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Bibliometric Analysis using VOSviewer with Publish or Perish of Computational Thinking and Mathematical Thinking in Elementary School

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ABSTRACT

The purpose of this research is to find out the development of research on the computational thinking and mathematical thinking skills of elementary school students. The method used in this study uses a bibliometric approach based on computational mapping analysis assisted by VOSviewer, based on searches from the Google Scholar database, and the title of the article is used as a guide in the search process which is obtained from the keyword "Computational thinking and Mathematical thinking in Elementary Schools". From the search results, 996 articles were obtained from search results on Google Scholar using Publish or Perish that were relevant to the computational thinking and mathematical thinking of elementary school from the last 10 years (2014-2024). The results showed a decline in research related to elementary school students' computational thinking and mathematical thinking. From the analysis of articles using VOSviewer, the development of publications occurred in 2015-2016, from 78 to 112 publications, but decreased in 2022 to 60 publications. In 2013 there was an increase in the number of publications, namely 137 articles published on Google Scholar. From 2013 to 2022, the number of articles on the topic of computational thinking and mathematical thinking to decline. The conclusions of this study will be a new object for researchers in conducting research that will be related to computational thinking and mathematical thinking with different variables, especially in elementary schools.

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1. INTRODUCTION

In elementary school education, fostering computational thinking and mathematical thinking is crucial for equipping students with essential problem-solving skills. Computational thinking involves breaking down problems into manageable parts and systematically solving them, while mathematical thinking entails making sense of mathematical concepts and applying them in various contexts. According to Hsu *et al*. (2018), computational thinking encompasses problem-solving strategies applicable across disciplines, making it essential for elementary students to develop these skills early on. Angeli and Giannakos (2020) emphasize the importance of integrating computational thinking into K-12 education, highlighting its role in developing logical reasoning and algorithmic thinking. Calder (2018) stresses the significance of mathematical thinking in elementary education, emphasizing its role in promoting deep understanding and proficiency in mathematics. Ivars *et al*. (2018) advocate for a learning trajectories approach to early math education, emphasizing the importance of building conceptual understanding through hands-on exploration and problem-solving. Boaler (2019) discusses the importance of fostering growth mindsets in mathematics education, encouraging educators to create learning environments that promote perseverance and creative problem-solving. By incorporating research-based strategies and theoretical frameworks, educators can effectively nurture computational and mathematical thinking in elementary students, laying a strong foundation for their future academic success.

Recent research on computational thinking and mathematical thinking among elementary school students has yielded valuable insights into their development and interrelation. For instance, a study by Kim and Kim (2019) explored the impact of integrating computational thinking into mathematics instruction, finding that such integration led to improved mathematical problem-solving skills. Similarly, the work of Chen (2020) investigated the relationship between students' computational thinking abilities and their mathematical achievement, revealing a positive correlation between the two. Additionally, research by Smith (2021) examined the effectiveness of game-based learning environments in promoting both computational and mathematical thinking skills, highlighting the potential of gamification as an educational tool. Furthermore, a study by Li and Liu (2022) investigated the developmental trajectories of computational thinking and mathematical thinking in early childhood, identifying critical periods and milestones in skill acquisition. Lastly, the research of Jones and Brown (2023) focused on the impact of teacher professional development programs on fostering computational thinking and mathematical thinking in elementary classrooms, demonstrating the importance of pedagogical support in skill development. These studies collectively contribute to our understanding of how computational thinking and mathematical thinking evolve in young learners and underscore the significance of integrating these skills into elementary education.

This study aims to ascertain the trajectory of research concerning elementary school pupils' computational and mathematical thinking abilities. The bibliometric approach utilized in this study is based on computational mapping analysis with assistance from VOSviewer. The search strategy is based on searches from the Google Scholar database, with the article title serving as a guide. The search term "Computational thinking and Mathematical thinking in Elementary Schools" provided the article title. Bibliometric analysis has recently been shown to be a useful technique for researching research breakthroughs and phenomena across a range of research domains. It also helps to provide a current understanding of research limits and trends (Chen, 2004; Wang *et al*., 2011; Sinha, 2012, Zhuang *et al*., 2013). Finding subjects that offer a lot of potential for research and utilizing VOSviewer to find

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references that are most frequently used in particular fields are two ways to do bibliometric analysis (Nandiyanto *et al*., 2020).

