Journal of Mathematics, Science, and Computer Education (JMSCEdu)
https://ppjp.ulm.ac.id/journals/index.php/jmsc-edu/index
Volume 3 Nomor 1 Tahun 2023

e-ISSN: 2807-9167
P-ISSN: 2807-9329

Bibliometric Study of Articles on Computational Thinking in Learning

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Received: 26 October 2022 Accepted: 16 April 2023 Published: 21 August 2023

DOI: https://doi.org/10.20527/jmscedu.v3i1.6672

Abstract
One of the fundamental concepts for the high-level problem-solving abilities required by humans in the twenty-first century is computational thinking. The basic principles and ideas found in informatics and computer science are used to solve issues computationally with the help of computational thinking. The bibliometric examination of the research on computational thinking in learning is explained in detail in this article. Using the Scopus database and the Publish or Perish (PoP) program, articles were found. According to the search and sorting results, 187 of the 200 items were located between 2019 and 2022. The Mendeley Desktop program was used to alter the chosen metadata. The VOSviewer program is then used to evaluate further and display the modifications. Most articles published in the 2019–2022 timeframe with the keyword of computational thinking have been quoted quite a bit.

Keywords: Bibliometric Analysis; Computational Thinking; Learning

How to Cite: Putri, V., Syahmani, S., & Prasetyo, Y. D. (2023). Bibliometric study of articles on computational thinking in learning**.** *Journal of Mathematics, Science, and Computer Education (JMSCEdu)*, 3(1), 1-11.

INTRODUCTION
Computational thinking (CT) approaches problems computationally using the core principles and ideas in informatics and computer science (Bocconi et al., 2016). By defining CT as the process of solving problems with the following stages: problem identification; information collection/ representation/ analysis; problem-solving/ selection/ planning; implementation of the solution; and evaluation, Kaleliolu et al. (2016) proposed an open framework for CT that has not yet been finalized. According to Wing's (2008) perspective, which calls for cognitive action at every level, solving this challenge is a stage that remains constant. Identification of the problem necessitates both abstraction and decomposition. In CT, abstraction plays a big role. The National Research Council (2011) asserts that it is permitted to omit non-essential elements of the issue to concentrate on the essential ones. Decomposition, a cognitive process that enables dividing large problems into simpler ones to achieve appropriate problem resolution, is strongly related to this skill. Through pattern mapping, pattern identification, and conceptualization, information gathering, representation, and analysis enable cognitive mastery of complex situations. Algorithmic thinking is required for making, choosing, and planning problems.

Wing (2010) claims that computational thinking is a collection of different mental tools that span the spectrum of computer science. Computational thinking is an essential cognitive process when creating challenges and solutions in order for solutions to be efficient data processing agents in solving problems.

Computational thinking is one of the core knowledge areas and problem-solving abilities humans must master in the twenty-first century. One of the abilities that must be developed from a young age is computational thinking because industrial 4.0 or society 5.0 will be prevalent in the future. Humans live in the physical world and a digital one that is replete with artificial intelligence, big data, and the Internet of Things (IoT).

Computational thinking is applied in a variety of different research fields, not just those involving computers. STEM, ethics, journalism, physics, and music are among the research areas that have been combined with computational thinking (Mgova, 2018). Although CT can be integrated into STEM courses, not all instructors are skilled, and not all students are enthusiastic about it. As a result, CT in STEM programs must expose students to realistic ideas in the industry. CT-stem, a framework created to address the issue of problem-solving abilities in the STEM area, is one example of its application. This framework's design was developed to give students an engaging subject to study and allow them to experiment with addressing practical STEM challenges. This C3stem framework is compared to helping students analyze traffic by utilizing the kinematics of the vehicles and fundamental driving behaviors. In this study, students perform tasks that are based on real-world scenarios to practice physics topics like speed and acceleration. Make rational choices in difficult circumstances when programming cars. Students create better ethical decision-making processes based on the justifications of diverse ethical approaches in order for robots to react. Students are indirectly required to think computationally by expanding their logical schema.

