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Bibliometric Computational Mapping Analysis of Publications on Computational Thinking in Science Education using VOSviewer

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ABSTRACT

The use of computing tools has provided support for learning science content and assisted students in understanding modern science experiences. Therefore, students must have an understanding on how computation could be useful for supporting science learning goals. In other words, students need a new skill to fulfil the tasks, that is computational thinking. This study aims to determine the development of research on computational thinking in science education through a bibliometric approach using the VOSviewer application. The article data was obtained from the Google Scholar database. The application used to obtain the article data was Publish or Perish. The keyword used to search for articles is "Computational Thinking in Science Education". 344 articles that were considered relevant to these keywords were found. The articles used were articles published in the last 10 years (2013 – 2022). The findings showed that the research on this topic decreased from 57 studies to 13 studies after 2020, and it became very popular in 2020. Furthermore, the research on computational thinking in science education still has a high enough chance to be carried out. We examined how many articles had been published about computational thinking in science education and its relation to problem areas using VOSviewer. We hope that this research can be a starting point for research related to other fields.

Keywords:
Bibliometric analysis; Computational thinking; Science education; VOSviewer

1. Introduction

The computer revolution has had a significant impact on how scientists think about science, experiments, and research [1-4]. This revolution has changed science with the possibility of new discoveries enabled by information technology.

Over the last few decades, scientific inquiries have become increasingly computational. As a result, computing has become a crucial aspect of many disciplines, particularly science, technology, engineering, and mathematics (STEM) [5-10]. Furthermore, advances in computing have led to fundamental changes in how scientific research is carried out. With computational tools, scientists can expand the problem space of scientific inquiry and enable them to investigate "big challenges" in science [11].

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The use of computing tools has provided support for learning science content [12,13] and assisted students in understanding modern science experiences [14]. Therefore, students must have an understanding on how to use, design, and evaluate computational tools effectively for science and how computation could be useful for supporting science learning goals [15,16]. In other words, students need a new skill to fulfil the tasks, that is computational thinking.

The term computational thinking is important [17,18]. It was first coined in 1980 in a discussion of the potential impact of computers on the way people think and learn. Computational thinking was first described as an umbrella. The term refers to the set of computational ideas that people use to represent their work through the design of computer hardware systems, software, and computation. It was later referred to as the procedural and probabilistic thought process of defining relationships between problems, solutions, and data arrangement [19]. Furthermore, computational thinking became more widely accepted after a viewpoint in Communication of the ACM. In his early writings, he stated that computational thinking involves solving problems, designing systems, and understanding human behaviour, by drawing on concepts fundamental to computer science [20]. In another paper, computational thinking is a thinking process for formulating problems and presenting solutions in a form that can be carried out effectively by information processing agents [21].

Although researchers and practitioners currently define computational thinking [22-24], there is no consensus on a formal definition of computational thinking [25-27]. Even so, several researchers and education practitioners have tried to integrate computational thinking into learning, which has been carried out from the elementary level to tertiary institutions [12,25,28,29]. Little research has been conducted on the implementation of computational thinking in science learning in K–12 classrooms [19]. To find out how many research results are related to computational thinking in science learning, VOSviewer software analysis is carried out to find out the mapping of the required data.

VOSviewer is a software that visualizes data set with bibliographic field [30]. VOSviewer is utilized in the realm of research for bibliometric analysis, seeking themes that can still be explored, and showing the more widely used references in certain domains [31].

There is an analytical technique that can be used to find out the development of research on the topic of computational thinking in science education, namely bibliometric analysis. Bibliometric analysis is a popular and rigorous method for exploring and analysing large amounts of scientific data. Through this method, we can open the screen of a certain field while highlighting the area that appears in that field [30]. Bibliometric analysis has gained great popularity in research in recent years. There are many studies on bibliometric analysis in the field of business [31-33], bibliometric analysis in STEM education [34-37], bibliometric analysis in environmental education research [38,39], bibliometric analysis on mathematics education research [40-42], and bibliometric analysis on science education [43,44]. However, research on computational mapping of bibliometric analysis on computational thinking in science education has not yet been carried out. Especially the bibliometric analysis for the last 10 years of research during the 2013-2022 period using the VOSviewer application. Detailed information for the bibliometric is shown in Table 1.

Therefore, this research performed a computational mapping analysis of articles on computational thinking in science learning indexed by Google Scholar using the VOSviewer application. This research was conducted with the hope that it could be used as a reference to conduct and determine research topics, especially those related to the field of computational thinking in science education.

Table 1
Previous studies on bibliometric

No	Title	Ref.
1	Involving Particle Technology in Computational Fluid Dynamics Research: A Bibliometric Analysis	[45]
2	Bibliometric Computational Mapping Analysis of Trend Metaverse in Education using VOSviewer	[46]
3	The Use of Information Technology and Lifestyle: An Evaluation of Digital Technology Intervention for Improving Physical Activity and Eating Behaviour	[47]
4	Strategies in language education to improve science student understanding during practicum in laboratory: Review and computational bibliometric analysis	[48]
5	How language and technology can improve student learning quality in engineering? definition, factors for enhancing students' comprehension, and computational bibliometric analysis	[49]
6	Mapping of nanotechnology research in animal science: Scientometric analysis	[50]
7	Scientific research trends of flooding stress in plant science and agriculture subject areas (1962-2021)	[51]
8	Introducing ASEAN Journal of Science and Engineering: A bibliometric analysis study	[52]
9	A bibliometric analysis of chemical engineering research using VOSviewer and its correlation with Covid-19 pandemic condition	[53]
10	A bibliometric analysis of materials research in Indonesian journal using VOSviewer	[54]
11	Bibliometric analysis of engineering research using VOSviewer indexed by google scholar	[55]
12	Bibliometric computational mapping analysis of publications on mechanical engineering education using VOSviewer	[56]
13	Research trend on the use of mercury in gold mining: Literature review and bibliometric analysis	[57]
14	Domestic waste (eggshells and banana peels particles) as sustainable and renewable resources for improving resin-based brakepad performance: Bibliometric literature review, techno-economic analysis, dual-sized reinforcing experiments, to comparison with commercial product	[58]
15	Bibliometric analysis of educational research in 2017 to 2021 using VOSviewer: Google scholar indexed research	[59]
16	Corncob-derived sulfonated magnetic solid catalyst synthesis as heterogeneous catalyst in the esterification of waste cooking oil and bibliometric analysis.	[60]
17	The compleat lextutor application tool for academic and technological lexical learning: Review and bibliometric approach.	[61]
18	Use of blockchain technology for the exchange and secure transmission of medical images in the cloud: Systematic review with bibliometric analysis.	[62]
19	Computational bibliometric analysis of research on science and Islam with VOSviewer: Scopus database in 2012 to 2022.	[63]
20	Digital transformation in special needs education: Computational bibliometrics.	[64]
21	Particulate matter emission from combustion and non-combustion automotive engine process: review and computational bibliometric analysis on its source, sizes, and health and lung impact	[65]

2. Methodology

This research was a bibliometric computational mapping analysis using VOSviewer software. Bibliometric mapping is an important research topic in the field of bibliometrics. Two aspects of bibliometric mapping could be distinguished: the construction of bibliometric maps and the graphical representation of such maps. In the bibliometric literature, most of the attention is given to the construction of bibliometric maps. Meanwhile, the graphical representation of bibliometric maps has received less attention [66]. This research focused on the graphical representation of bibliometric maps using VOSviewer. VOSviewer is a program developed for creating and viewing bibliometric maps. VOSviewer can display maps in many different ways, each emphasizing a different aspect. Detailed information for how to use bibliometric is explained elsewhere [67,68].

