematics is a universal science that plays a crucial role in the utilization of modern technology [8], [18], [10]. In addition to its role in technology, mathematics also has connections to various disciplines. In practice, mathematics is presented in various formal schools for learning purposes. The mathematics lessons taught in formal schools have a structured content or mathematical curriculum that progresses at each institution. The content presented in mathematics lessons has interconnections with one another and serves as a prerequisite for explaining subsequent content [7], [15], [23]. As a field that establishes connections between different concepts, students are expected to have the ability to solve advanced mathematical problems based on the content they have learned previously [23].

The National Council of Teachers of Mathematics (NCTM) [20] establishes five standards of mathematical proficiency that students should possess in mathematics education, which are: (1) problem-solving skills, the ability to use mathematical concepts and skills to solve problems; (2) communication skills, the ability to convey mathematical ideas and concepts effectively; (3) connection skills, the ability to make connections between mathematical concepts, both within mathematics itself and with other disciplines (other subjects and real-life situations); (4) reasoning skills, the ability to provide reasoning to evaluate arguments, both inductive and deductive; and (5) representation skills, the ability to use methods, models, approaches, techniques, tools, and concepts to analyze and describe mathematical data.

Each standard of mathematical proficiency has its own stages and indicators in the learning process. These stages facilitate teachers in achieving the desired goals of mathematics education and help students in understanding the learned content [14]. The most important stages in problem-solving are understanding the problem, analyzing it, and checking the answer [21], [14]. Furthermore, divided problem-solving into four indicators, which are (1) understanding the problem; (2) devising a plan; (3) implementing the plan; and (4) evaluation [14]. Mastery of fundamental concepts is one of the key factors in successfully developing students' problem-solving abilities. In addition to the standards of mathematical proficiency, NCTM also divides mathematics education into five domains of study, which are number, algebra, geometry, measurement, and statistics [20]. Based on these five standards of mathematical proficiency, students are expected to solve problems in these domains according to the established standards. With a mastery of these five standards, students can easily understand mathematics in the learning process or apply it to everyday life.

Mathematical abilities are important to be taught at the elementary school level, particularly the understanding and application of basic mathematical concepts. This is emphasized in the goals of mathematics education, which include understanding mathematical concepts, the relationships between mathematics itself and other related fields, and applying them to solve specific problems accurately. The ability to solve mathematical problems or problems outside the context of mathematics is called Mathematical Power [16]. This power includes the ability to explore, conjecture, and reason logically to solve non-routine problems, communicate through mathematics, and connect mathematical ideas with other intellectual activities [24]. The essence of achieving mathematical abilities lies in developing problem-solving, communication, reasoning, and connection skills [24]. Additionally, mathematical abilities can enhance students' confidence in evaluating and using accurate information [16], [12]. Therefore, mathematics is included as a mandatory subject in all aspects of formal education, from elementary school to higher education, in order to equip students with logical, analytical, systematic, critical, and creative thinking skills.

Research in the field of mathematics education in schools has been extensively conducted by researchers, incorporating various tools and learning media. As stated in the past decade, research in mathematics education has focused on various perspectives, ranging from the use of technology, assessment, learning disabilities, learning models, learning methods, learning approaches, learning techniques, to mathematical representations [9]. The use of technological devices in mathematics learning provides diverse pathways for students to understand mathematics [4]. However, the use of these tools does not guarantee the development of collaborative approaches in learning due to the incomplete support of the learning environment and students' characteristics. This has made the use of technology in mathematics education a popular issue in the past decade. In addition to the use of technology in mathematics learning, measuring mathematical performance has also become an important issue, such as the development of achievement tests to predict mathematics learning outcomes [1], [3], [19]. Recent research has focused on large-scale assessments and computer-based tests [29]. These studies not only cover specific issues such as diagnostic models, diagnostic tools, and multilingual assessments but also investigate underprivileged groups such as students with special needs and immigrant students.