Computational thinking enables us to understand complicated issues and enhance potential solutions, according to the BBC Bitesize (n.d.) online education curriculum. Then, these issues and solutions can be expressed in a language understandable to computers and people. According to the education module, computational thinking entails problem decomposition, abstraction, thought, algorithm formulation, and creating patterns for resolving related issues. Trends and developments in research on “computational thinking” have previously been researched by Tekdal (2021), but the subject area is very broad. In this study, more emphasis is placed on computational thinking in learning.

This essay aims to explain the abovementioned reasons thoroughly by analyzing the bibliometric literature on computational thinking in learning. The literature that was retrieved from the Scopus database was then examined and divided into groups according to author distribution and affiliation. This analysis looks at prospects for future research and "computational thinking" subjects regularly published. The methodology employed by the Publish or Perish (PoP) software is bibliometric analysis. The Mendeley Desktop tool is then used to alter the PoP results, and the VOSviewer program is used to view distribution patterns. The researchers then discussed the results and made inferences from the completed bibliometric literature analysis. For 2019–2022, computational thinking is the subject of published publications that have undergone bibliometric analysis to identify them. Additionally, it is intended that bibliometric analysis would indicate trends in author collaboration on computational thinking. This bibliometric analysis is expected to contribute to uncovering future research directions and increasing knowledge that the application of CT in learning is very important in improving the quality of education.

METHOD

This bibliometric literature review is founded on a methodical and explicit process (Garza-Reyes, 2015). The five-step technique is the research methodology adopted in the bibliometric analysis (Setyaningsih et al., 2018), and it is depicted in Figure 1.

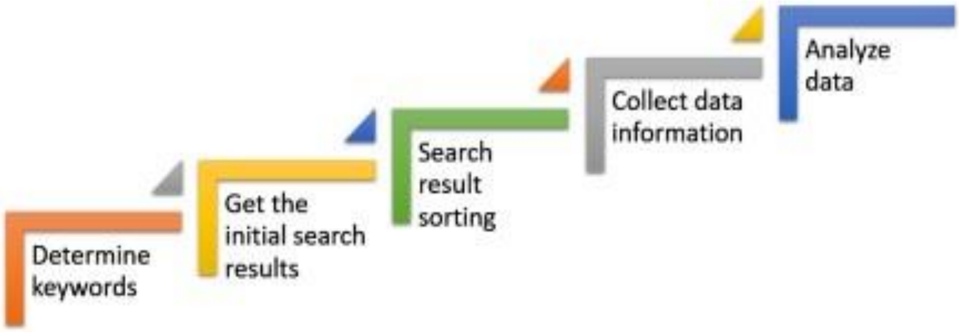

Figure 1 Steps of the bibliometric analysis method

Determine Keywords

In August 2019, a literature search was conducted using "scientific creativity." The Crossref database was chosen because it is a substantial, well-known non-profit with connections to hundreds of millions of metadata records for journal articles, books, etc., and relationships with thousands of publishers. PoP was picked since it was found to be the program that aided metadata tracking for articles the most (Baneyx, 2008). Finding the First Search Results, The search results were limited to 2019–2022 publications. The Scopus database was first searched for 200 articles. The search results are kept in Research Information Systems (RIS) format in the PoP database.

Search Results Sorting

The papers are then arranged according to the publication format, specifically the 200 articles that makeup journal articles. Two hundred articles were divided into other categories based on their topics, primarily science, and their educational components, particularly secondary and higher education, yielding a total of 187 articles. Sorting results are saved in RIS format. The RIS-formatted data is then imported into the Mendeley Desktop program for further data analysis.

Collect Data Information

The Mendeley Desktop software reviews the RIS-formatted data by looking at each piece of metadata. To match the metadata with published articles, any missing or incorrect metadata must be corrected. The RIS format is also used to save edits.

Analyzing Data

The Mendeley Desktop-edited RIS-formatted data were subjected to additional examination using the VOSviewer program. VOSviewer can effectively analyze data and generate analytical output through in-depth data and visually appealing visuals (van Eck & Waltman, 2010).