In this study, all article data used were articles indexed by Google Scholar. This was because Google Scholar indexation was an open access. An application called Publish or Perish was used to obtain data from the Google Scholar database. Publish or Perish was software that was used to conduct a literature review on a particular topic. In this study, we carried out a series of stages referring to reference [30,31] which included:

i. defining the aims and scope of the bibliometric study
ii. choosing the technique for bibliometric analysis
iii. collecting the data for bibliometric analysis
iv. run the bibliometric analysis and report the findings.

Data filtration was carried out using the keyword "Computational Thinking in Science Education". The articles used were articles published during the 2013-2022 period. Furthermore, the articles that had been obtained and met the criteria were exported into two file types, namely research information systems (.ris) and comma-separated value format (.csv). In the end, VOSviewer was used to visualize and evaluate trends using bibliometric maps.

VOSviewer was used to create three variations of mapping publications, namely network visualization, density visualization, and overlayed visualization based on existing data. When making bibliometric maps, we used a minimum frequency of keywords three times. So that 212 terms were obtained and the irrelevant rest were eliminated.

3. Results

3.1 Publication of Data Search Results

Based on search results from Publish or Perish on the Google Scholar database, 344 articles that met the criteria were obtained. The obtained data is shown in article metadata which consists of the author's name, title, year, journal name, publisher, number of citations, article links, and related URLs. Table 2 shows some examples of published data used in the VOSviewer analysis in this study. The sample data taken are the 10 best articles that have the highest number of citations. The number of citations of all articles in this study is 19727, with the number of citations per year of 1972.70. Furthermore, the number of citations per article is 57.35, with an average number of authors of 2.76. All articles used in this study had an average h-index of 72 and a g-index of 122.

Table 2
Publication data of computational thinking in science education

No	Author	Title	Year	Cites
1	Weintrop *et al.,* [14]	Defining computational thinking for mathematics and science classrooms	2016	1470
2	Osborne [69]	Teaching scientific practices: Meeting the challenge of change	2014	721
3	Angeli *et al.,* [70]	A K-6 computational thinking curriculum framework: Implications for teacher knowledge	2016	506
4	Sullivan and Bers [71]	Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade	2016	471
5	English [72]	Advancing elementary and middle school STEM education	2017	402
6	Wing [73]	Computational Thinking’s influence on Research and education for All	2017	263
7	Jaipal-Jamani and Angeli [74]	Effect of robotics on elementary preservice teachers’ self-efficacy, science learning, and computational thinking	2017	250
8	Leonard *et al.,* [75]	Using robotics and game design to enhance children’s self-efficacy, STEM attitudes, and computational thinking skills	2016	250
9	Papadakis *et al.,* [76]	Developing fundamental programming concepts and computational thinking with ScrachJr in preschool education: a case study	2016	240
10	Erduran *et al.,* [77]	Research trends on argumentation in science education: A journal content analysis from 1988-2014.	2015	227

3.2 Development of Research in the Field of Computational Thinking in Science Education

Figure 1 shows research developments in the field of computational thinking in science education published in Google Scholar-indexed journals. Based on the data shown in Figure 1, it can be seen that the number of studies on computational thinking in science education is 344. Based on the number of publications, it can be seen that research on computational thinking in science education is still relatively small each year. Its development looks quite fluctuating. Based on Figure 1, it can be seen that from 2020 to 2022, the development of research related to computational thinking in science education has decreased. This decline can be seen in the number of publications in 2020, which went from 57 to only 13 in 2022. This shows that interest in research on computational thinking in the science learning field is decreasing.

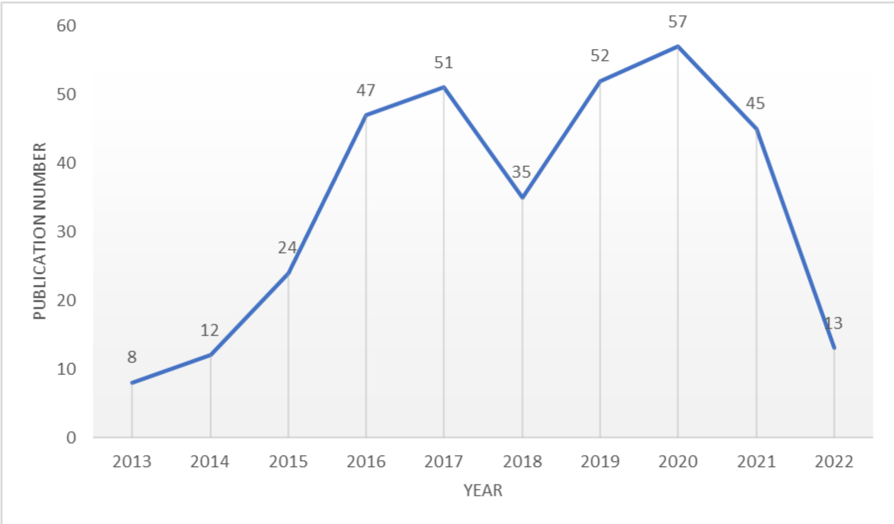

Fig. 1. Distribution of publication numbers of computational thinking in science education

3.3 Visualization of Computational Thinking in Science Learning Topic Area using VOSviewer

In this study, computational mapping was also carried out using the VOSviewer application. Based on the obtained data, VOSviewer can display maps in three different ways: network visualization, overlayed visualization, and density visualization. In network visualization, items are shown with labels, and by default, they are shown with circles. The more important an item is, the larger the label and circle will be. And to distinguish one cluster from another, each label is displayed in a coloured circle (see Figure 2).

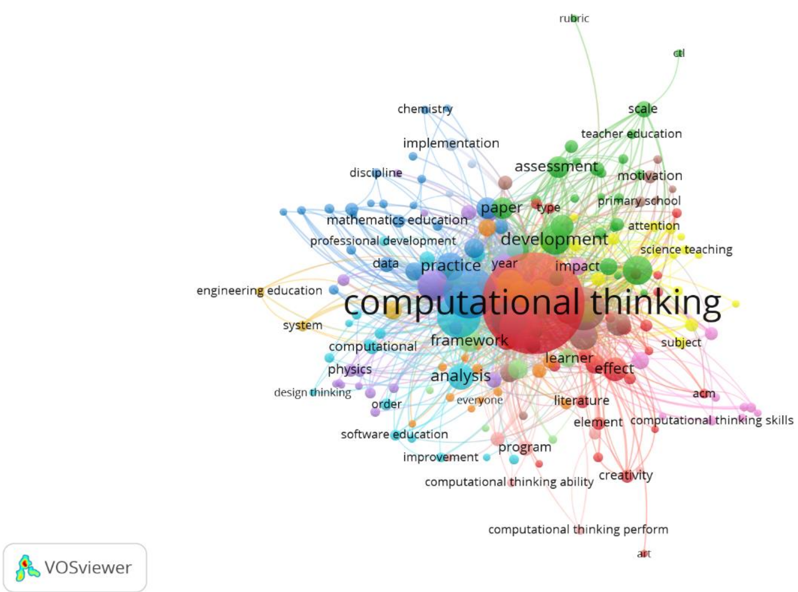

Fig. 2. Network visualisation of computational thinking in science education keyword

Based on the results of the mapping, 212 items were found. The items found and related to computational thinking in science education are divided into 12 clusters marked with coloured circles, namely red, green, blue, yellow, purple, sky blue, orange, brown, pink, dusty pink, light green, light sky blue, and goldenrod. Each cluster has a function to describe the relationship between terms, and each cluster describes the relationship between two or more terms [77,78].

