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The Relationship Between Computational Thinking and Critical Thinking Disposition in Mathematical Problem Solving: Bibliometric Analysis

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ABSTRACT

In the contemporary period, it is imperative for individuals to possess a repertoire of abilities encompassing problem-solving, critical thinking, and computational thinking. In contexts where challenges exhibit a growing level of intricacy and unpredictability. Efforts were made to improve these capabilities. Among them is the integration of learning in this modern curriculum. Mathematics is a branch of science that is expected to be a means for students to hone their abilities. The purpose of this study is to identify trends and research patterns published on the relationship between computational thinking and critical thinking dispositions in solving mathematical problems using bibliometric analysis. In addition, this article also encourages further research to explore various aspects related to the development of sustainable critical thinking and computational thinking in the context of problem-solving in mathematics learning. Data was obtained from the Google Scholar database which has been refined with four stages (identification, screening, eligibility, and inclusion). The results of the study show that 2020 is the year with the highest and most influential publications because it has the highest h-index value. The research focus related to this topic from 2013-2023 is divided into 4, namely, 1) problem, student, and critical thinking; 2) computational thinking, teacher; 3) mathematics and projects; 4) disposition and science. Project and critical thinking skills are the novelty of this research topic.

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1. INTRODUCTION

Mathematics is a very important field of science in the development of the world of education. Mathematics plays a big role in shaping logical thinking, problem-solving, and basic calculations to

broad cognitive abilities (Suh et al., 2021). Mathematics is defined as a field of science that studies numbers, components of geometric shapes, geometric shapes and structures of number changes (Lee et al., 2019). Mathematics is a branch of universal science that is studied continuously in all corners of the world (Al-Mutawah et al., 2022). This shows how crucial mathematics is as a field of knowledge in education. According to Kallia (2021), Mathematics also plays a role in shaping a person's character or personality in acting in everyday life.

Problem solving is one of the thinking skills that must be mastered by someone to facilitate decision-making (Ubaidullah et al., 2021). However, this ability is not immediately owned by someone, it takes practice, habituation and experience. Experience is gained in many ways, for example, social interaction, student learning process, and unexpected everyday life events (Shin et al., 2022). In learning, problem-solving is closely related to learning mathematics (Ogegbo & Ramnarain, 2022). In learning mathematics, in general, students' thinking skills are honed through mathematical problems that still tend to be abstract. Students are taught to think more broadly in understanding mathematical objects which will then seek solutions to the problems given. Problem-solving encourages individuals to find solutions that did not exist before, so in this case, creativity is required from each individual (Lin et al., 2021). Computational thinking and critical thinking are tools for individuals to hone their creativity (Korkmaz & Xuemei, 2019).

Computational thinking is defined as the ability to design and develop solutions to complex problems using abstraction, decomposition, pattern recognition, and algorithms (Ogegbo & Ramnarain, 2022). Computational thinking is a very important ability to have (Maharani, 2019). This ability helps individuals to solve problems effectively and efficiently and enables them to develop innovative and creative solutions (Maharani et al., 2019; Yuntawati et al., 2021). Computational thinking is often interpreted as an ability that is closely related to the program. However, computational thinking is not only limited to developing computer programs. This ability is also useful in various fields, such as in science, technology, engineering, and mathematics (Bråting & Kilhamn, 2020). In general, computational thinking can be used to identify patterns in data and extract useful information from the data, which can then be used to determine new developmental variations (Maharani et al., 2020).

Meanwhile, critical thinking exists as a fruit of someone's curiosity. Curiosity arises because of the broad logic of thinking. Someone with computational thinking skills will have a broad mindset because, in the process, computational thinking teaches someone to abstract, break problems into smaller parts, recognize patterns, and apply algorithms, which are stages of computational thinking. In the modern curriculum, this ability is often taught explicitly, because it can help students learn, solve problems, and make the right decisions (Ogegbo & Ramnarain, 2022; Shin et al., 2022).

From the explanation of the variables above, a continuous relationship is drawn where mathematics as a branch of knowledge is an important pillar in education as a form of scientific discipline. Problem-solving is an integral part of learning mathematics (Ubaidullah et al., 2021). Where mathematics as a scientific discipline studies complex and universal problems with problem solving as a problem solver in it (Atmaja et al., 2023; Maharani et al., 2019). The relationship between problem-solving, critical thinking, and computational thinking is that these three are important analytical thinking skills to be developed in solving problems. Problem-solving is the ability to identify, analyze, and solve problems (Ubaidullah et al., 2021). Critical thinking is the ability to think critically and analyze information objectively (Atmaja et al., 2023). While computational thinking is the ability to solve problems using computational methods and algorithms (Lyon, 2020).