RESULT AND DISCUSSION

VOSviewer software, to ascertain the most popular search terms, was utilized to examine PoP software output documents. The search terms in VOSviewer are utilized only to gather and analyze data. VOSviewer is used to visualize maps using bibliometric data.

Two hundred articles were first pulled from the Scopus database. "Computational thinking" was used to gather this data from 2019 to 2022. The 200 articles are then further organized by a science-related topic and according to the educational setting, which ranges from elementary school to higher education. One hundred eighty-seven articles were ultimately gathered. According to the information shown by PoP, articles are systematically arranged in Table 1.

Table 1 The Most Relevant Article by PoP

No.	Year Published	Author	Title	Journal	Cited
1.	2019	Meng-Jung Tsai, Ching-Yeh Wang, and Po-Fen Hsu	Developing the computer programming self-efficacy scale for computer literacy education	Journal of Educational Computing Research, 56(8), 1345-1360	52
2.	2020	Roberto Verganti, Luca Vendraminelli, and Marco Iansiti	Innovation and design in the age of artificial intelligence	Journal of Product Innovation Management, 37(3), 212-227	48
3.	2020	Stamatios Papadakis	Robots and robotics kits for early childhood and first school age	International Journal of Interactive Mobile Technologies, 14(18), 34-56	47
4.	2019	Marina Umaschi Bers	Coding as another language: a pedagogical approach for teaching computer science in early childhood	Journal of Computers in Education, 6(4), 499-528	45
5.	2019	Ronny Scherer, Fazilat Siddiq, and Bárbara Sánchez Viveros	The cognitive benefits of learning computer programming: A meta-analysis of transfer effects	Journal of Educational Psychology, 111(5), 764-792	40
6.	2020	Stamatios Papadakis	Evaluating a game-development approach to teach introductory programming concepts in secondary education	International Journal of Technology Enhanced Learning, 12(2), 127-145	36
7.	2020	Diane Jass Ketelhut, Kelly Mills, Emily Hestness, Lautaro Cabrera, Jandelyn Plane, and J. Randy McGinnis	Teacher change following a professional development experience in integrating computational thinking into elementary science	Journal of Science Education and Technology, 29(1), 174-188	34
8.	2019	Stamatios Papadakis and Michail Kalogiannakis	Evaluating a course for teaching introductory programming with Scratch to pre-service kindergarten teachers	International Journal of Technology Enhanced Learning, 11(3), 231-246	33
9.	2019	Bian Wu, Yiling Hu, A.R. Ruis, and Minhong Wang	Analyzing computational thinking in collaborative programming: a quantitative ethnography approach	Journal of Computer Assisted Learning, 35(3), 421-434	33
10.	2019	Yune Tran	Computational thinking equity in elementary classrooms: what third-	Journal of Educational Computing Research, 57(1), 3-31	33

No.	Year Published	Author	Title	Journal	Cited
			grade students know and can do		

The ten articles included in the search results on PoP are the most relevant to the phrase "computational thinking". The first place has the greatest relevance. In 2019–2022, the growth development of the computational thinking debate did not significantly increase. In 2020, 67 publications (35.6%) were added to the discussion of computational thinking, which had the highest Scopus indexing. Table 2 provides more information about the increase in global publications on computational thinking.

Table 2 Growth of International Publications on Computational Thinking

Year of Publication	Number of Articles	Percentage (%)
2019	56	29.95
2020	67	35.80
2021	56	29.95
2022	8	4.30
Total	**187**	**100**

Three different visualizations for bibliometric analysis mapping are available through VOSviewer (Hamidah et al., 2020). Figure 2 displays the network visualization, Figure 3 displays the overlay visualization, and Figure 4 displays the density visualization.