In this study, 13 clusters were obtained and are visualized in Figure 2. The 13 clusters are:

i. Cluster 1 consists of 29 items marked in red. These items are acm, algorithmic thinking, art, association, computational modelling, computational thinking, computer, context, creative thinking, creativity, critical thinking, effect, element, elementary school student, influence, language, literacy, literature, math, pair programming, part, primary school student, problem, representation, science learning, self-efficacy, teaching, type, and world.
ii. Cluster 2 consists of 28 items marked in green. These items are assessment, computational thinking skill, ctl, curriculum, development, early childhood classroom, early childhood education, educational robotic, examination, experience, game design, implication, lesson, need, outcome, paper, project, robotic, robotics, scale, stem, stem attitude, style, teacher education, term, validation, and young child.
iii. Cluster 3 consists of 25 items marked in blue. These items are activity, article, artificial intelligence, chemistry, complex system, connection, data, disciplinary perspective, discipline, effectiveness, engineering, engineering practice, high school student, journal, mathematics education, opportunity, practice, researcher, science education, science education research, scientific practice, special issue, technology, visual representation, and young student.
iv. Cluster 4 consists of 23 items marked in yellow. These items are abstract, abstraction, action, adult education, area, attention, case study, computational thinking development, decade, e-learning, early childhood, ict, interest, learning, nature, programming, science teaching, scratch, secondary education, subject, teacher, understanding, and use.

v. Cluster 5 consists of 20 items marked in purple. These items are approach, argument, attitude, difficulty, evidence, explanation, field, information, integration, mathematics, metacognition, physics, preschool child, process, robot, school, solution, step, strategy, and systematic review.
vi. Cluster 6 consists of 19 items marked in sky blue. These items are analysis, argumentation, classroom, cognition, computational, design thinking, improvement, inquiry, order, pedagogy, professional development, research trend, science, software education, steam education, study, sw education, trend, and university.
vii. Cluster 7 consists of 16 items marked in orange. These items are addition, child, coding, definition, everyone, exploration, fundamental skill, idea, lack, modelling, research, scientist, set, tool, wing, and writing.
viii. Cluster 8 consists of 15 items marked in brown. These items are application, computer science, computer science education, computing, concept, country, education, example, motivation, perspective, pre-service teacher, primary school, service, software education program, and view.
ix. Cluster 9 consists of 11 items marked in pink. These items are 21st century, acm inroads, case, computational thinking skills, computer science education community, game, http, impact, org, role, and scrachjr.
x. Cluster 10 consists of 10 items marked in dusty pink. These items are ability, block, computational thinking ability, computational thinking performance, middle school, program, relationship, student, way, and year.
xi. Cluster 11 consists of 8 items marked in light green. These items are artificial intelligence education, environment, framework, importance, learner, multiple representation, skill, and stem education.
xii. Cluster 12 consists of 5 items marked in light sky blue. These items are computational experiment, implementation, model, physical computing, and simulation.
xiii. Cluster 13 consists of 3 items marked in goldenrod. These items are engineering education, and system, thinking.

Figure 3 shows the overlay visualization. In the network visualization view, labels represent items in the same way. The lighter the colour, the newer the research. It also implies the novelty of a research topic. According to the findings, the majority of computational thinking research was conducted during 2018 and 2019. It is also clear that research on the topic has slowed since that year. This could be an opportunity to do more research in this area.

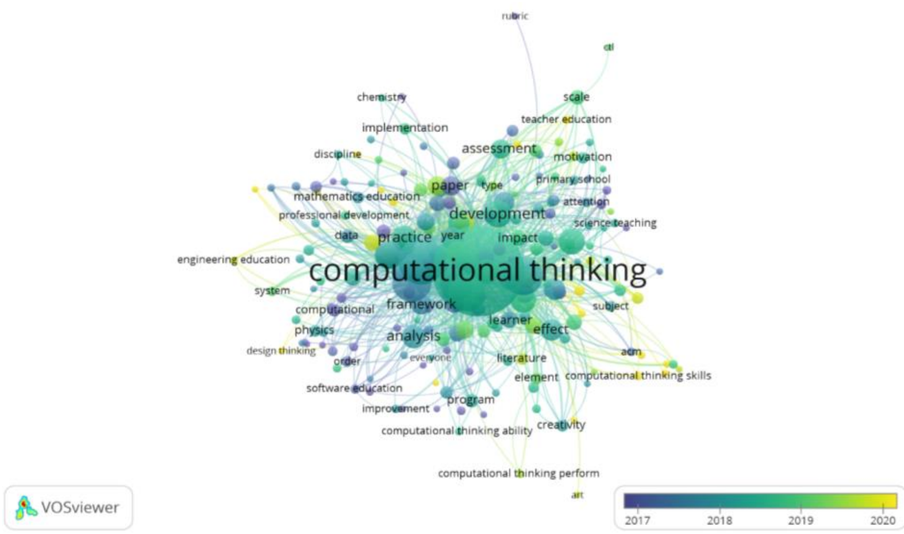

Fig. 3. Overlay visualisation of computational thinking in science education keyword

Figure 4 shows the density visualization related to the research topic of computational thinking in science education. Every circle on the map has a colour, with different densities and items in the circles. The colour of the map represents the number of items around the circle. Density visualization is very useful for getting an overview of the general structure of the map and for drawing attention to the most important areas of the map [66].