Problem solving, critical thinking and computational thinking together are skills that everyone must have in this dynamic era (Verschaffel et al., 2020). Where the problems are increasingly complex and unpredictable. Efforts were made to improve these capabilities. Among them, the integration of learning in this modern curriculum. Mathematics is a branch of science that is expected to be a means for students to hone their abilities (Abreu, 2020).

Through the bibliometric analysis, an overview of research on the topic of mathematics learning influences the ability of computational thinking and critical thinking in solving mathematical

problems. Bibliometric analysis is a scientific approach used to measure, analyze and describe characteristics and patterns in the scientific literature (Evendi, 2022). It will be able to see the development of research in recent years so that it can be used as insight or reference for further research. This study aims to examine publications on the topic of the relationship between computational thinking and critical thinking disposition in mathematical problem solving and to visualize them.

2. METHODS

This study used a visualized bibliometric analysis method or a bibliometric visualization method. The bibliometric visualization method is a structural description to show a particular research mapping. Meanwhile, bibliometric analysis is defined as a scientific method that is used to see trends in the relationship of the characteristics of a literature through patterns that have been visualized. The bibliometric analysis used is descriptive bibliometric which will describe the characteristics of a literature.

The sample used in this study is 500 data taken through publish or perish with the Google Scholar database. To get 500 published or perish data using the Google Scholar database, researchers used the keyword "relationship between computational thinking and critical thinking disposition in mathematical problem solving" with a range of 2013-2023. Of the 500 data that have been obtained, several stages will be passed to see the feasibility and linearity of the data with the research topic. For the stages of data feasibility filtration can be seen in the image below:

The stages can be seen more clearly in the following figure:

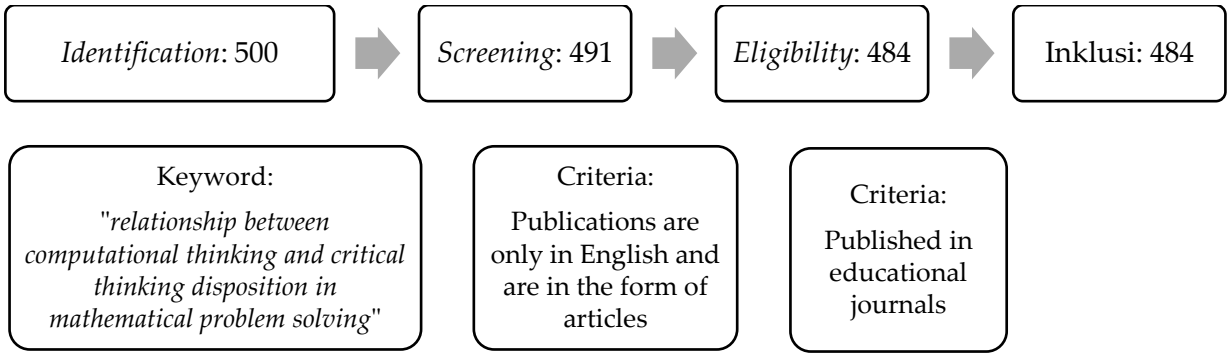

Figure 1. Stages in selecting the data

Researchers use various applications to analyze the data that has been collected. In making publication trend tables and citation trends, researchers use the Microsoft Excel application and process data that has been collected from Google Scholar via PoP. PoP or Publish or Perish is used to retrieve data and analyze citation trends and publication trends such as NCP, C/CP, h-index and g-index. In addition, researchers use the Vosviewer application to visualize trending research topics and research updates.

3. FINDINGS AND DISCUSSION

In the results section, the researcher will display an analysis of the data that has been obtained and has passed the feasibility test. The data analysis uses the help of the Vosviewer application. The researcher will present an analysis of publication trends for the last 10 years, citation trends, journal distribution, author influence, research trends, and research novelty.

3.1 Trend of Publication and Trend of Citation

The year of publication is used to classify the number of published publications. Below are pictures of trending publications by topic *"Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving"* from 2013 to 2023, shown in figure 2.

