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Trend Publication of Computational Thinking in Mathematics Education: Bibliometrik Review

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Abstrak: *Computational thingking* dan matematika berhubungan erat yaitu matematika berperan dalam mengatasi tantangan dan memahami konsep dalam *computational thinking*, sementara *computational thiking* pada akhirnya menyederhanakan dan mengabstraksi situasi dengan merumuskan dan menyajikan permasalahan dalam bentuk matematis. Tujuan penelitian ini yaitu untuk mengidentifikasi tren dan pola penelitian dengan topik *computational thinking in mathematics education* menggunakan analisis bibliometrik. Data diperoleh dari *database dimmensions* yang telah disempurnakan melalui 4 tahapan *(identification, screening, eligibility, inclusion)*. Hasil penelitian menunjukkan bahwa puncak publikasi terkait penelitian *computational thinking in mathematics education* terjadi pada tahun 2022. Jurnal *science of education and technologi* menjadi jurnal paling berpengaruh dengan sitasi terbanyak yaitu 877 sitasi walau hanya dengan 7 publikasi. United States menjadi negara yang paling berpengaruh pada bidang ini karena baik jumlah publikasi jumlah kutipan merupakan yang terbanyak dari negara lainnya. Adapun tiga fokus penelitian terkait penelitian *computational thinking in mathematics education* pada *database dimmensions* dari tahun 2013-2023 yaitu, 1) *mathematics, study, teacher*; 2) *problem, child, learning*; 3) *student, steam, CT skill.*
Kata kunci: *Computational thinking*; Bibliometrik; Matematika

Abstract: *Computational thinking and mathematics are closely related, namely mathematics plays a role in overcoming challenges and understanding concepts in computational thinking, while computational thiking ultimately simplifies and abstracts situations by formulating and presenting problems in mathematical form. The purpose of this study is to identify trends and research patterns with the topic of computational thinking in mathematics education using bibliometric analysis. Data is obtained from the dimmensions database which has been refined through 4 stages (identification, screening, eligibility, inclusion). The results showed that the peak of publications related to computational thinking in mathematics education research occurred in 2022. The journal of science of education and technology became the most influential journal with the most citations, namely 877 citations even though only with 7 publications. The United States is the most influential country in this field because of the good number of publications, the number of citations is the highest of any other country. There are three research focuses related to computational thinking in mathematics education research on the dimmensions database from 2013-2023, namely, 1) mathematics, study, teacher; 2) problem, child, learning; 3) student, steam, CT skill.*
Keywords*: Computational thinking; Bibliometric; Mathematics*

Introduction

Mathematics is a branch of education that studies patterns, structures, numbers and shapes (Zhang & Savard, 2023). Mathematics is an educational science that will be studied

on an ongoing basis, starting from elementary school to tertiary level (Ye et al., 2023). Studying mathematics requires a good understanding of the basic concepts so that in its implementation you can find relationships between the material being taught (Wu & Yang, 2022; Yuntawati et al., 2021). In addition, according Apriani et al., (2021); Papadakis et al., (2017); Sung et al., (2017) Mathematics is an abstract science where mathematics does not have a direct physical representation that is real in life. Mathematics involves logic, thinking and objects that need to be understood and studied carefully. Computational thinking is a concept of mathematical thinking that involves stages in it. Computational thinking has five stages of thinking, namely, decomposition, pattern recognition, abstraction, algorithm, evaluation (Maharani, Nusantara, As' ari, et al., 2020a; Wu & Yang, 2022). Computational thinking is used as a thinking tool in solving problems by describing how computers work (Basson, 2021).

Mathematics plays a role in overcoming challenges and understanding concepts in computational thinking, while computational thinking ultimately simplifies and abstracts situations by formulating and presenting problems in a mathematical form (Maharani, Nusantara, As'ari, et al., 2020). Mathematical form is a way of presenting abstract mathematical concepts into a simple form that is easier to understand (Rodríguez-Martínez, 2020). In this case there is a reciprocal relationship between mathematics and computational thinking which complement each other. Integration of computational thinking in mathematics learning will explain mathematical concepts that are considered complicated in a simpler mathematical form (Pardo, 2018). So that it will make it easier for students to absorb and understand math problems. Not only students, teachers or educators will find it easier to explain mathematical concepts in a structured and clear way using computational thinking.