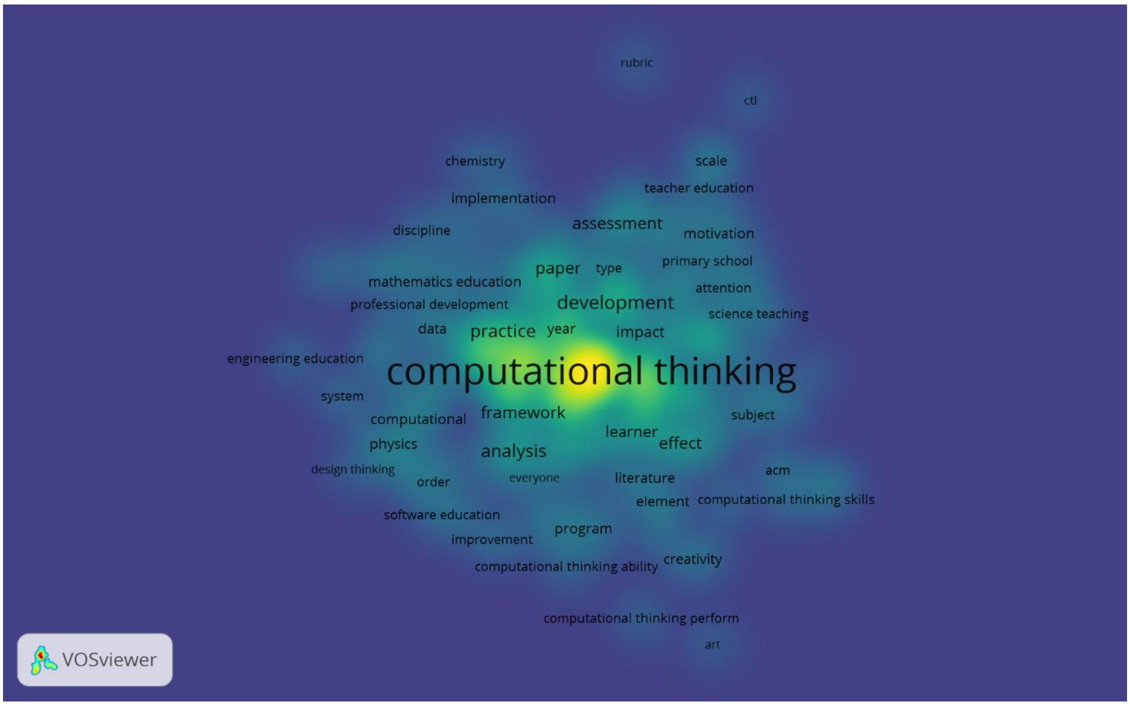

Fig. 4. Density visualisation of computational thinking in science education keyword

Density visualization states that the brighter the yellow colour and the larger the diameter of the circles on the term labels, the more often these terms appear [79]. This indicates that many studies have been conducted with these terms. Vice versa, if the colour of a term fades, then the number of studies on that term is still small. Based on the results of Figure 4, it can be seen that research related to computational thinking is a research topic that has been widely studied.

Figure 5 only show terms related to the topic, namely computational thinking. Based on the Figure 5, the network visualization shows that the theme of computational thinking is in cluster 1 with 210 links, 2860 total link strength, and 456 occurrences. Besides, in Figure 5, the keywords within the shinning zones appear the most recent investigative trends. In the interim, keywords within the dim zone appear investigative patterns that have been investigated for a long time [80].

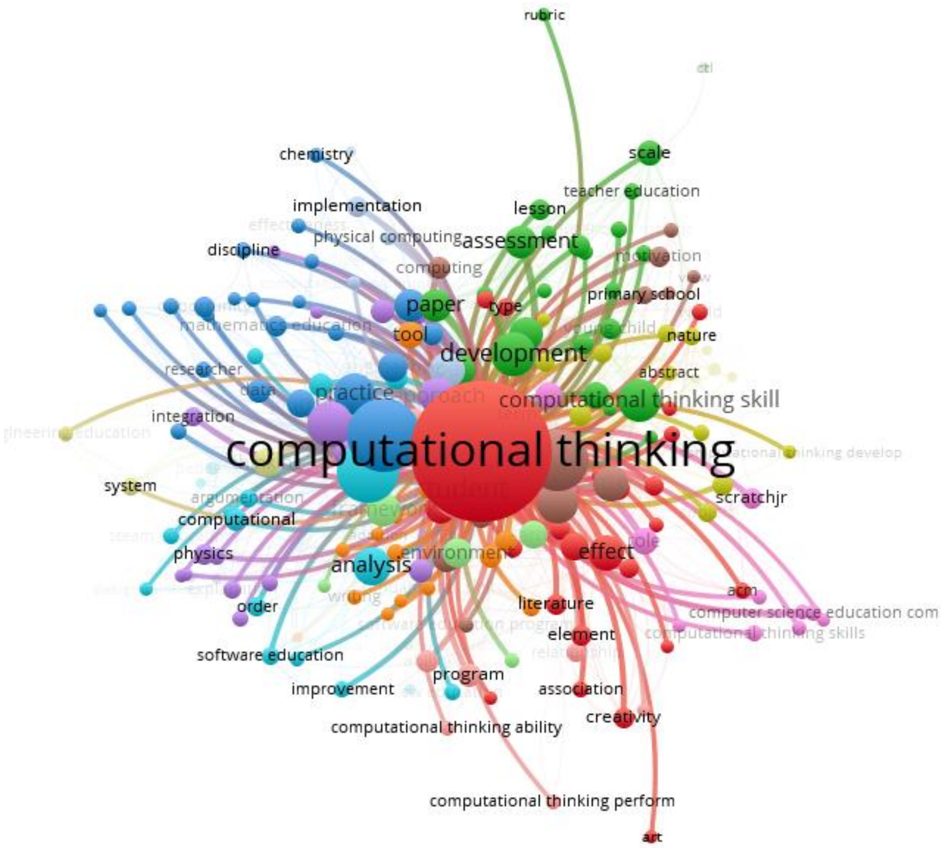

Fig. 5. Network visualization of the term computational thinking (cluster 1)

Figure 6 only displays terms related to the topic, namely “computational thinking skill”. Based on Figure 6, the term “computational thinking skill” is in cluster 2. “Computational thinking skill” is associated with 79 other terms with a total link strength 255, and an accuracy of 38.