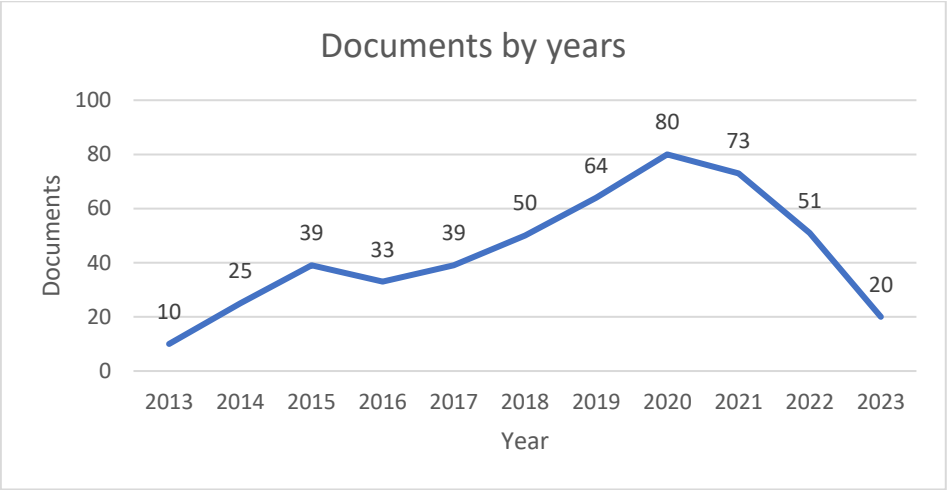

Figure 2. Trend of Publication

From Figure 2, it can be seen an overview of publication data fluctuations from 2013 to 2023. Topic *"Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving"* began to be in demand in 2015, seen from a significant increase from the previous year. However, in 2016 it experienced a decline in publications. Various factors including changes in research priorities and changes in regulations/policies can cause this. Furthermore, the publication trend with the topic "Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving" has continued to increase starting in 2017 until its peak in 2020 with 80 publications. Increase in the span of 4 years between 10-20 publications. The following year, namely 2021 to early 2023, it continued to experience a decline but not too significantly. This could have been influenced by the pandemic that took place in that year, which hampered research on related topics. From this description it can be seen that research with the topic "*Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving*" is quite popular but there have been ups and downs in publications in the last 10 years. 2020 was the year with the most publications, reaching 80 publications. But in the following year it experienced a decline in publications.

Table 1 Trend of Citation

Tahun	TP	NCP	TC	H	G
2013	10	10	3267	9	10
2014	25	25	6171	20	25
2015	39	39	4508	27	39
2016	33	33	3579	26	33
2017	39	39	5015	26	39
2018	50	50	2920	28	50
2019	64	64	2549	30	49
2020	80	80	3990	31	62
2021	73	73	4726	24	68
2022	51	51	1342	15	35
2023	20	20	139	5	11

TP: Total Publication; NCP: Number Citation Paper; TC: Total Citation; H: h-index; G: g-index

Table 1 will analyze the trend of citations on the topic "*Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving*" in the 2013-2023 range. In table 1, TP is presented each year, TP is the number of publications made in that year. The largest TP value

occurred in 2020 with 80 publications. Then there is also the NCP, namely the number of articles that have been cited more. While TC is the number of publication citations that occurred in that year. The largest TC value occurred in 2014, namely 6171 citations made in 25 publications published that year. However, even though 2014 has the largest TC value, it does not mean that 2014 will be the most influential year in research on the topic "*Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving*". The most influential year is shown with the highest H value. The H value is an h-index which is defined as a metric used to assess the extent of the productivity and influence of a researcher's or scientist's scientific work. The highest H score was in 2020 with a score of 31. This shows that 2020 is the most impactful year in research with the topic "*Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving*". In the last column, G or g-index is presented. The G-index is a bibliometric metric used to evaluate the impact of a person's scientific work based on the number of publications and the number of citations received by the publication. The highest g-index value is in 2023, which means that many publications have received a high number of citations in that year.

Next, the distribution of the most influential studies in 2020 will be shown as the most influential year on this topic. The distribution table for publications in 2020 can be seen in table 2 as follows.