Integration of computational thinking in mathematics learning has enormous benefits in the development of education (Reichert, 2020). Computational thinking is not only useful in facilitating understanding of concepts but will also become a strong foundation in understanding sustainable mathematical material. Besides the benefits from a cognitive perspective, integrating computational thinking into learning will also train students' abilities to think critically, analyze problems and solve problems systematically (Lee, 2020). These abilities will be needed later in social life in society (Lee et al., 2022). In terms of learning mathematics, mathematics which is considered as a complex and abstract lesson can be seen as a concrete form of mathematics through the integration of computational thinking in learning (Rich, 2022). Computational thinking is a modern way of overcoming difficulties in learning mathematics (Tang, 2020).

Computational thinking is a skill that must be possessed in the 21st century (Maharani, Nusantara, As' ari, et al., 2020). Computational thinking in learning mathematics will be a means of rapid educational development because it touches the cognitive and affective sides of students. Therefore research on computational thinking in mathematics learning is very important to understand the proper integration process. Through this research, educators and practitioners will be able to identify learning needs and strategies by applying computational thinking appropriately. Previous research on computational thinking has been widely applied to elementary school children to understand basic concepts. However, it needs to be studied further about effective teaching strategies and learning methods in the right material. Research on computational thinking in mathematics learning will help identify effectiveness and other factors that influence the success of educational developments. In addition, it will become an insight for further research regarding the wider application of computational thinking, not only for school students but also for tertiary students.

In the last 10 years research on computational thinking in mathematics learning has developed rapidly (Evendi, 2022). By applying bibliometric analysis, we have the ability to

identify emerging research trends in this domain, topics of interest, as well as patterns of relationships between researchers. In previous bibliometric research, the results show that in computational thinking in mathematics learning, the main focus of research tends to lead to the concepts and methods of learning with student and teacher subjects. Thus, there are still research gaps that need to be explored further, for example, research on learning technology, teaching materials and broader subjects, for example on university students.

Through a bibliometric analysis of computational thinking in mathematics learning, a complete picture of trends and a complete picture of the development of research on the topic of computational thinking in mathematics learning will be obtained. According to Evendi, (2022); Huda et al., (2023) Bibliometric analysis is a statistical method that contains the information needed by researchers in analyzing the topic areas of the researcher's discussion. The bibliometric method will visualize the data obtained by the researcher in easy-to-understand diagrams. Through the image that has been visualized, it can be seen the trend of a study so that new ideas can be obtained for future developments.

Computational thinking research in mathematics learning through bibliometric analysis is an important novelty step in understanding trends and formulating new, better research. It is hoped that through collaborative research the development of computational thinking in mathematics learning will develop more rapidly not only in the segmentation of understanding concepts but can also emerge learning technology. More broadly, computational thinking in mathematics learning does not only focus on school education but is also developed in universities.

Methods

The descriptive bibliometric analysis method is the research method used in this study. Bibliometric analysis is a scientific approach to measuring, analyzing, and describing characteristics and patterns in scientific literature to measure the impact, popularity, and productivity of scientific research by utilizing information such as the number of citations, number of publications, collaborations between researchers, and so on. Research using bibliometric analysis methods collects data from various data sources such as Google Scholar, Scopus, Publicised, Dimensions and so on. In this study the database used is the dimensions database. There are 4 steps of analysis carried out, namely identification, screening, eligibility, inclusion. The identification stage is the initial stage carried out in this study. Through the database dimensions at this stage, 667 publications were obtained with the keywords that had been determined. The keywords were "Computational Thinking in Mathematics Education". Of the 667 publications obtained, not all of them were used in this research. These publications will go through the next stages to see their feasibility.