In the 2010s, studies in mathematics education also focused on different methods, approaches, and training for various mathematics learning disabilities. As emphasized in the literature on mathematics education, there are also no clear boundaries among related disciplines [6]. In the literature review, research in mathematics education has been extensively conducted in recent years, and the number of studies continues to increase, covering various important issues. However, the purpose of this study is to uncover research trends in mathematics education, particularly in primary schools, between 2003 and 2022. This trend study is expected to provide insights into areas that require further research related to mathematics education in primary schools and to contribute to further research by addressing the issues revealed in this study.

2. RESEARCH METHODS

The current study investigates research trends in mathematics education in primary schools, focusing on students' mathematical abilities indexed in the Scopus database over the past 20 years. In recent years, powerful methods have been developed to discover and analyze research in the literature and to construct literature analysis systems [4]. Bibliometric analysis is used for statistical evaluation of articles, identifying trends in studies related to mathematics education by examining co-occurring keywords [5]. It also includes publication output analysis, cluster analysis, keyword analysis, cluster analysis, and mapping of interrelated variables or themes [9], [25]. In this way, it is possible to obtain information about trends in research studies through a retrospective review [9].

2.1 Research Design

This research design consists of four stages: exploration, visualization, identification, and verification, as shown in Figure 1. The exploration phase involves scrutinizing the Scopus database; the visualization stage involves visualizing the data using VOSviewer software; the identification stage involves naming the networks; and the verification stage involves finding evidence [9]. These stages provide a pathway for searching related articles and characterizing clusters based on the emerging terms.

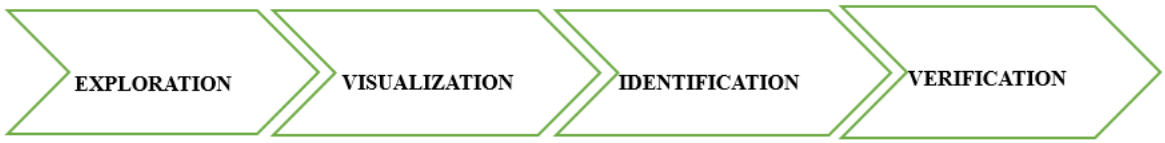

Fig. 1. Research Stages

2.2 Data Collection

The data used in this study consists of all articles gathered from the Scopus database based on the search criteria from 2003 to 2022. The search for articles was specifically conducted in English language and indexed in the Social Science Citation Index (SSCI), Social Science Citation Expanded (SCIE), and Emerging Sources Citation Index (ESCI). After applying the predetermined criteria and considering which articles could be included in this study, a total of 239 documents related to elementary school students' mathematical abilities were identified and further analyzed using bibliometric methods. Details regarding the exploration stage are presented in Table 1 below.

Table 1. Summary of search criteria

Criteria	
Data source	Scopus
Field	Topic (title, abstract, author keywords, and additional keywords)
Search terms	“Mathematics Ability” AND “Primary School”
Citation indexes	SSCI, SCI Expanded, ESCI
Publication period	2003-2022
Document types	Articles, conference papers, conference reviews
Language	English

2.3 Data Analysis

The data analysis in this study utilizes descriptive analysis conducted through the Scopus system. Bibliometric analysis is performed using the VOSviewer software. The VOSviewer software provides statistical information about items, connections between items, and the relationships among item clusters that occur most frequently during bibliometric analysis [26]. Through this software, bibliometric maps can be created, such as network maps that show the connections between items and group them into clusters based on the strength of their connections, overlay maps that display color bars depending on changes over the years, and density maps that indicate the frequency of item occurrences with frequently appearing keywords in publications [9]. The defined criteria in the scope of this research involve transferring data from 298 accessed articles from the Scopus database to the VOSviewer software, conducting bibliometric analysis, and creating mappings.

3. RESULT AND DISCUSSION

This section presents the findings obtained during the research based on the stages in the research design.

3.1 Exploration

The exploration phase involves identifying studies in the Scopus database according to the predetermined criteria within the research scope and examining them from various aspects. Firstly, the article trends achieved during the past twenty years between 2003 and 2022 are explored, as indicated in the following Figure 2.