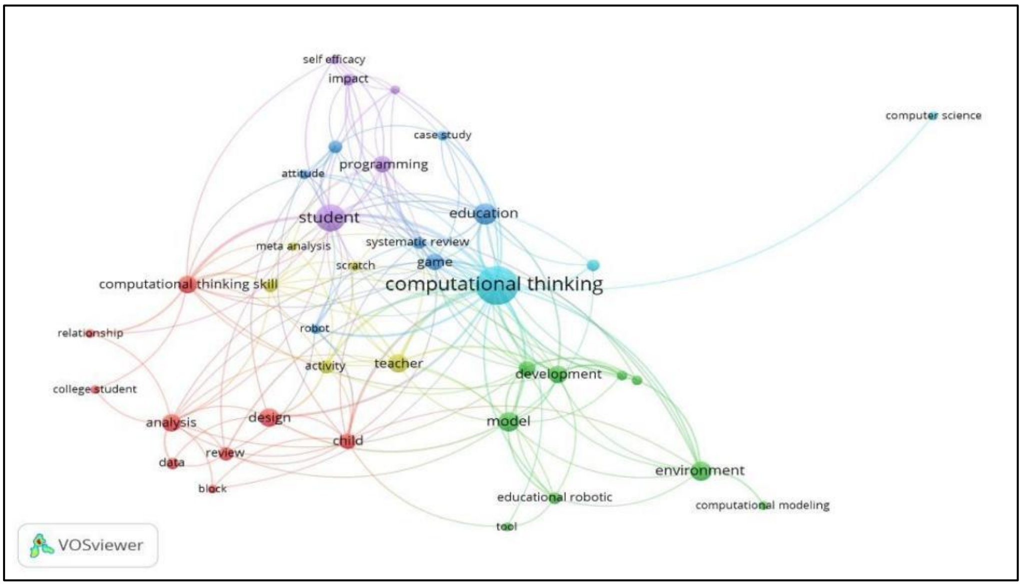

Figure 2 Scopus Network Database Visualization

Three clusters can be seen in Figure 2, each of which is distinguished by different colors (red, green, or blue). Each color indicates the zone's division and the number of related keywords. Five zones can be seen in Figure 2, with the red zone on the left, the green zone on the lower right, and the blue, yellow, and purple zones in the middle. The same color will be used to indicate keywords related to each other. There are nine items related to red, seven to blue, six to green, five to yellow, and four to purple.

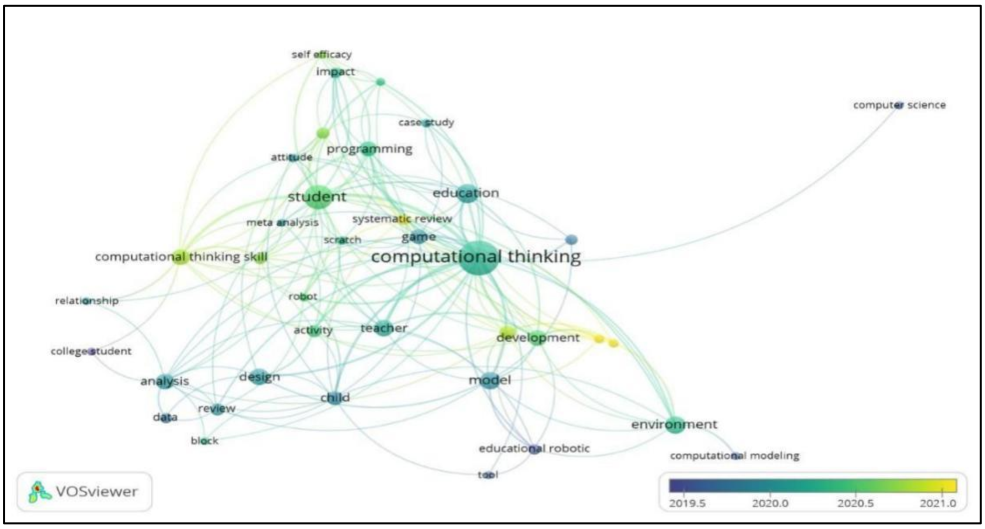

Figure 3 Scopus Database Overlay Visualization

The update rate of keyword publications is shown in Figure 3 and is denoted by the blue and yellow shading. It gets younger if it gets closer to yellow and rises earlier if it gets closer to blue. It is clear from Figure 3 that other authors have used the keywords "computational thinking skills" and "systematic review" in their most recent articles.