In the second stage, screening was selected based on the criteria for the year of publication in the last 10 years, namely in the 2013-2023 range and in the form of an article, 268 publications were obtained. The third stage is the publication feasibility test, namely the eligibility stage. At this stage the articles used as data were only taken from educational journals so that 196 publications were obtained as the final data. Publications that have passed these three stages enter the last stage, namely inclusion of 196 data. The following sequence of stages can be seen in Figure 1.

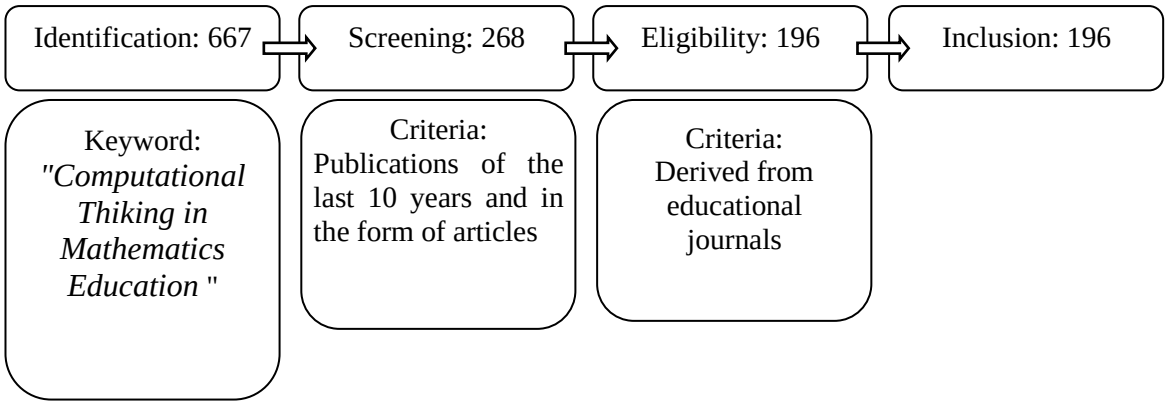

Figure 1. The stages of selecting data

The distribution of data in the 2013-2023 range that has been obtained is presented in tabular form to view publication trends that have occurred over the last 10 years. Also presented is the percentage distribution of publication data that has been obtained from the database dimensions that have gone through the refinement process above. Computational Thinking in Mathematics Education publication data in the period 2013-2023 can be seen in the following table:

Table 1. Number and percentage of Computational Thinking in Mathematics Education publications in the period 2013-2023

No	Year	Number of Publications	Percentage
1	2014	1	1%
2	2015	5	3%
3	2016	5	3%
4	2017	8	4%
5	2018	13	7%
6	2019	17	9%
7	2020	23	12%
8	2021	41	21%
9	2022	49	25%
10	2023	34	17%
	Total	196	100%

From table 1 it can be seen that the average publication has increased every year. This shows that this topic of computational thinking in mathematics education is in great demand. The increase in the number of publications in the 2013-2023 range experienced the greatest increase in 2022, namely as many as 46 publications, which reached 25% of the 196 data for the last 10 years. The analysis technique used is descriptive by utilizing the vosviewer application as a data processing application. Vosviewer will display an overview of the data with clear and attractive visualizations. The visualization displayed by Vosviewer is in the form of country distribution, trending keywords, relationships between authors, trend novelty, influential journals in this study. Furthermore, the output of the vosviewer application will be analyzed by descriptive qualitative method.

Result and Discussion

In presenting the results of the analysis of the inclusion results obtained, the researcher starts from publication trends, journal distribution, relations between countries and research focus.

Trend of Publication

The trend of publications is displayed by grouping the number of publications by year of publication. Publication trends from 2014 to 2023 related to computational thinking in mathematics education research can be seen in figure 2.