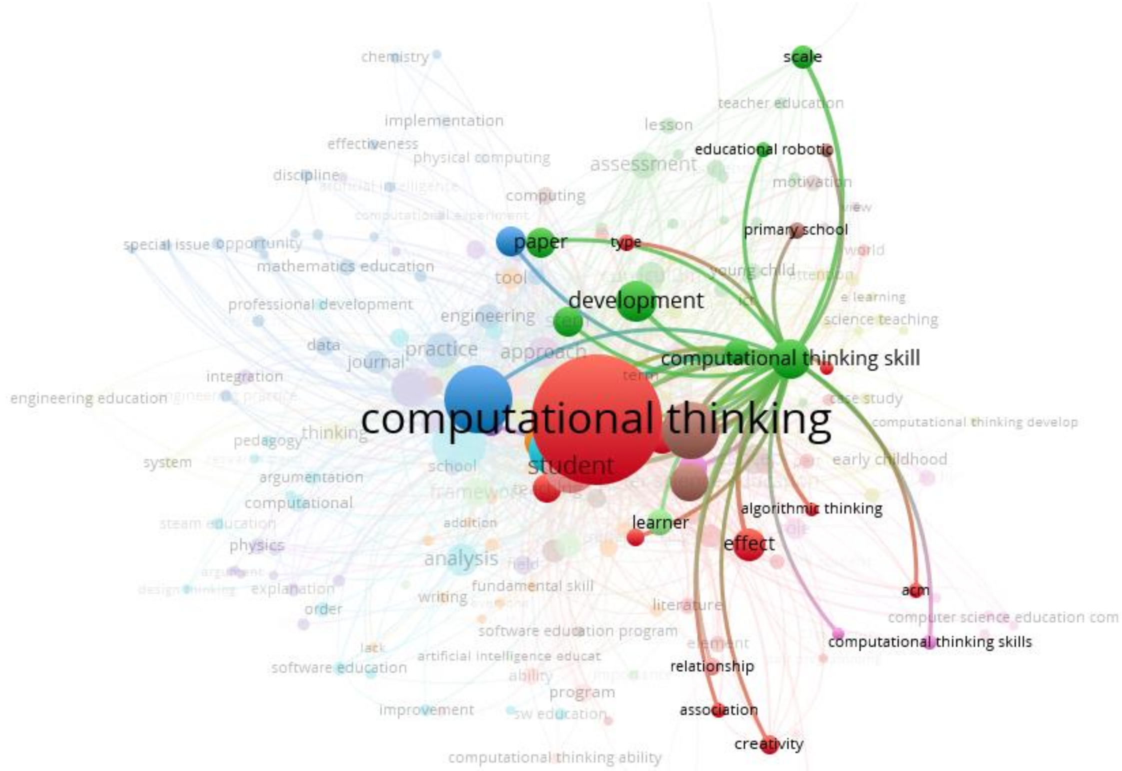

Fig. 6. Network visualization of the term computational thinking skill (cluster 2)

Therefore, the terms of "science education" displays in Figure 7. The term "science education" in in cluster 3. "Science education" is associated with 174 other terms with a total link strength is 1011, and an accuracy of 122.

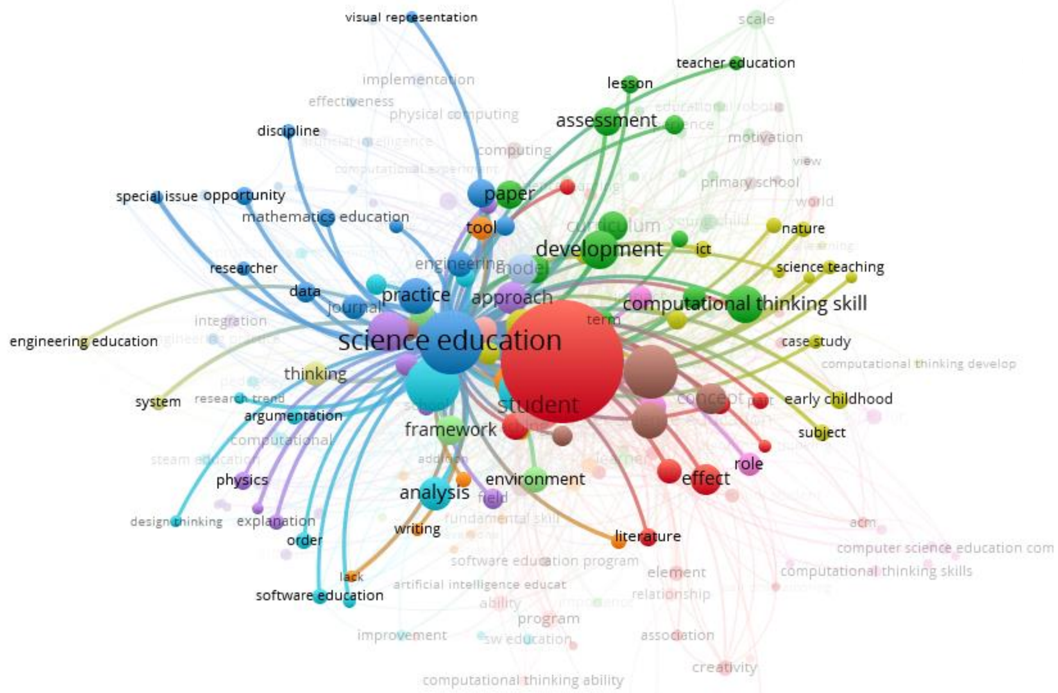

Fig. 7. Network visualization of the term science education (cluster 3)

Computational thinking is a thought processes involved in formulating problems so their solution can be represented as computational steps and algorithms. Computational thinking has a trending topic in science education. The study results indicates that the computational thinking has a good influence and impact on science education. Research on computational thinking in science education continues to increase from year to year. This show that the computational thinking continues to be developed and integrated into science education. This has a significant impact that the computational thinking will occur on a large scale and affect the application of education. This study can give additional information for understanding research trend using bibliometric analysis.

4. Conclusions

This study aims to perform a computational analysis of bibliometric data from research articles. The publication topic is computational thinking in science Education. The articles used were taken from the Google Scholar database using the Publish or Perish software. Library data taken in this study include titles and abstracts. Based on the results, a total of 344 relevant articles have been published between 2013 and 2022. The findings reveal that research on computational thinking in scientific education increased from 2012 to 2020, but fell from 2020 to 2022. In addition, it appears that the research topic of computational thinking in science education is directly related to the theme of science learning.

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References
[1] Daramola, Florence Olutunu. "The development and evaluation of the instructional kid blog for teaching selected computer science concepts in primary schools in Ilorin Metropolis." *Indonesian Journal of Teaching in Science* 2, no. 1 (2022): 39-50. https://doi.org/10.17509/ijotis.v2i1.44741
[2] Nuhu, Kehinde Muritala, Nafisat A. Adedokun-Shittu, Caleb Asiyanbola, and Adedeji Hammed Ajani. "Assessment of Students' Application of Binary Concept Using Computer-Science-Unplugged-Method in A Selected Secondary School in Ilorin, Kwara State, Nigeria." *ASEAN Journal of Science and Engineering Education* 3, no. 1 (2023): 27-34.
[3] Shaturaev, Jakhongir, and Khakimova Khulkar Khamitovna. "A computer-based approach to teaching foreign languages." *ASEAN Journal of Educational Research and Technology* 2, no. 2 (2023): 89-98.
[4] Babalola, Ebenezer Omolafe, and Eyiyemi Veronica Omolafe. "Effect of developed mobile application on undergraduates academic performance in computer science." *ASEAN Journal of Science and Engineering Education* 2, no. 3 (2022): 215-222.
[5] Kaczmarczyk, Dr Lisa, and Renee Dopplick. "Rebooting the pathway to success: Preparing students for computing workforce needs in the United States." *Available at SSRN 3573225* (2014).
[6] Jaafar, Nurulaini, Siti Rohani Mohd Nor, Siti Mariam Norrulashikin, Nur Arina Bazilah Kamisan, and Ahmad Qushairi Mohamad. "Increase students' understanding of mathematics learning using the technology-based learning." *International Journal of Advanced Research in Future Ready Learning and Education* 28, no. 1 (2022): 24-29.
[7] Hurt, Timothy, Eric Greenwald, Sara Allan, Matthew A. Cannady, Ari Krakowski, Lauren Brodsky, Melissa A. Collins, Ryan Montgomery, and Rena Dorph. "The computational thinking for science (CT-S) framework: Operationalizing CT-S for K–12 science education researchers and educators." *International Journal of STEM Education* 10, no. 1 (2023): 1. https://doi.org/10.1186/s40594-022-00391-7
[8] Lestari, Dwi Ayu, I. R. Suwarma, and Endi Suhendi. "Feasibility analysis of the development of STEM-based physics e-book with self-regulated learning on global warming topics." *Indonesian Journal of Teaching in Science* 4, no. 1 (2024): 1-10.
[9] Tipmontiane, Krittin, and P. John Williams. "The integration of the engineering design process in biology-related STEM activity: A review of Thai secondary education." *ASEAN Journal of Science and Engineering Education* 2, no. 1 (2022): 1-10. https://doi.org/10.17509/ajsee.v2i1.35097

[10] Jaafar, Nurulaini, Siti Rohani Mohd Nor, Siti Mariam Norrulashikin, Nur Arina Bazilah Kamisan, and Ahmad Qushairi Mohamad. "Increase students' understanding of mathematics learning using the technology-based learning." *International Journal of Advanced Research in Future Ready Learning and Education* 28, no. 1 (2022): 24-29.