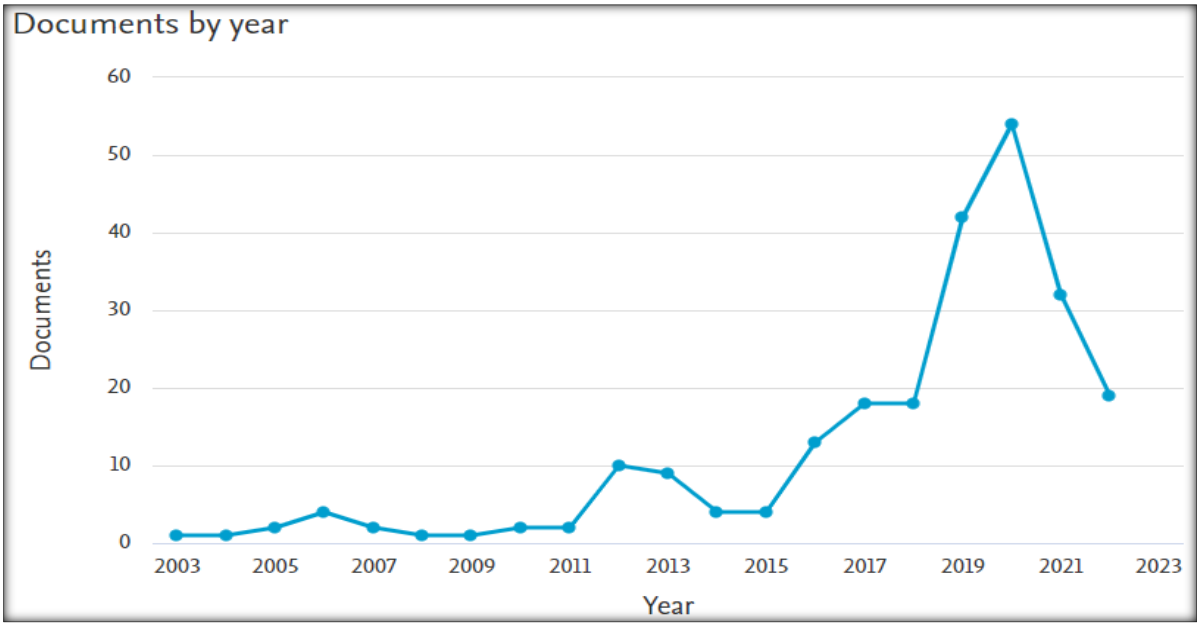

Fig. 2. Trend in the number of articles on elementary school students' mathematical abilities

Figure 2 above shows the trend of increasing publications over the past twenty years, from 2003 to 2022. From 2003 to 2006, there was an increase in the number of articles published in the Scopus database. However, from 2006 to 2011, there was a decline in the number of articles published. Subsequently, there was an increase in the number of articles published between 2011 and 2012, followed by a decrease between 2012 and 2015. From 2016 to 2020, there was a significant increase in the number of published articles, reaching four times the number published from 2003 to 2015. The peak was reached in 2020 with 54 documents published. However, there was a decrease in the number of articles published between 2021 and 2022. In 2021, 32 documents were published, and in 2022, there was a further decline of almost 50% compared to the previous year, with only 19 documents published.

In the second part, an analysis of the document trends based on the affiliation of the top 10 countries that published articles on elementary school students' mathematical abilities in the Scopus database will be presented.