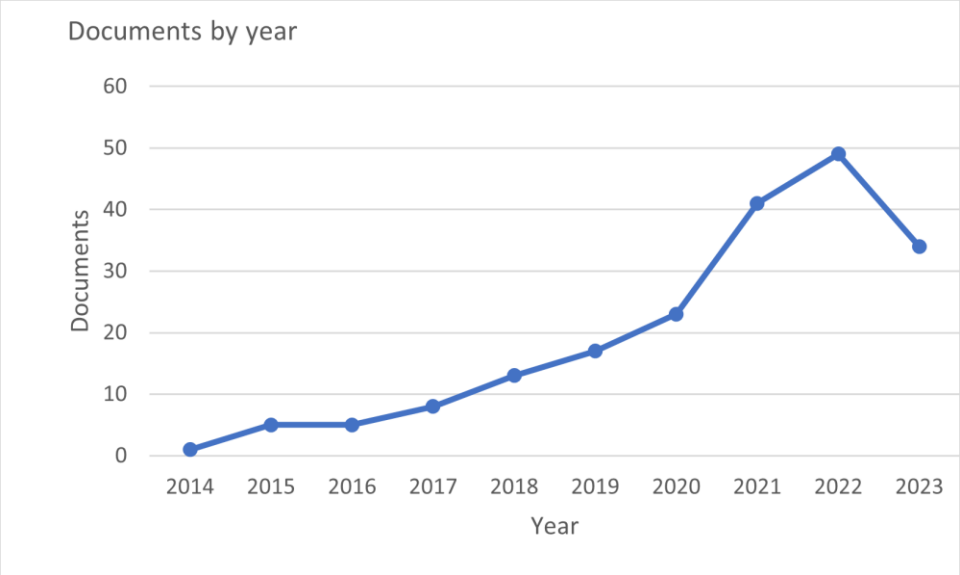

Figure 2. trend of publications

The publication trend of research on the topic of computational thinking in mathematics education has increased rapidly in 2022 and tends to increase every year. In fact, in 2023 when the data was collected it was still in August, which means that articles published after August until the end of 2023 have not been counted, however, the amount of data has exceeded publications in 2021.

Furthermore, from the distribution of publication data in the 2013-2023 range, we will look at the most influential journals over the last 10 years in terms of the number of citations. The following is presented in the form of a picture of the 5 most widely cited educational journals in the last 10 years.

Selected	Source	Documents	Citations	Total link strength
☑	journal of science education and tech...	7	877	18
☑	digital experiences in mathematics e...	7	151	13
☑	education and information technolo...	8	142	8
☑	education sciences	9	37	8
☑	computer applications in engineering...	5	110	3

Figure 3. Number of documents based on Journal

From Figure 3 the number of documents based on journals can be seen the total documents published based on journals, the number of citations carried out and their strength. The education sciences journal is the journal with the most publications, namely 9 publications. However, it is not a journal with the most citations. The science of education and technology

journal is the journal with the most citations, namely 877 citations, even though there are only 7 publications. This makes the science of education and technology journal the most influential journal on this topic.

In the next figure, namely figure 4, after analyzing the influence of the journal, we will analyze the novelty of the five journals above. In the picture below the blue color shows publications published in 2019, the dark green color represents 2020, the green color means the publication is 2021 and the yellow color is the last 1 year's publication. This means, the brighter the visualized color describes the novelty of the research. From the visualization of Figure 4, the education sciences journal is a journal with the latest publication, namely 2022.