[11] Denning, Peter J. "Computational thinking in science." *American Scientist* 105, no. 1 (2017): 13-17. https://doi.org/10.1511/2017.124.13

[12] Aksit, Osman, and Eric N. Wiebe. "Exploring force and motion concepts in middle grades using computational modeling: A classroom intervention study." *Journal of Science Education and Technology* 29, no. 1 (2020): 65-82. https://doi.org/10.1007/s10956-019-09800-z

[13] Sengupta, Pratim, John S. Kinnebrew, Satabdi Basu, Gautam Biswas, and Douglas Clark. "Integrating computational thinking with K-12 science education using agent-based computation: A theoretical framework." *Education and Information Technologies* 18 (2013): 351-380. https://doi.org/10.1007/s10639-012-9240-x

[14] Weintrop, David, Elham Beheshti, Michael Horn, Kai Orton, Kemi Jona, Laura Trouille, and Uri Wilensky. "Defining computational thinking for mathematics and science classrooms." *Journal of science education and technology* 25 (2016): 127-147. https://doi.org/10.1007/s10956-015-9581-5

[15] Grover, Shuchi, and Roy Pea. "Computational thinking in K–12: A review of the state of the field." *Educational researcher* 42, no. 1 (2013): 38-43. https://doi.org/10.3102/0013189X12463051

[16] Chi, Cai, Melor Md Yunus, Karmila Rafiqah M. Rafiq, Hamidah Hameed, and Ediyanto Ediyanto. "A Systematic Review on Multidisciplinary Technological Approaches in Higher Education." *International Journal of Advanced Research in Future Ready Learning and Education* 36, no. 1 (2024): 1-10.

[17] Mitrayana, M., and Elah Nurlaelah. "Computational thinking in mathematics learning: Systematic literature review." *Indonesian Journal of Teaching in Science* 3, no. 2 (2023): 133-142. https://doi.org/10.17509/ijotis.v3i2.60179

[18] Reskianissa, Anastasya, Asri Wibawa Sakti, and Nissa Nur Azizah. "TikTok platform to train middle school students' computational thinking skills in distance learning." *ASEAN Journal of Educational Research and Technology* 1, no. 1 (2022): 79-86.

[19] Ogegbo, Ayodele Abosede, and Umesh Ramnarain. "A systematic review of computational thinking in science classrooms." *Studies in Science Education* 58, no. 2 (2022): 203-230. https://doi.org/10.1080/03057267.2021.1963580

[20] Wing, Jeannette M. "Computational thinking." *Communications of the ACM* 49, no. 3 (2006): 33-35. https://doi.org/10.1145/1118178.1118215

[21] Wing, Jeanette. "Research notebook: Computational thinking—What and why." *The link magazine* 6 (2011): 20-23.

[22] Aho, Alfred V. "Computation and computational thinking." *The computer journal* 55, no. 7 (2012): 832-835. https://doi.org/10.1093/comjnl/bxs074

[23] Furber, S. "Shut down or restart? The way forward for computing in UK Schools. London, England: The Royal Society." (2012).

[24] Yadav, Aman, Chris Mayfield, Ninger Zhou, Susanne Hambrusch, and John T. Korb. "Computational thinking in elementary and secondary teacher education." *ACM Transactions on Computing Education (TOCE)* 14, no. 1 (2014): 1-16. https://doi.org/10.1145/2576872

[25] Barr, Valerie, and Chris Stephenson. "Bringing computational thinking to K-12: What is involved and what is the role of the computer science education community?." *ACM inroads* 2, no. 1 (2011): 48-54. https://doi.org/10.1145/1929887.1929905

[26] Voogt, Joke, Petra Fisser, Jon Good, Punya Mishra, and Aman Yadav. "Computational thinking in compulsory education: Towards an agenda for research and practice." *Education and information technologies* 20 (2015): 715-728. https://doi.org/10.1007/s10639-015-9412-6

[27] Cansu, Fatih Kursat, and Sibel Kilicarslan Cansu. "An overview of computational thinking." *International Journal of Computer Science Education in Schools* 3, no. 1 (2019): 17-30. https://doi.org/10.21585/ijcses.v3i1.53

[28] Adler, Rachel F., and Hanna Kim. "Enhancing future K-8 teachers' computational thinking skills through modeling and simulations." *Education and Information Technologies* 23 (2018): 1501-1514. https://doi.org/10.1007/s10639-017-9675-1

[29] Mannila, Linda, Valentina Dagiene, Barbara Demo, Natasa Grgurina, Claudio Mirolo, Lennart Rolandsson, and Amber Settle. "Computational thinking in K-9 education." In *Proceedings of the working group reports of the 2014 on innovation & technology in computer science education conference*, pp. 1-29. 2014. https://doi.org/10.1145/2713609.2713610

[30] Donthu, Naveen, Satish Kumar, Debmalya Mukherjee, Nitesh Pandey, and Weng Marc Lim. "How to conduct a bibliometric analysis: An overview and guidelines." *Journal of business research* 133 (2021): 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070