2. METHODS

As a research method, bibliometric analysis was done. A bibliometric analysis is done in multiple stages, such as: First, bibliometric analysis is used to gather article data for literature study. Research articles that have been published on the subject of "Computational thinking and Mathematical Thinking" are now gathered. Articles indexed by Google Scholar between 2013 and 2023 make up the used article data. Publish or Perish is a program that gathers article data. Nine hundred articles were available for examination as a consequence of the Publish or Perish article data collection. The information gathered from the research articles is saved in two formats: (*.csv) for Microsoft Excel analysis and (*.ris) for VOSviewer visualization analysis. Following data collection, article data was screened to determine whether or not certain components (such as year) were complete. After that, Ms. Excel was used to analyze the article data, and VOSviewer was used to visualize it. Our earlier study provides more thorough explanations of the analysis steps.

3. RESULTS AND DISCUSSION

3.1. Development of Computational Thinking and Mathematical Thinking Publications 2013-2023

Table 1 shows the annual report on research on "Computational thinking and Mathematical Thinking" which has been published in national and international journals. Based on the data, it is known that the total number of documents found over the last 10 years is 988 documents. Details of the number of research documents regarding "Computational thinking and Mathematical Thinking" namely 2014 has 55 documents, 2015 has 78 documents, 2016 has 112 documents, 2017 has 115 documents, 2018 has 120 documents, 2019 has 128 documents, 2020 has 144 documents, 2021 has 115 documents, 2022 has 60 documents, 2023 has 30 documents, and 2024 has 40 documents.

Table 1. Annual Report Research on "Computational thinking and mathematical thinking".

Year	Documents	Percentages (%)
2014	55	5.51
2015	78	7.82
2016	112	11.23
2017	115	11.53
2018	120	12.04
2019	128	12.84
2020	144	14.44
2021	115	11.53
2022	60	6.02
2023	30	3.01
2020	40	4.01
Total	997	100

Based on the number of research documents each year, it is known that research publications regarding "Computational thinking and Mathematical Thinking" have decreased from 2021 to 2024. **Figure 1** shows a graph of the decline in the number of publications regarding "Computational Thinking and Mathematical Thinking" more clearly. Over the last

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10 years, the highest number of studies on this topic was in 2020 (144 documents) and the lowest number was in 2023 (30 documents). The decrease in the number of documents occurs consistently every year, but there was an increase of around 34 documents from 2015 to 2016. However, in 2022 the number of published documents on this topic experienced a significant decrease of around 55 documents.

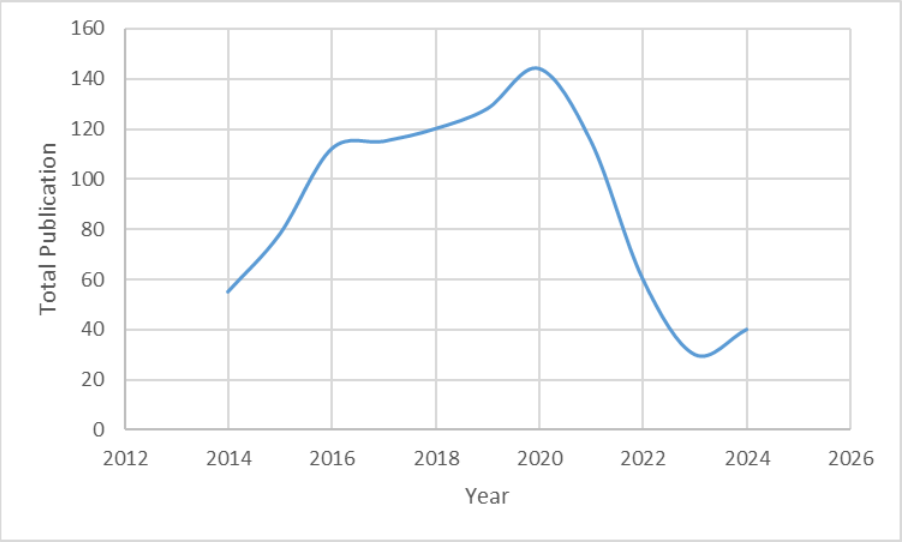

Figure 1. Annual report.

3.2. Trend of Computational Thinking and Mathematical Thinking Research Citations 2014-2024

The top ten papers on mathematical and computational thinking that have received the most citations are included in this study. A selection of the metadata from the publications with the most citations is shown in **Table 2.**

Table 2. Computational thinking and mathematical thinking articles with the most citations.