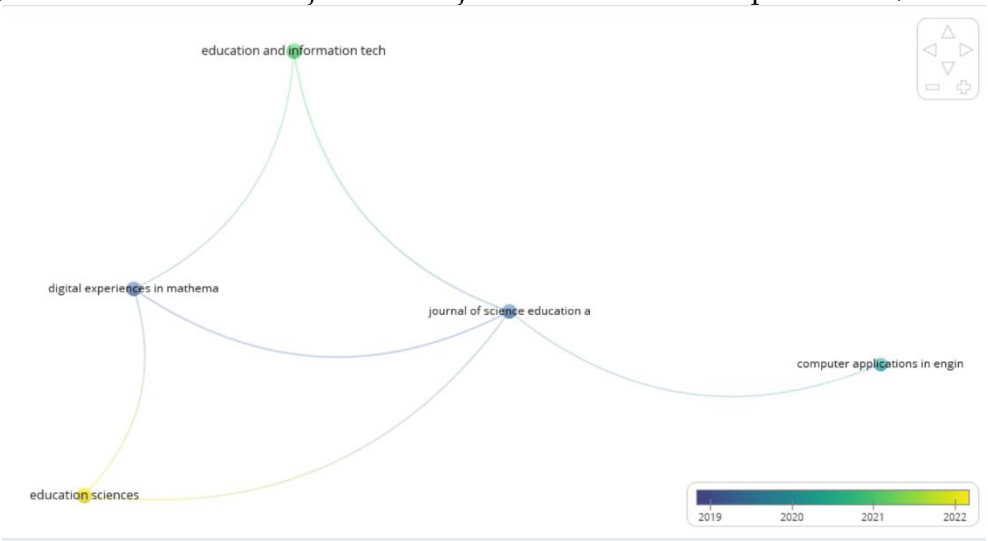

Figure 4. The novelty of the journal with the topic of Computational thinking in Mathematics Education

Bibliograpich Coupling of Country

The image below is generated by the vosviewer application, researchers determine the minimum number of documents that a country fulfills. The researcher determines that there are at least 5 documents that a country must have in order to be visualized in this image. From the distribution of publication data, the United States is the most productive country with 48 publications that have been cited 1921 times, followed by China and Canada in second and third place. This means that research on the topic of computational thinking in mathematics education in these three countries is very intensively carried out when viewed from the publications that have been produced. If we look at the distribution of countries presented in the table, it can be seen that the topic of computational thinking in mathematics education has been extensively researched by developed countries that are already aware of education. Surprisingly, Indonesia as a developing country has also started to be interested in the topic of computational thinking in mathematics education. It can be seen that Indonesia is in seventh place with 8 documents that have been cited 23 times. This is a positive thing for the world of education in Indonesia.

Country	Documents	Citations	Total link strength
united states	48	1921	3659
china	15	148	2785
canada	9	164	1338
spain	13	243	1158
norway	5	39	773
turkey	5	54	668
indonesia	8	23	381
brazil	9	7	174

Figure 5. Bibliograpich Coupling Country

In addition to the data distribution above, Vosviewer also displays the relationship between these countries and can visualize the network below. These networks describe the linkages of countries that have been selected based on predetermined thresholds.

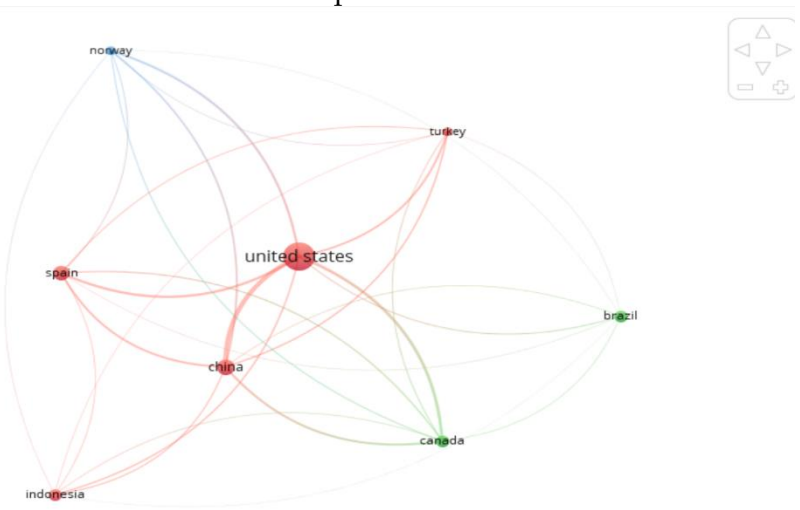

Figure 6. Relations between countries

From Figure 6, it can be seen that there are 7 countries with different color networks. These colors represent the clusters of several countries. The red color is the largest cluster filled with the United States, China, Spain, Turkey and Indonesia. The second cluster, namely in green, is filled with two countries, namely Brazil and Canada. While the smallest cluster, namely the third cluster in blue, is filled with Norway. The cluster describes cooperation or relations between countries in conducting research on this topic, namely computational thinking in mathematics education. Furthermore, the diameter of the circle describes the number of published documents from that country, the larger the number of documents produced.