Table 2. Publication in 2016

Cites	Authors	Title	Source	Publisher
422	(Steffe & Ulrich, 2020)	Constructivist Teaching Experiment	Encyclopedia of Mathematics Education	Springer
380	(Tang et al., 2020)	Assessing *Computational thinking*: A Systematic Review of Empirical Studies	Computers & Education	Elsevier
199	(Verschaffel et al., 2020)	Word problems in mathematics education: a survey	ZDM	Springer
145	(Olmo-Muñoz et al., 2020)	*Computational thinking* through unplugged activities in early years of Primary Education	Computers & Education	Elsevier
120	(I. Lee, 2020)	*Computational thinking* from a Disciplinary Perspective: Integrating *Computational thinking* in K-12 Science, Technology, Engineering, and Mathematics Education	Journal of Science Education and Technology	Springer

The publications in 2020 that have the greatest impact are publications with the most citations, namely research conducted by Steffe & Ulrich (2020). The research entitled "Constructivist Teaching Experiment" discussing constructivist teaching approaches that often involve interactions between students, instructors, and learning materials. Where students are encouraged to ask questions, find solutions, collaborate with their colleagues, and design their own understanding through learning experiences that involve critical thinking and computational thinking in solving problem solving in mathematics learning. This article has been cited 422 times, making it the most influential article. This article also discusses the relationship that encourages students to become active, analytical, and independent learning participants, with the hope that they will be more effective in understanding and using knowledge in various situations. This article discusses the relationship of this approach to be used in various disciplines. It also reviews the topic of understanding children's numerical thinking and how that thinking might change, rather than relying on models developed outside of mathematics education for purposes other than educating children.

Other articles that are widely cited are articles from Tang et al. (2020). The article entitled "Assessing Computational thinking: A Systematic Review of Empirical Studies" discusses CT being applicable to various subjects at various levels of education, which brings challenges as well as opportunities. Teachers and researchers from different disciplines and educational levels should

increase cooperation so that we can better assess and promote CT. In addition, CT was developed further because of its usefulness in solving problems in the field of mathematics.

The two articles discuss the learning approach to students which is expected to improve students' ability to analyze a problem critically, work in teams and solve problems creatively. Then in the second article the focus is on the ability of computational thinking to be developed in other fields of science to make CT better. In this case, the relationship and correlation of computational thinking with critical thinking in solving problem-solving in mathematics learning are unknown. Then what is the best approach in improving problem-solving abilities in learning mathematics. Therefore, further research is needed to answer the above questions.

3.2 Research focus

The focus of research related to the topic "*Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving*" obtained data visualization with the help of the vosviewer application. Figure 3 is the distribution of keywords related to the research topic, while Figure 4 is the novelty of keywords related to the research topic. Figure 3 is obtained from Vosviewer in the network visualization section, then in Figure 4 from the overlay visualization section. Keywords that appear at least 3 times in an article.