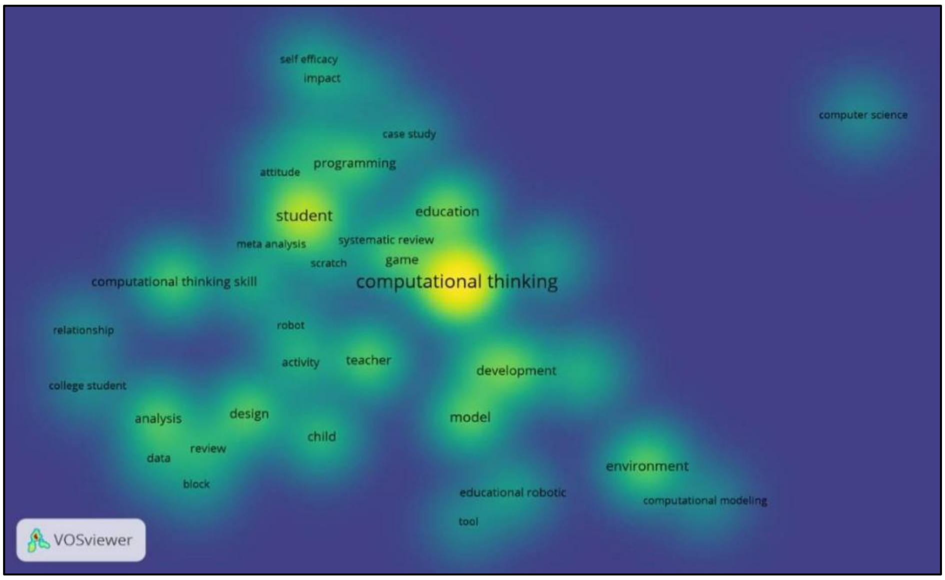

Figure 4 Scopus Database Density Visualization

The density of the relationship between keywords can be seen in Figure 4. The yellow pattern will form over several areas where there is a relationship between the computational thinking variable keywords, and the closer the relationship, the more areas it will cover. Conclusion: Based on Figure 4, it is clear that authors frequently use the keywords "computational thinking," "student," and "education" when discussing the use of computational thinking in learning. With the aid of the VOSviewer program, 187 articles that were selected based on the article's title, keywords, and abstract were extracted to create this visualization. Three minimum of three events is the default. Thirty-eight items fulfilled the requirements. Each item is identified by a colored dot that stands for a keyword.

Figure 5 illustrates the author's analysis, the relationship between authors, and the pattern of author collaboration. Thirty-eight groups/ clusters can be recognized and described by different colors, as seen in Figure 5.