From this figure, it can be concluded that the United States, China, Spain, Turkey and Indonesia have a collaborative relationship in research on the topic of computational thinking in mathematics education with the most documents coming from the United States because they have scattered circle diameters. Furthermore, the second cooperation relationship is from Brazil and Canada, while Norway does not yet have cooperation with any other country in research on the topic of computational thinking in mathematics education.

In addition to the collaborative research relations of these countries, in Vosviewer on the overlay visualization you can also see the latest countries conducting research on the

topic of computational thinking in mathematics education. Countries with yellow circles are countries with the latest research on the topic of computational thinking in mathematics education. In the picture below, China and Indonesia have been intensively conducting research on the topic of computational thinking in mathematics education in recent years.

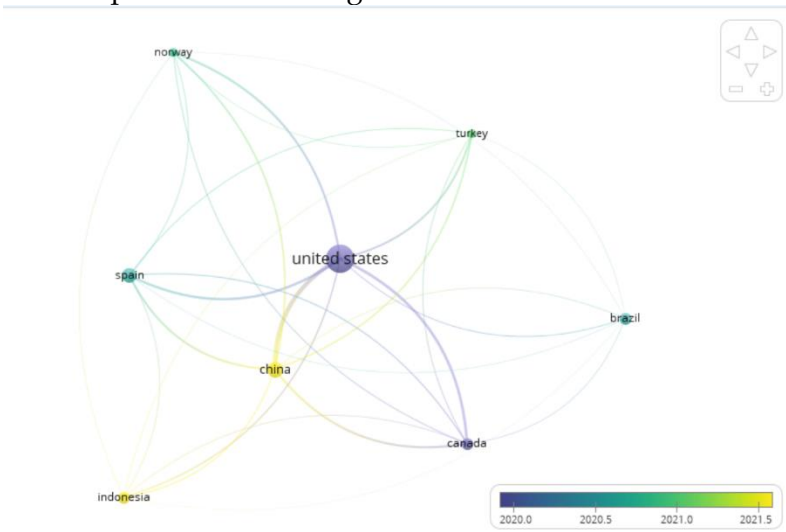

Figure 7. The country's novelty with the research topic Computational Thinking in Mathematics Education

Research Focus

The research focus on the topic of computational thinking in mathematics education can be seen in Figure 8, while Figure 9 shows the novelty of research in recent years. The focus of this research is taken by providing a threshold of 5, meaning that only keywords that appear in at least 5 documents will be displayed by vosviewer. In addition, keywords have also been filtered according to the topic. The following is a visualization displayed by vosviewer regarding the focus of research in this study:

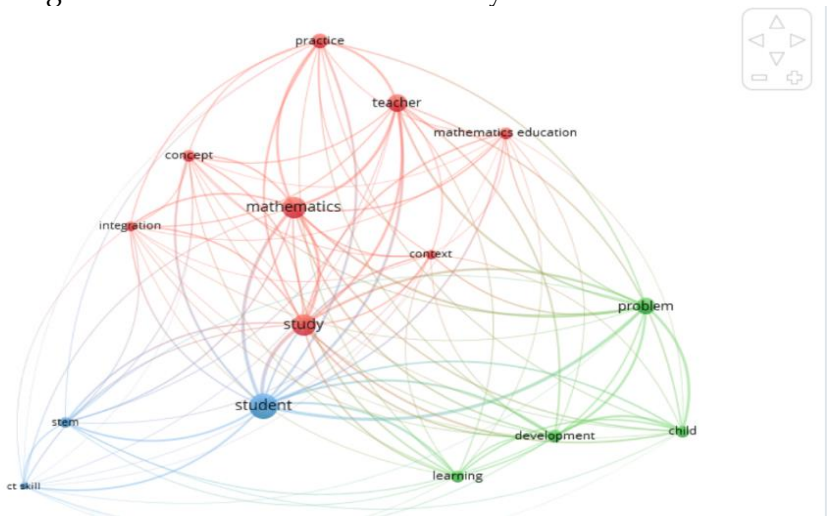

Figure 8. Research focus

From Figure 8 it can be seen that there are 15 keywords scattered in various colors and forming a network. There are 3 different colors, namely red, green and blue. These colors represent clusters that are interconnected. The largest cluster is the first cluster which is the main research focus. In the figure you can see red as the first cluster because it has the largest network. In the first cluster there are 8 research focus keywords. The diameter of the circle indicates the main research focus, in the first cluster, namely mathematics, study, teacher.