[31] Donthu, Naveen, Satish Kumar, Nitesh Pandey, and Prashant Gupta. "Forty years of the International Journal of Information Management: A bibliometric analysis." *International Journal of Information Management* 57 (2021): 102307. https://doi.org/10.1016/j.ijinfomgt.2020.102307
[32] Donthu, Naveen, Satish Kumar, and Debidutta Pattnaik. "Forty-five years of Journal of Business Research: A bibliometric analysis." *Journal of business research* 109 (2020): 1-14. https://doi.org/10.1016/j.jbusres.2019.10.039
[33] Khan, Muhammad Asif, Debidutta Pattnaik, Rohail Ashraf, Imtiaz Ali, Satish Kumar, and Naveen Donthu. "Value of special issues in the journal of business research: A bibliometric analysis." *Journal of business research* 125 (2021): 295-313. https://doi.org/10.1016/j.jbusres.2020.12.015
[34] Marín-Marín, José-Antonio, Antonio-José Moreno-Guerrero, Pablo Dúo-Terrón, and Jesús López-Belmonte. "STEAM in education: a bibliometric analysis of performance and co-words in Web of Science." *International Journal of STEM Education* 8, no. 1 (2021): 41. https://doi.org/10.1186/s40594-021-00296-x
[35] Shidiq, Ari Syahidul, Anna Permanasari, and Sumar Hendayana Hernani. "The use of simple spectrophotometer in STEM education: A bibliometric analysis." *Moroccan Journal of Chemistry* 9, no. 2 (2021): J-Chem.
[36] Talan, Tarik. "Augmented Reality in STEM Education: Bibliometric Analysis." *International Journal of Technology in Education* 4, no. 4 (2021): 605-623. https://doi.org/10.46328/ijte.136
[37] Novia, N., A. Permanasari, and R. Riandi. "Research on educational games in STEM area 2010-2020: A bibliometric analysis of literature." In *Journal of Physics: Conference Series*, vol. 1806, no. 1, p. 012209. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/1806/1/012209
[38] Hudha, Muhammad Nur, Ida Hamidah, Anna Permanasari, Ade Gafar Abdullah, Indriyani Rachman, and Toru Matsumoto. "Low Carbon Education: A Review and Bibliometric Analysis." *European Journal of Educational Research* 9, no. 1 (2020): 319-329. https://doi.org/10.12973/eu-jer.9.1.319
[39] Li, Zhaofeng, Zheng Chen, Ningshu Yang, Kaiyao Wei, Zexin Ling, Qinqi Liu, Guofeng Chen, and Ben Haobin Ye. "Trends in research on the carbon footprint of higher education: A bibliometric analysis (2010–2019)." *Journal of Cleaner Production* 289 (2021): 125642. https://doi.org/10.1016/j.jclepro.2020.125642
[40] Dede, Ercan, and Ercan Ozdemir. "Mapping and Performance Evaluation of Mathematics Education Research in Turkey: A Bibliometric Analysis from 2005 to 2021." *Journal of Pedagogical Research* 6, no. 4 (2022): 1-19. https://doi.org/10.33902/JPR.202216829
[41] Muhammad, Ilham, and Lilis Marina Angraini. "Research On Students' Mathematical Ability In Learning Mathematics In The Last Decade: A Bibliometric Review." *JOHME: Journal of Holistic Mathematics Education* 7, no. 1 (2023): 108-122. https://doi.org/10.19166/johme.v7i1.6867
[42] Durmaz, Burcu. "The use of literary elements in teaching mathematics: A bibliometric analysis." *Journal of Teacher Education and Lifelong Learning* 5, no. 1 (2023): 152-172. https://doi.org/10.51535/tell.1232736
[43] Effendi, Denti Nanda, Welly Anggraini, Agus Jatmiko, Henita Rahmayanti, Ilmi Zajuli Ichsan, and Md Mehadi Rahman. "Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education." In *Journal of Physics: Conference Series*, vol. 1796, no. 1, p. 012096. IOP Publishing, 2021. https://doi.org/10.1088/1742-6596/1796/1/012096
[44] Maryanti, R. I. N. A., N. I. Rahayu, M. Muktiarni, D. F. Al Husaeni, A. C. H. M. A. D. Hufad, S. Sunardi, and ASEP BAYU DANI Nandiyanto. "Sustainable development goals (SDGs) in science education: Definition, literature review, and bibliometric analysis." *Journal of Engineering Science and Technology* 17 (2022): 161-181.
[45] Nandiyanto, Asep Bayu Dani, Risti Ragadhita, and Muhammad Aziz. "Involving particle technology in computational fluid dynamics research: A bibliometric analysis." *CFD Letters* 15, no. 11 (2023): 92-109. https://doi.org/10.37934/cfdl.15.11.92109
[46] Muktiarni, M., Nur Indri Rahayu, Affero Ismail, and Amalia Kusuma Wardani. "Bibliometric computational mapping analysis of trend metaverse in education using vosviewer." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 32, no. 2 (2023): 95-106. https://doi.org/10.37934/araset.32.2.95106
[47] Rahayu, Nur Indri, Adang Suherman, and M. Muktiarni. "The use of information technology and lifestyle: An evaluation of digital technology intervention for improving physical activity and eating behavior." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 32, no. 1 (2023): 303-314. https://doi.org/10.37934/araset.32.1.303314
[48] Fauziah, Siti Pupu, Irman Suherman, Mega Febriani Sya, Martin Roestamy, Amirullah Abduh, and Asep Bayu Dani Nandiyanto. "Strategies in language education to improve science student understanding during practicum in laboratory: Review and computational bibliometric analysis." *International Journal of Language Education* 5, no. 4 (2021).
[49] Al Husaeni, D. F., D. N. Al Husaeni, R. Ragadhita, M. R. Bilad, A. S. M. Al-Obaidi, A. Abduh, and A. B. D. Nandiyanto. "How language and technology can improve student learning quality in engineering? Definition, factors for

enhancing students comprehension, and computational bibliometric analysis." *International Journal of Language Education* 6, no. 4 (2022): 445-476. https://doi.org/10.26858/ijole.v6i4.53587

[50] Kumar, Kutty. "Mapping of nanotechnology research in animal science: Scientometric anlaysis." *Kumar (22021) Mapping of Nanotechnology Research in Animal Science: Scientometric Analysis. ASEAN Journal of Science and Engineering* 1, no. 2 (2021): 111-126. https://doi.org/10.17509/ajse.v1i2.35092

[51] Nurrahma, Arinal Haq Izzawati, Hana Haruna Putri, and Ray March Syahadat. "Scientific research trends of flooding stress in plant science and agriculture subject areas (1962-2021)." *ASEAN Journal of Science and Engineering* 3, no. 2 (2023): 163-178. https://doi.org/10.17509/ajse.v3i2.46148

[52] Nandiyanto, Asep Bayu Dani, Dwi Novia Al Husaeni, and Dwi Fitria Al Husaeni. "Introducing ASEAN journal of science and engineering: A bibliometric analysis study." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 31, no. 3 (2023): 173-190.

[53] Nandiyanto, Asep Bayu Dani, D. N. Al Husaeni, and D. F. Al Husaeni. "A bibliometric analysis of chemical engineering research using vosviewer and its correlation with covid-19 pandemic condition." *Journal of Engineering Science and Technology* 16, no. 6 (2021): 4414-4422.

[54] Nandiyanto, Asep Bayu Dani, and Dwi Fitria Al Husaeni. "A bibliometric analysis of materials research in Indonesian journal using VOSviewer." *Journal of Engineering Research* (2021).

[55] Nandiyanto, Asep Bayu Dani, and Dwi Fitria Al Husaeni. "Bibliometric analysis of engineering research using vosviewer indexed by google scholar." *Journal of Engineering Science and Technology* 17, no. 2 (2022): 883-894.

[56] Al Husaeni, Dwi Fitria, and Asep Bayu Dani Nandiyanto. "Bibliometric computational mapping analysis of publications on mechanical engineering education using vosviewer." *Journal of Engineering Science and Technology* 17, no. 2 (2022): 1135-1149.

[57] Nandiyanto, A. B. D., R. Ragadhita, D. N. Al Husaeni, and W. C. Nugraha. "Research trend on the use of mercury in gold mining: Literature review and bibliometric analysis." *Moroccan Journal of Chemistry* 11, no. 1 (2023): 11-1.