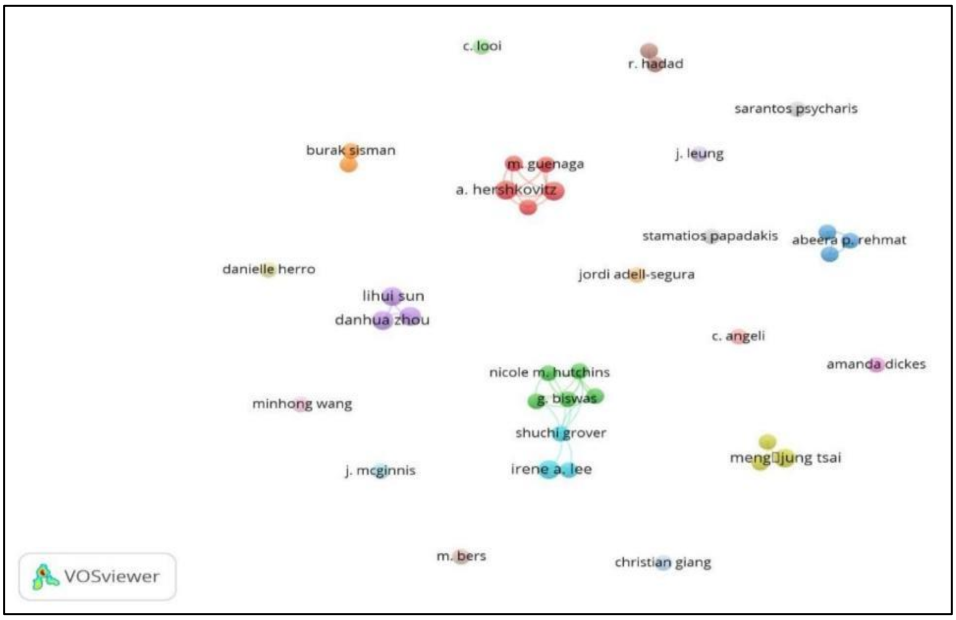

Figure 5 Relationship Between Authors and the Pattern of Collaboration Between Authors

As shown in Figure 5, many authors are strangers to one another and have never worked together. The red cluster is the one with the strongest pattern of collaboration. Figure 6 elaborately displays the author's pattern of collaboration in the red cluster.

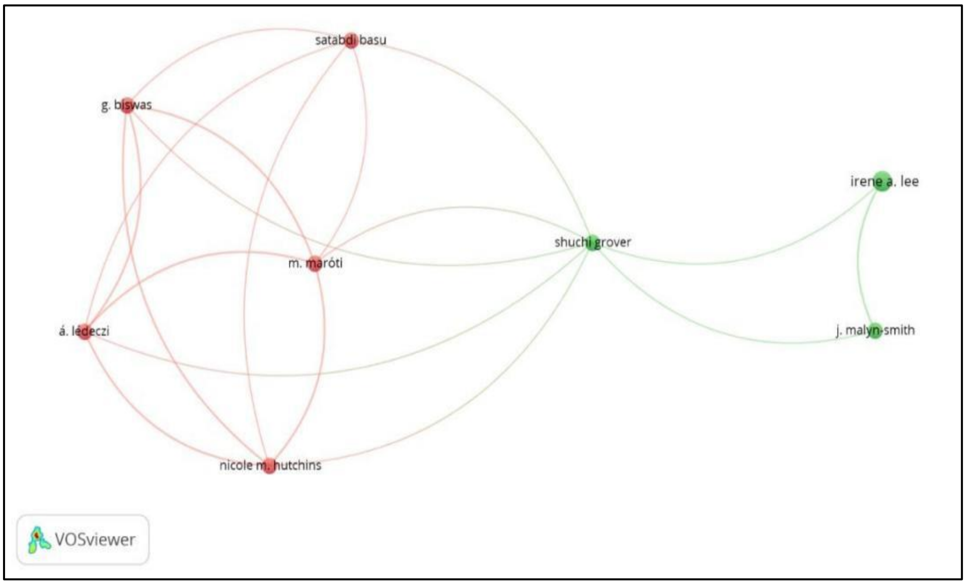

Figure 6 Visualization of Pattern Collaboration Analysis among the Largest Cluster Authors

Figure 6 demonstrates how each author is related to the others. If this relationship between these writers is looked into further, it becomes clear that they are all affiliated with the same institution. Based on these findings, it can be concluded that authors from one institution had the strongest collaborative relationship concerning computational thinking keywords. Unfortunately, because there is no collaboration between other institutions, writing collaboration still takes place within the confines of one institution. Figure 7 illustrates the novelty analysis of writing as a time strain.