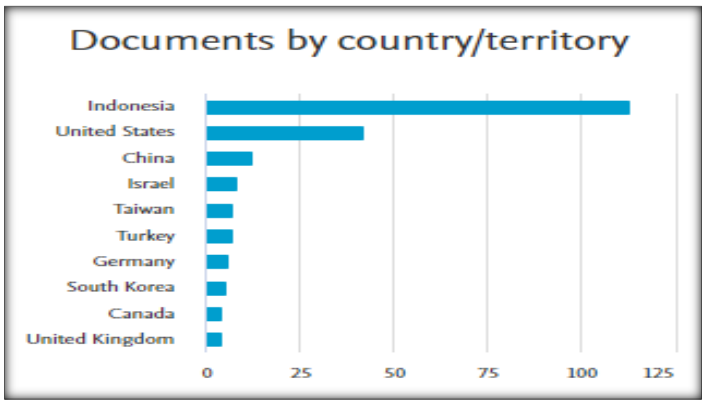

Fig. 3. Number of articles published by the top 10 affiliated countries

Based on Figure 3 above, the country that has the highest participation in publishing documents on elementary school students' mathematical abilities indexed in the Scopus database is Indonesia, followed by the United States in second place, China in third place, and so on. The 10th position is occupied by the United Kingdom.

In the third part, an analysis of the number of documents based on the authors published in the Scopus database will be presented, as shown in Figure 4 below.

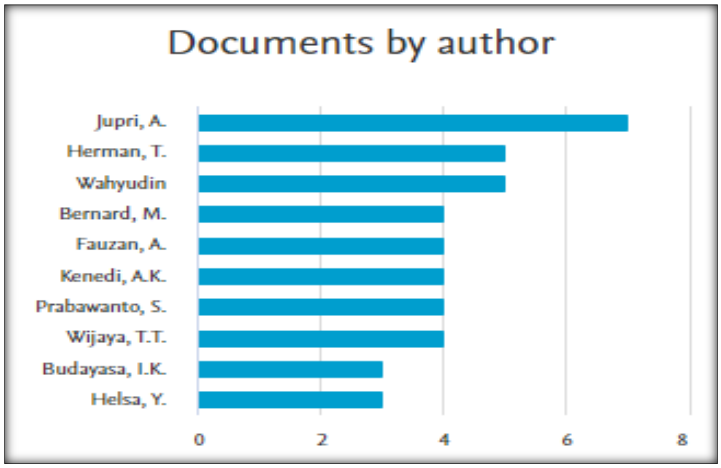

Fig. 4. Number of documents based on authors

From Figure 4 above, it is evident that the author who has published the most documents is Jupri, A., with a total of 7 documents. This is followed by Herman, T. and Wahyudin in second place, each with 5 documents. The next positions are occupied by Bernard, M., Fauzan, A., Kenedi, A.K., Prabawanto, S., and Wijaya, T.T., each with 4 documents, and the last positions are held by Budayasa, I.K., and Helsa, Y., each with 3 documents.

In the fourth part, an analysis will be presented regarding the number and types of documents used based on the English language, as shown in Figure 5 below.

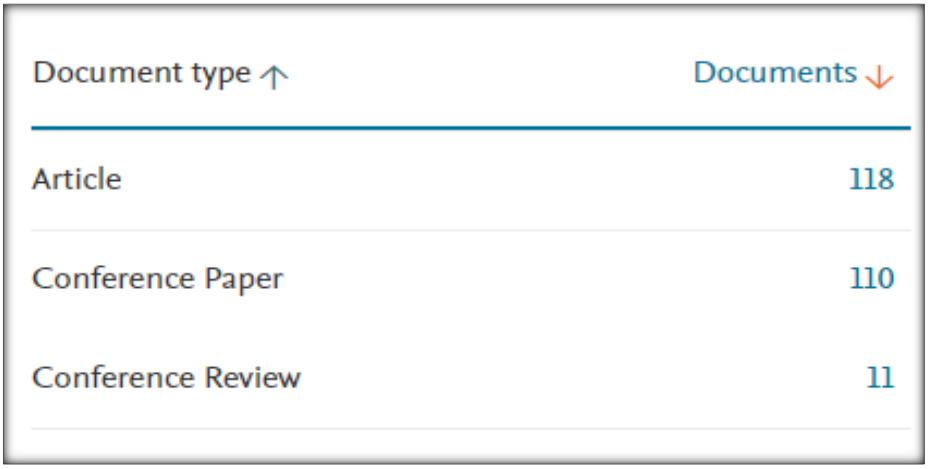

Fig. 5. Number and types of documents using the English language

Based on Figure 5 above, it is evident that the most frequently published document type is articles, with a total of 188 documents. This is followed by conference papers with 110 documents, and the last document type is conference reviews with 11 documents.