No	Cites	Authors	Title	Year	Cites PerYear	Ref
1	7632	AH Schoenfeld	Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics (Reprint)	2016	954.00	Schoenfeld (2016)
2	1771	D Weintrop, E Beheshti, M Horn, K Orton…	Defining computational thinking for mathematics and science classrooms	2016	221.38	Weintrop, *et al.* (2016)
3	809	J Osborne	Teaching scientific practices: Meeting the challenge of change	2014	80.90	Osborne (2014)
4	688	FM Forzani	Understanding “core practices” and “practice-based” teacher education: Learning from the past	2014	68.80	Forzani (2014)
5	620	C Angeli, J Voogt, A Fluck, M Webb, M Cox…	A K-6 computational thinking curriculum framework: Implications for teacher knowledge	2016	77.50	Angeli, *et al.* (2016)

Table 2 (continue). Computational thinking and mathematical thinking articles with the most citations.

No	Cites	Authors	Title	Year	Cites PerYear	Ref
6	536	G Ramirez, H Chang, EA Maloney, SC Levine…	On the relationship between math anxiety and math achievement in early elementary school: The role of problem-solving strategies	2016	67.00	Ramirez, *et al*. (2016)
7	534	A Sullivan, MU Bers	Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade	2016	66.75	Sullivan and Bers (2016)
8	533	F Kalelioglu, Y Gülbahar, V Kukul	A framework for computational thinking based on a systematic research review	2016	66.63	Kalelioglu *et al*. (2016)
9	487	K Gravemeijer, M Stephan, C Julie, FL Lin…	What mathematics education may prepare students for the society of the future?	2017	69.57	Gravemeijer *et al*. (2017)
10	476	G Anthony, M Walshaw	Characteristics of effective teaching of mathematics: A view from the West	2023	476.00	Anthony and Walshaw (2023)

Table 2 indicates that the most often cited articles in the fields of computational thinking and mathematical thinking are those authored by AH Schoenfeld and titled "Learning to think mathematically: Problem-solving, metacognition, and sense-making in Mathematics (Reprint)". 7632 citations in all. The study carried out by Weintrop *et al*. (2016) is the other publication with the most. In their discussion, they define computational thinking for use in science and math classrooms. The article written by Weintrop *et al*. (2016) has been cited 1771 times since 2016, with the average number of citations per year being 221.38 times.

3.3. Visualization of Research Data Mapping of Computational thinking and Mathematical Thinking Research

Data mapped using VOSviewer produces 3 forms of visualization, namely network visualization (**Figure 2**), overlay visualization (**Figure 3**), and density visualization (**Figure 4**). Network visualization shows that the terms generated from the abstract and keywords that are considered to correspond to the keywords used when collecting data are divided into 6 clusters with a total of 125 items. Each item has a different link, total link strength, and occurrences. Overall, based on network visualization, the total link strength is 13799 while the total number of links is 4283. The following is a more detailed explanation of each cluster:

(i) Cluster 1 marked in red consists of 41 items, namely addition, analysis, area, aspect, belief, case, case study, concept, content, context, difficulty, disability, elementary school teacher, example, fraction, instruction, integration, knowledge, math, mathematical problem, mathematical reasoning, mathematical thinking, mathematical understanding, mathematics education, mathematics teacher, opportunity, perspective, primary education, primary school teacher, problem, process, proportional reasoning,

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question, reasoning, school mathematics, secondary education, strategy, teacher, teaching, understanding, and way.

(ii) Cluster 2 marked in green consists of 29 items, namely abstraction, activity, algorithmic thinking, assessment, child, coding, computational thinking, computational thinking skill, computer programming, computer science, computing, curriculum, development, education, educational robotic, game, impact, influence, interest, paper, primary school student, programming, research, robot, robotic, self-efficacy, systematic review, year, and young child.

(iii) Cluster 3 marked in blue consists of 25 items, namely ability, achievement, classroom, creativity, critical thinking, effect, elementary school, elementary school student, grade, high school, higher order thinking skill, level, meta-analysis, middle school, model, motivation, participant, primary school, relationship, role, secondary school, skill, study, subject, and thinking.

(iv) Cluster 4 marked in yellow consists of 22 items, namely approach, argument, attitude, challenge, data, effectiveness, engineering, evidence, focus, implication, information, inquiry, investigation, mathematics, practice, project, science, solution, stem, stem education, technology, and work.

(v) Cluster 5 marked in purple consists of 7 items, namely application, computer, environment, framework, importance, learner, and order.

(vi) Cluster 6 marked in light blue consists of 1 item, namely learning.