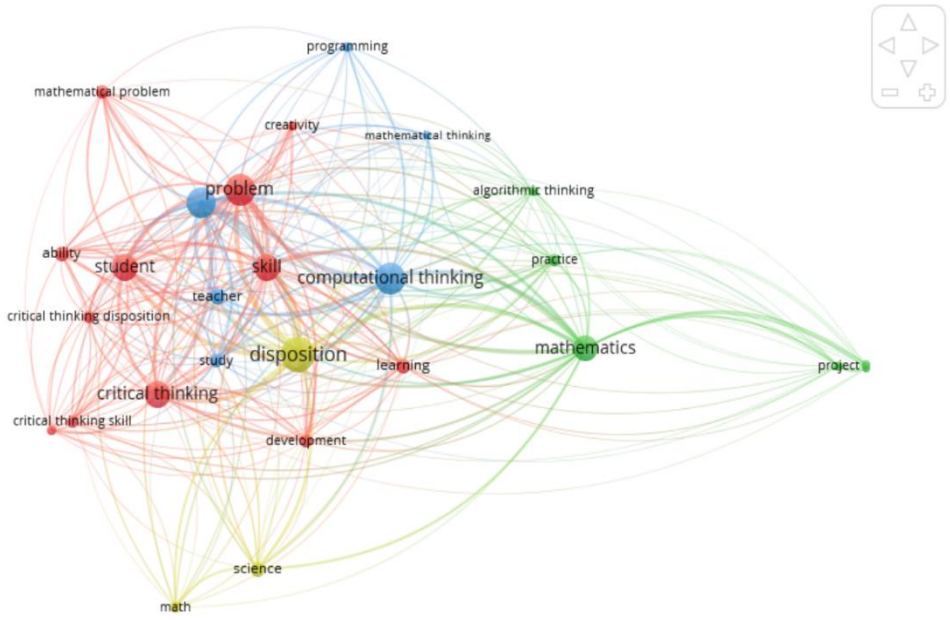

Figure 3 Research Focus

The visualization results shown in Figure 3 show connected networks but with different colors. There are 4 network colors namely, red, blue, green and yellow. These colors indicate clusters or groups. Where each cluster has a research focus that will later relate to one another. The largest network is the red network indicating the first cluster. In this cluster there is a spread of 12 keywords. The biggest circle is the focus of research, meaning that the word appears most often in research topics related to "Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving". The focus of research on the first cluster is, problem, student and critical thinking. In the second cluster, namely blue, there are 8 keywords with a research focus, namely, computational thinking and teacher. The green color as the third cluster only has 4 keywords. The biggest circle as the focus of research is mathematics and projects. For the last cluster, namely the yellow color, there is disposition and science as the research focus.

The keywords Mathematics, computational thinking, problems, and disposition as the research focus of each cluster are directly related to each other in the visualizations displayed. However, the

keywords critical thinking in the first cluster and science are not directly related. This can be useful for determining the focus of research in further research.

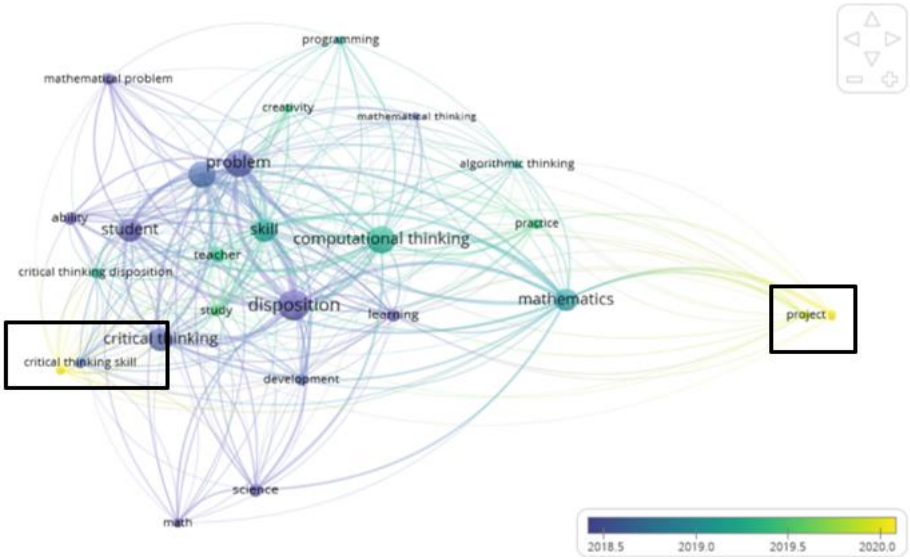

Figure 4 Research novelty

If in Figure 3 the network colors describe clusters, in Figure 4 the network colors describe the time range these keywords are used. The dark blue color indicates that these keywords are often used in 2018. The green colour is the color for keywords used in 2019. Meanwhile, the yellow color is a keyword that has been popular in recent years in this research topic. It can be seen that the project keyword, which is the focus of research in cluster 3 is a novelty. Another keyword which is a novelty is critical thinking skill. However, these keywords are not directly connected to the research focus. So that it can be used as a novelty in further research.

4. CONCLUSION

Based on the results of previous research, it can be concluded that 2020 will be a productive year with the most publications, reaching 80 publications. But in the following year it experienced a decline in publications. 2014 had the largest TC value however, 2020 became the most influential year in this study because it had the highest h-index value of 31. The article entitled "Constructivist Teaching Experiment" by Steffe & Ulrich (2020) became the most cited article of 2020. So that makes Steffe & Ulrich (2020) as a writer who has had a major impact on research topics related to "Relationship Between Computational thinking and Critical thinking Disposition in Mathematical Problem solving". The research focus is divided into 4 clusters, namely, problem, student and critical thinking. In the second cluster, computational thinking and teacher. The third cluster is mathematics, project and the last cluster is disposition and science. Project keywords which are the focus of research on cluster 3 and critical thinking skills are novelties on this topic. However, these keywords are not directly connected so that this can be used as novelty in further research.

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