In the fifth part, an analysis will be presented regarding the frequently occurring keywords used in the documents about students' mathematical abilities in elementary schools, as shown in Table 2 below.

Table 2. Keywords appearing in articles about students' mathematical abilities in elementary schools

No.	Keyword	Occurrences	Total link strength
1	Students	99	413
2	Elementary schools	76	299
3	Teaching	31	144
4	Mathematical problems	23	118
5	Problem solving	27	117
6	Mathematics learning	22	105

No.	Keyword	Occurrences	Total link strength
7	Mathematics	20	94
8	Education computing	21	92
9	Elementary students	19	83
10	Education	19	81
11	Mathematical problem solving	15	78
12	Mathematical concepts	10	61
13	Elementary student	6	53
14	Physiology	5	51
15	Learning systems	11	49
16	Problem solving skills	9	46
17	Mathematics educations	11	43
18	Problem-solving abilities	9	42
19	Achievement	5	39
20	Learning mathematics	8	37
21	Cognition	6	32
22	Mathematical communication	9	31
23	Mathematical repretentations	6	30
24	Learning materials	5	27
25	Teaching and learning	5	26
26	Daily lives	5	25
27	Elementary education	6	25
28	Learning process	6	24
29	Mathematical techniques	5	22
30	e-learning	5	21
31	Geometry	8	19
32	Elementary school	13	15
33	Fractions	6	10
34	Mathematical thinking	6	10

In Table 2 above, it is observed that the 10 most frequently occurring keywords in articles about students' mathematical abilities in elementary schools, with relatively high frequencies, are "Students" with 99 occurrences, followed by "Elementary schools" with 76 occurrences, "Teaching" with 31 occurrences, "Mathematical problems" with 23 occurrences, "Problem solving" with 27 occurrences, "Mathematics learning" with 22 occurrences, "Mathematics" with 20 occurrences, "Education computing" with 21 occurrences, and "Elementary students" with 19 occurrences. When compared to the keywords classified under mathematical abilities defined by NCTM, the keyword "communication" appeared 9 times, "representation" appeared 6 times, while "connection" and "reasoning" were not found. The most frequently found keyword related to mathematical abilities in elementary schools is "problem solving".

3.2 Visualization

The analysis of the study is based on the distribution of data visualized in an overlay map, where the most frequently used keyword items are hierarchically categorized based on publication year criteria, as shown in Figure 6. This map illustrates the items that have been most commonly used in studies obtained by filtering "students' mathematical abilities in elementary schools" according to the study topic in the Scopus database for the past 6 years from 2015 to 2020. The color in the bottom right corner of the map indicates the transition from blue to yellow, providing information on how the most frequently used items in the research have changed from the first year to the last year.

From Figure 6, it is evident that articles on mathematical abilities in elementary schools have been published from 2015 to 2020, focusing on topics such as "problem-solving abilities," "mathematical thinking," "mathematical problems," and more, as indicated by the yellow color. It is worth noting that the most commonly used terms in current studies on students' mathematical abilities in elementary schools are "problem-solving abilities," "mathematical problems," and others, as shown by the yellow data overlay.