[58] Nandiyanto, Asep Bayu Dani, Risti Ragadhita, Meli Fiandini, Dwi Fitria Al Husaeni, Dwi Novia Al Husaeni, and Farid Fadhillah. "Domestic waste (eggshells and banana peels particles) as sustainable and renewable resources for improving resin-based brakepad performance: Bibliometric literature review, techno-economic analysis, dual-sized reinforcing experiments, to comparison..." *Communications in Science and Technology* 7, no. 1 (2022): 50-61. https://doi.org/10.21924/cst.7.1.2022.757

[59] Al Husaeni, Dwi Fitria, Asep Bayu Dani Nandiyanto, and Rina Maryanti. "Bibliometric analysis of educational research in 2017 to 2021 using VOSviewer: Google scholar indexed research." *Indonesian Journal of Teaching in Science* 3, no. 1 (2023): 1-8. https://doi.org/10.17509/ijotis.v3i1.43182

[60] Mardina, Primata, Hesti Wijayanti, Rinna Juwita, Meilana Dharma Putra, Iryanti Fatyasari Nata, Rowina Lestari, Muhammad Faqih Al-Amin, Regi Abizar Suciagi, Oktefani Kusuma Rawei, and Liza Lestari. "Corncob-derived sulfonated magnetic solid catalyst synthesis as heterogeneous catalyst in the esterification of waste cooking oil and bibliometric analysis." *Indonesian Journal of Science and Technology* 9, no. 1 (2024): 109-124. https://doi.org/10.17509/ijost.v9i1.64219

[61] Abduh, Amirullah, Ade Mulianah, Besse Darmawati, Fairul Zabadi, Umar Sidik, Wuri Handoko, Karta Jayadi, and Rosmaladewi Rosmaladewi. "The compleat lextutor application tool for academic and technological lexical learning: Review and bibliometric approach." *Indonesian Journal of Science and Technology* 8, no. 3 (2023): 539-560. https://doi.org/10.17509/ijost.v8i3.63539

[62] Chukwu, Emeka, and Lalit Garg. "A systematic review of blockchain in healthcare: frameworks, prototypes, and implementations." *Ieee Access* 8 (2020): 21196-21214. https://doi.org/10.1109/ACCESS.2020.2969881

[63] Al Husaeni, Dwi Fitria, and Dwi Novia Al Husaeni. "Computational bibliometric analysis of research on science and Islam with VOSviewer: Scopus database in 2012 to 2022." *ASEAN Journal of Religion, Education, and Society* 1, no. 1 (2022): 39-48.

[64] Al Husaeni, Dwi Fitria, and W. Wahyudin. "Digital transformation in special needs education: Computational bibliometrics." *ASEAN Journal of Community and Special Needs Education* 2, no. 2 (2023): 97-110.

[65] Nandiyanto, Asep Bayu Dani, Risti Ragadhita, Muji Setiyo, Abdulkareem Sh Mahdi Al Obaidi, and Arif Hidayat. "Particulate matter emission from combustion and non-combustion automotive engine process: Review and computational bibliometric analysis on its source, sizes, and health and lung impact." *Automotive Experiences* 6, no. 3 (2023): 599-623.

[66] Van Eck, Nees, and Ludo Waltman. "Software survey: VOSviewer, a computer program for bibliometric mapping." *scientometrics* 84, no. 2 (2010): 523-538. https://doi.org/10.1007/s11192-009-0146-3

[67] Al Husaeni, Dwi Fitria, and Asep Bayu Dani Nandiyanto. "Bibliometric using Vosviewer with Publish or Perish (using google scholar data): From step-by-step processing for users to the practical examples in the analysis of digital learning articles in pre and post Covid-19 pandemic." *ASEAN Journal of Science and Engineering* 2, no. 1 (2022): 19-46. https://doi.org/10.17509/ajse.v2i1.37368

[68] Azizah, Nissa Nur, Rina Maryanti, and Asep Bayu Dani Nandiyanto. "How to search and manage references with a specific referencing style using google scholar: From step-by-step processing for users to the practical examples in the referencing education." *Indonesian Journal of Multidiciplinary Research* 1, no. 2 (2021): 267-294. https://doi.org/10.17509/ijomr.v1i2.37694

[69] Osborne, Jonathan. "Teaching scientific practices: Meeting the challenge of change." *Journal of Science Teacher Education* 25, no. 2 (2014): 177-196. https://doi.org/10.1007/s10972-014-9384-1

[70] Angeli, Charoula, Joke Voogt, Andrew Fluck, Mary Webb, Margaret Cox, Joyce Malyn-Smith, and Jason Zagami. "A K-6 computational thinking curriculum framework: Implications for teacher knowledge." *Journal of Educational Technology & Society* 19, no. 3 (2016): 47-57.

[71] Sullivan, Amanda, and Marina Umaschi Bers. "Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade." *International Journal of Technology and Design Education* 26 (2016): 3-20. https://doi.org/10.1007/s10798-015-9304-5

[72] English, Lyn D. "Advancing elementary and middle school STEM education." *International Journal of Science and Mathematics Education* 15 (2017): 5-24. https://doi.org/10.1007/s10763-017-9802-x

[73] Wing, Jeannette. "Computational thinking's influence on research and education for all." *Italian Journal of Educational Technology* 25, no. 2 (2017): 7-14.

[74] Jaipal-Jamani, Kamini, and Charoula Angeli. "Effect of robotics on elementary preservice teachers' self-efficacy, science learning, and computational thinking." *Journal of science education and technology* 26 (2017): 175-192. https://doi.org/10.1007/s10956-016-9663-z

[75] Leonard, Jacqueline, Alan Buss, Ruben Gamboa, Monica Mitchell, Olatokunbo S. Fashola, Tarcia Hubert, and Sultan Almughyirah. "Using robotics and game design to enhance children's self-efficacy, STEM attitudes, and computational thinking skills." *Journal of Science Education and Technology* 25 (2016): 860-876. https://doi.org/10.1007/s10956-016-9628-2

[76] Papadakis, Stamatios, Michail Kalogiannakis, and Nicholas Zaranis. "Developing fundamental programming concepts and computational thinking with ScratchJr in preschool education: a case study." *International Journal of Mobile Learning and Organisation* 10, no. 3 (2016): 187-202. https://doi.org/10.1504/IJMLO.2016.077867

[77] Erduran, Sibel, Yasemin Ozdem, and Jee-Young Park. "Research trends on argumentation in science education: A journal content analysis from 1998–2014." *International Journal of STEM Education* 2 (2015): 1-12. https://doi.org/10.1186/s40594-015-0020-1

[78] Sukyadi, D. I. D. I., Rina Maryanti, N. I. Rahayu, and M. Muktiarni. "Computational bibliometric analysis of english research in science education for students with special needs using vosviewer." *Journal of Engineering Science and Technology* 18 (2023): 14-26.

[79] Maryanti, R. I. N. A., ASEP BAYU DANI Nandiyanto, A. C. H. M. A. D. Hufad, S. Sunardi, D. N. Al Husaeni, and D. F. Al Husaeni. "A computational bibliometric analysis of science education research using VOSviewer." *Journal of Engineering Science and Technology* 18, no. 1 (2023): 301-309.

[80] Muktiarni, M., Nur Indri Rahayu, Affero Ismail, and Amalia Kusuma Wardani. "Bibliometric computational mapping analysis of trend metaverse in education using vosviewer." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 32, no. 2 (2023): 95-106. https://doi.org/10.37934/araset.32.2.95106