The green color is the second cluster with 4 keywords, where child, problem, and learning together become the focus of research in this cluster because it has the largest circle diameter. The last cluster, namely the third cluster in blue, has 3 keywords, with a research focus on student, steam and CT skills. There are three research focuses related to computational thinking in mathematics education research on database dimensions from 2013-2023, namely, 1) mathematics, study, teacher; 2) problems, children, learning; 3) student, steam, CT skills.

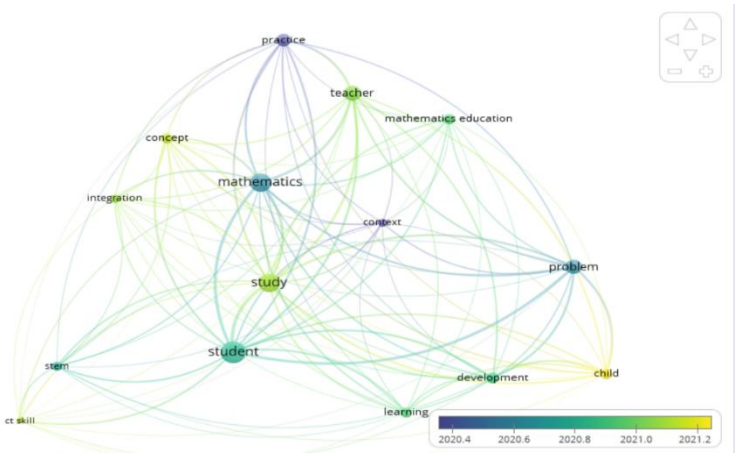

Figure 9 Research novelty

Furthermore, Figure 9 shows the novelty of research on the topic of computational thinking in mathematics education. The colors created display the publication period or the update of the keywords that appeared in previous research. The brighter the color produced means that the keyword is the newest keyword in research on the topic of computational thinking in mathematics education. The dark blue color is the keyword that appeared in the 2020 research, followed by the light blue color which is the research keyword for 2021, the green color for 2022 and the yellow color is the newest keyword for the past year. Keywords child and CT skills are visualized with the brightest color, which is yellow, meaning that the latest research on this topic is about CT skills and chill. It can be seen that the largest network is the focus of research with the keywords mathematics, study, teacher directly related to the novelty keywords, namely CT skill and chill. It can be concluded that research on the topic of computational thinking in mathematics education over the past few years has discussed school education because the keywords that appear are related to the world of schooling. In this case, it can be used as an insight in the next few years that research on the topic of computational thinking in mathematics education can be developed more broadly not only in school education but also in other segments, for example, the general public or higher education with more varied subjects.

Conclusion

From the research that has been conducted above, it can be concluded that the peak of publications related to computational thinking in mathematics education research will occur in 2022. In 2022 publications will reach their peak for the last 10 years, namely with 49 publications. However, it is possible that in 2023 there will also be a fairly rapid increase. The science of education and technology journal is the most influential journal with the most citations, namely 877 citations, although only with 7 publications. The United States is the most influential country in this field because both the number of publications and the number of citations are the highest than any other country. There are three research focuses related to computational thinking in mathematics education research on database dimensions from 2013-2023, namely, 1) mathematics, study, teacher; 2) problems, children,

learning; 3) student, steam, CT skills. Over the past few years, research that has focused on computational thinking in mathematics education has discussed the context of education in schools. This can be seen from the keywords that often appear related to the formal education environment. In the coming period, there is potential to expand the scope of this research more broadly. For example, apart from only focusing on education in schools, research on computational thinking in mathematics education can also involve other aspects such as the general public or higher education level environments, with a more diverse range of subjects.

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