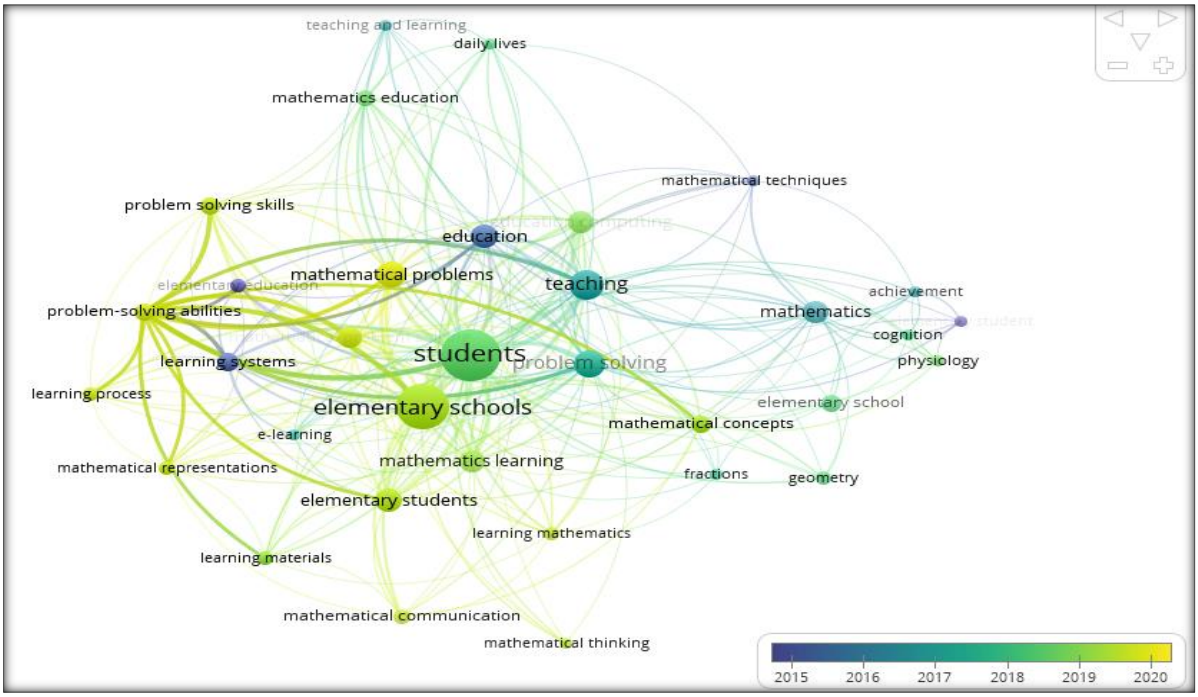

Fig. 6. Timeline analysis of frequently occurring keywords.

Figure 7 displays a density map where the terms included in the articles are colored according to their frequency of use. In this figure, items that are frequently used are shown in dark yellow, less frequently used items are shown in light yellow, and items that are used less frequently are displayed in green and blue, respectively.

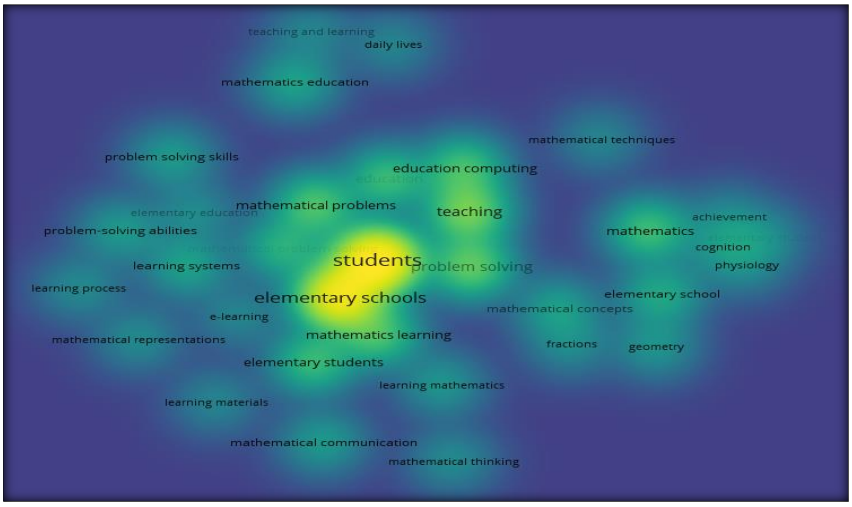

Fig. 7. Distribution map of research on mathematical abilities in elementary schools between 2013 and 2022.

From Figure 7 above, it can be observed that the most frequently used terms in articles about mathematical abilities in elementary schools are "students," "elementary schools," "problem solving," etc., while more recent and less frequently used topics include "mathematical thinking," "mathematical communication," "mathematical representations," and "learning process."