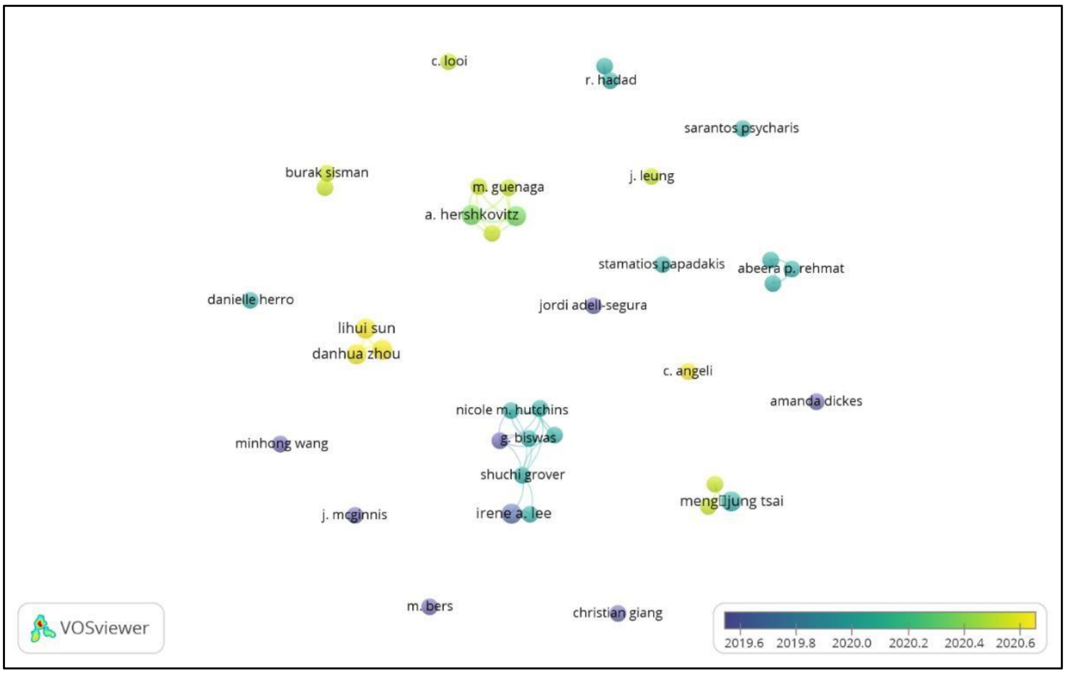

Figure 7 Visualization of the Author Overlay and the Pattern of Collaboration between Authors on the Scopus Base

Figure 7 demonstrates how yellow patterns and shapes, such as one of Lihui Sun's studies, have only recently been used to research the term "computational thinking." Similar to Figure 3, as it approaches yellow, it indicates that it is becoming more recent, and as it approaches blue, it indicates that it is becoming more ancient (earlier). Other hues do not support the notion that additional research was delayed excessively. The novelties of this study include (1) the successful discovery of scientific creativity research in chemistry education in the Scopus database, which was not available in the previous year; (2) the discovery that the collaborative relationships of Indonesian researchers who studied computational thinking in the Scopus indexed learning in the previous year was not found; and (3) the lack of research based on data gathered from the Scopus database.

The journals that published the most articles on computational thinking in learning in the previous year were also analyzed. Of the 187 articles that were published, 16 additional articles and 21 additional articles were published in the Journal of Science Education and Technology. Only ten articles with this keyword have been published in other journals. This demonstrates that articles about computational thinking are actively published in both journals. According to network analysis based on the occurrence of keyword pairs, clusters of the same color have more closely related keywords than clusters of other colors (Liu et al., 2015). Another analytical method frequently used in bibliometric research to determine the similarities of various research fields is the examination of author collaboration patterns (Hudha et al., 2020). The collected data can generally give an overview of education's scientific creativity research trend over the past ten years. This study has the potential to serve as a resource for other researchers looking to delve deeper into the relationship between computational thinking and other variables in the context of basic, secondary, and higher education.

CONCLUSION

According to the findings of the bibliometric analysis, papers with the keyword "computational thinking" in the 2019–2022 time period have received a significant number of citations. It is still difficult to discern the pattern of author collaboration among institutions. This study's gap reveals the direction of future research, which suggests that applying computational thinking to learning is an important subject that should be investigated in cooperation between national institutions and worldwide. Some suggestions for future research include utilizing English keywords, extending the year records of post searches, such as the last five years, and using additional databases like Google Scholar, Crossref, Microsoft Academic, Web of Science, etc. Additionally, keyword selection for subjects like affiliations and cities might be aided by bibliometric analysis.

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