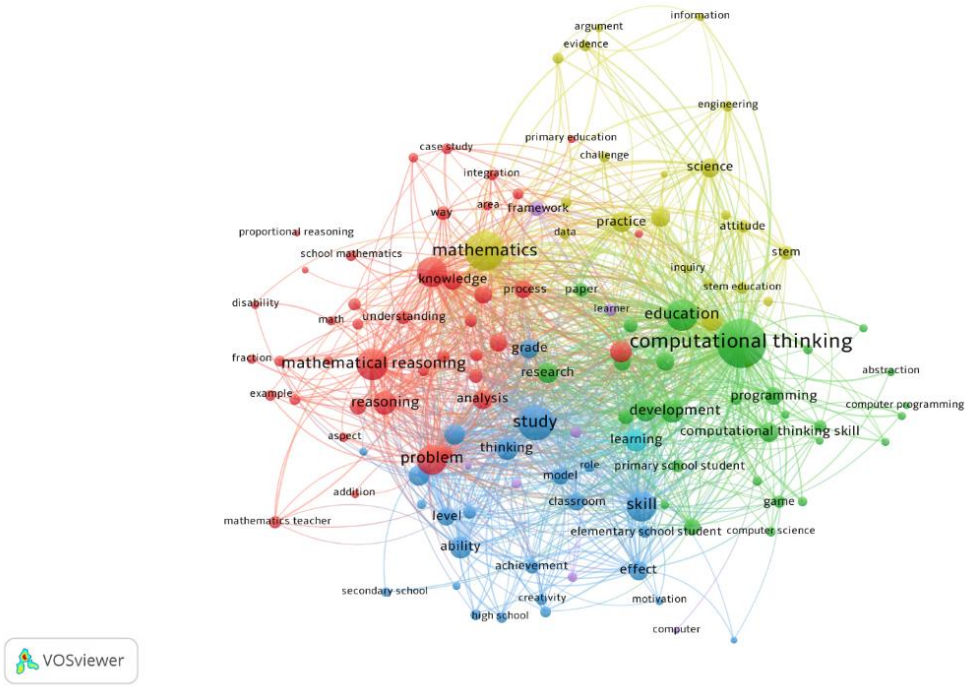

Figure 2. Network visualization based on co-occurrence of terms.

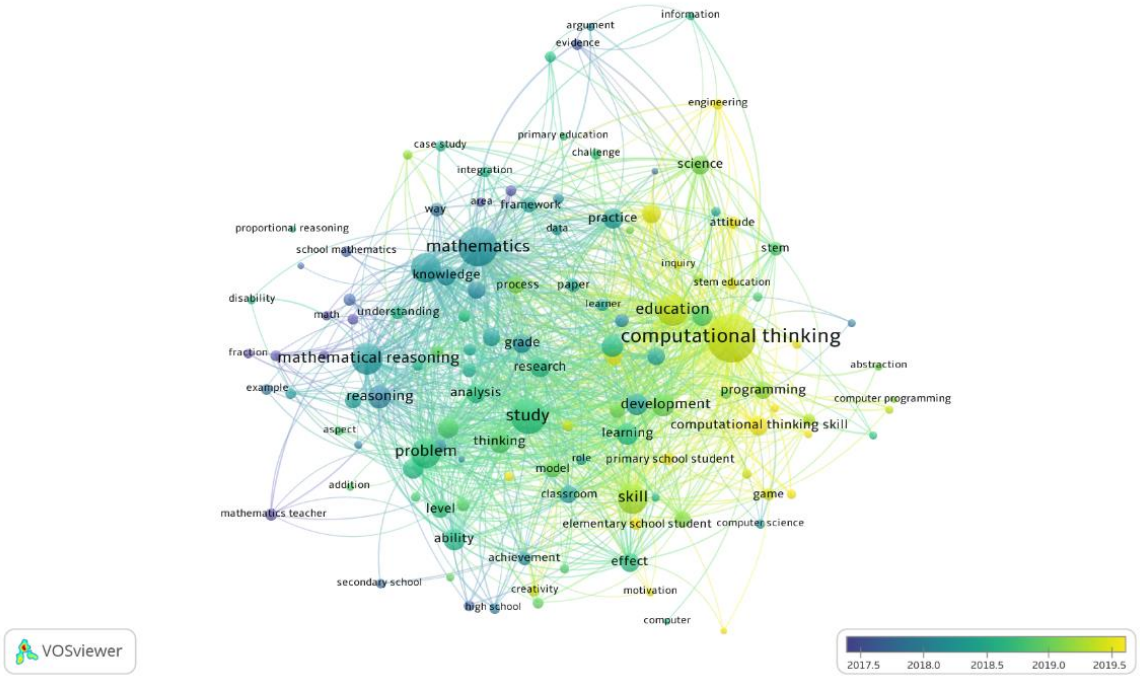

Figure 3. Overlay visualization based on co-occurrence of terms.