3.3 Identification

Figure 8 was created based on the most frequently occurring items, and cluster naming was done according to the network distribution map below.

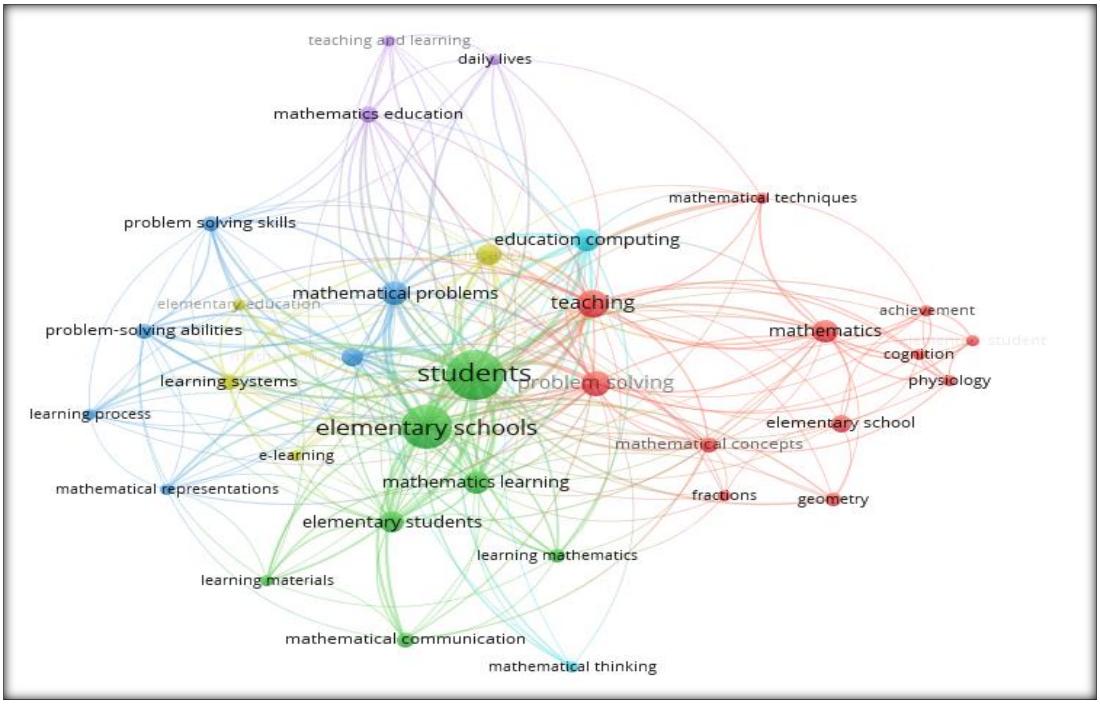

Fig. 8. Network map of research on mathematical abilities in elementary schools between 2003 and 2022.

Table 3 lists the frequencies associated with the most frequently occurring items from the six clusters depicted in Figure 8.

Table 3. Cluster Identification

Color	Cluster	Cluster effect
Red	1 (12 items)	Teaching, Problem solving, Mathematics, Mathematical concepts, Elementary student, Physiology, Achievement, Cognition, Mathematical techniques, Geometry, Elementary school, Fractions.
Green	2 (7 items)	Elementary schools, Elementary students, learning materials, Learning mathematics, Mathematical communication, Mathematics learning, Students.
Blue	3 (6 items)	Learning process, Mathematical repretentations, Mathematical problem solving, Mathematical problems, Problem solving skills, Problem-solving abilities
Yellow	4 (4 items)	e-learning, Education, Elementary education, Learning systems
Puple	5 (3 items)	Daily lives, Mathematics educations, Teaching and learning
Light blue	6 (2 items)	Education computing, Mathematical thinking