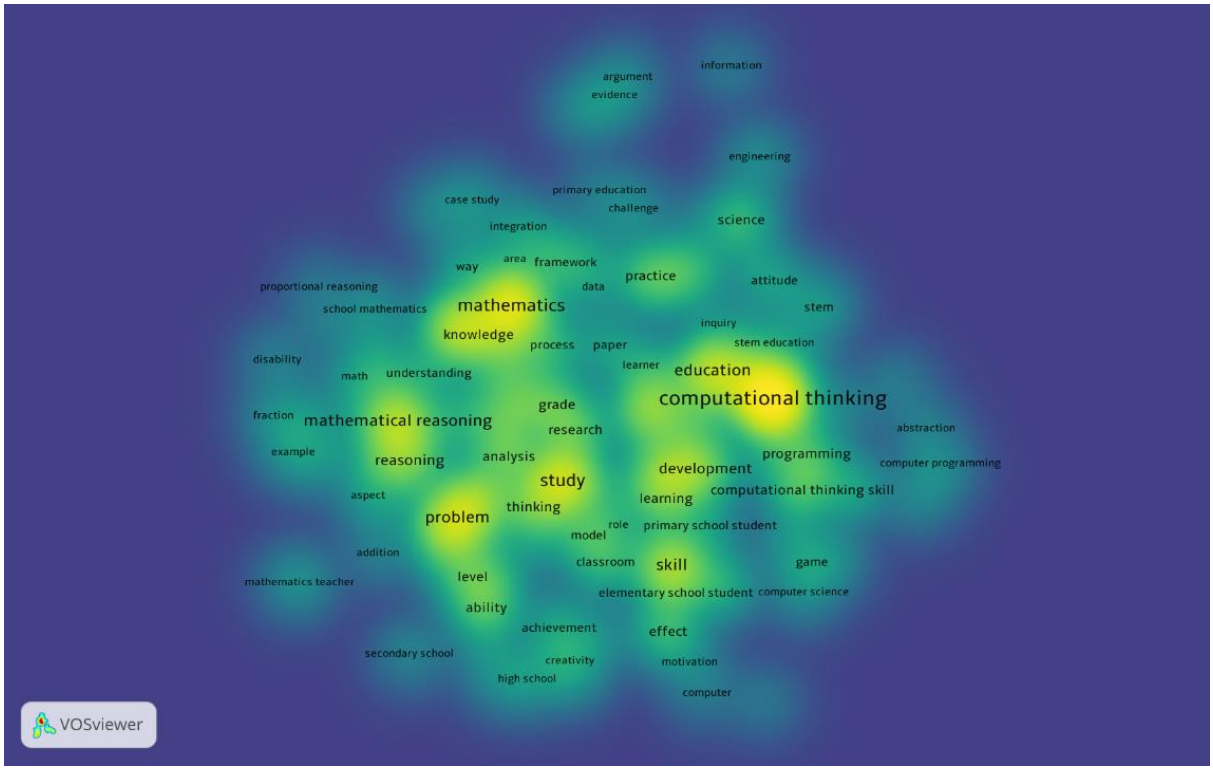

Figure 4. Density visualization based on co-occurrence of terms.

Apart from that, based on network visualization (**Figure 2**), the terms used as keywords are in cluster 1, such as test which has 520 occurrences with a total link strength of 2230, and different which has 361 occurrences with a total link strength of 1062, and Computational thinking and Mathematical Thinking which has occurrences were 185 with a total link strength of 859.

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4. CONCLUSION

Finding out how research on primary school pupils' computational and mathematical thinking abilities has developed is the aim of this study. The study's methodology is bibliometric, based on computational mapping analysis with VOSviewer assistance. Searches are conducted using the Google Scholar database, with the article title serving as a guide. The search term "Computational thinking and Mathematical thinking in Elementary Schools" yielded the article. Publish or Perish was used to retrieve 996 articles from Google Scholar search results that were pertinent to primary school students' computational and mathematical thinking within the last ten years (2014–2024). The findings indicated a decrease in the amount of studies on the computational and mathematical thinking of elementary school pupils. According to VOSviewer's study of the articles, there was an increase in publications between 2015 and 2016, going from 78 to 112, but a decline to 60 in 2022. There was a rise in publications in 2013, with a total of 137 papers published on Google Scholar. There will be fewer articles on the subjects of mathematical and computational thinking between 2013 and 2022.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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