In the process of cluster naming, frequently occurring items such as "Learning process," "Mathematical representations," "Mathematical problem solving," "Mathematical problems," "Problem solving skills," and "Problem-solving abilities" are grouped in Cluster 3. Meanwhile, "Teaching," "Problem solving," "Mathematics," "Mathematical concepts," "Elementary student," "Physiology," "Achievement," "Cognition," "Mathematical techniques," "Geometry," "Elementary school," and "Fractions" are found in Cluster 1. Cluster 2 includes items like "Elementary schools," "Elementary students," "learning materials," "Learning mathematics," "Mathematical communication," "Mathematics learning," and "Students." Cluster 4 contains items such as "e-learning," "Education," "Elementary education," and "Learning systems." In Cluster 5, the most frequent items are "Daily lives," "Mathematics education," and "Teaching and learning." Lastly, Cluster 6 is characterized by the prevalence of items like "Education computing" and "Mathematical thinking."

3.4 Verification

To verify the clusters displayed on the network map and named during the identification phase, the items appearing in each cluster were examined in detail from the articles. When examining the red cluster, items such as "Teaching," "Problem solving," "Mathematics," "Mathematical concepts," "Elementary student," "Physiology," "Achievement," "Cognition," "Mathematical techniques," "Geometry," "Elementary school," and "Fractions" suggest intervention studies focusing on academic achievement in mathematics and science, with independent variables such as "Physiology," "Achievement," and "Cognition" being of particular interest in investigating intervention effects. On the other hand, in the green cluster, items such as "Elementary schools," "Elementary students," "learning materials," "Learning mathematics," "Mathematical communication," "Mathematics learning," and "Students" suggest a greater emphasis on the gender role in influencing basic mathematical abilities and skills, such as numeracy skills, using comprehensive assessments aligned with the curriculum development that encompasses standards-based actions, as well as non-routine tasks requiring abstract thinking.

4. CONCLUSION

This study aimed to investigate the trends of articles on elementary school students' mathematical abilities through bibliometric analysis. The bibliometric analysis of studies on the mathematical abilities of elementary school students revealed a significant increase in publications in 2020. The findings indicate that research on mathematical abilities in elementary schools has experienced a significant increase in the past 20 years, although there were periods, such as 2021 and 2022, where a decrease in publications was observed. Looking at the publications over the past 20 years since 2003, it is evident that the number of articles published in Scopus-indexed journals has shown a significant increase.

It is noteworthy that the number of research studies conducted on this issue has significantly increased between the period of 2015 to 2020. The number of articles published in 2020 reached twice the number of all articles published in the preceding three years. However, during the period of 2021 to 2022, there was a decrease in the number of publications compared to the previous years. On the other hand, it is important to note that the number of papers published during the six-year period from 2015 to 2020 has significantly increased, exceeding twice the number of papers published in the preceding years. This data confirms that articles on elementary school students' mathematical abilities continue to experience a significant increase in the number of published publications, particularly in recent years. This indicates that the mathematical abilities of elementary school students have maintained their popularity in the mathematics education literature. It is believed that the studies on mathematical abilities, particularly in elementary schools, addressing various issues in recent years, have contributed to this situation.

Furthermore, the fact that studies on the use of keywords "mathematical abilities" and "elementary school" [2] were published after 2019, in the recent period, indicates that these issues are current trends in the field. On the other hand, keyword analysis reveals that in many studies [17], [22] mathematical abilities in elementary school are linked to various aspects, but there are still many unanswered questions about the nature of these relationships. Therefore, it is believed that more research is needed to discuss and explain these relationships. The network map is created based on the analysis of the most commonly used items in the abstracts of articles on elementary school students' mathematical abilities, and it visualizes the items grouped into six clusters, depending on the level of association of each key item.

In this study, some keywords related to mathematical abilities as defined by NCTM, such as "connection" and "reasoning," were not found. On the other hand, the most frequently found keyword was "problem solving." This research only examined articles on students' mathematical abilities in elementary school in English that were published in the Scopus database. Future studies can explore research trends in various databases, languages, and specific mathematical abilities. New studies conducted in line with the trends identified in the published articles on elementary school students' mathematical abilities in this research can contribute to obtaining more detailed information in this field of study.

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