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Developing Computational Thinking through Mathematics Learning in Indonesia: Scientific Mapping and Bibliometric Analysis

Ahmad Gufron[1]* Wardono[2], Scolastika Mariani[3]
[1,2,3]Universitas Negeri Semarang, Indonesia
gufron1922@students.unnes.ac.id, wardono@mail.unnes.ac.id, mariani.mat@mail.unnes.ac.id
*Corresponding Author: gufron1922@students.unnes.ac.id

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Abstract:

This research aims to explore and map the teaching methods used in developing Computational Thinking (CT) through mathematics learning in Indonesia, using a bibliometric analysis approach. Based on a literature review from Scopus and Sprott-indexed databases, this research analyzes trends, contributions and challenges in the implementation of CT at various levels of education. Teaching methods such as Scratch, Problem-Based Learning (PBL), Augmented Reality (AR), and robotics were identified as the most effective strategies in improving students' computational thinking skills. The findings show that the majority of publications published in educational and CT-related sources about teaching mathematics are mostly about teaching computational skills and teaching computer programming using practice and algorithmic thinking, although these methods have had a significant impact, some limitations, such as lack of instrumentation, limited technological resources, and curriculum adaptation are still challenges. This analysis also highlights opportunities for further research in developing more comprehensive evaluation instruments and improving technology access in computational education. It is hoped that the results of this research can provide guidance for educators, policymakers and researchers to increase the integration of CT in the mathematics curriculum, as well as expand the scope of computational research in the Indonesian educational context. This research opens new insights to overcome barriers and optimize the potential of CT in the future.

Keywords: Computational Thinking, Mathematics Learning, Bibliometric Analysis, Problem-Based Learning, Augmented Reality, Scratch, Robotics.

1. Introduction

Computational thinking is one of the main skills of the 21st century which is increasingly important in global education, especially in the context of the rapid development of digital technology. Computational thinking involves a series of cognitive processes such as problem-solving, logical analysis, and abstraction, which enable individuals to formulate algorithm-based solutions (Istiqlal et al., 2024). In mathematics education, computational thinking has a significant role because mathematics and computing both rely on logical structures and systematic thinking (Masfingatin & Maharani, 2019). Integrating computational thinking into mathematics learning can enrich students' skills in solving complex problems while preparing them for challenges in the digital world (Budiyanto et al., 2022). However, in Indonesia, the application of this concept in the context of mathematics education is still in the developing stage (Putra et al., 2022). Mathematics education in Indonesia, which traditionally focuses more on memorization and solving routine problems (Prahmana et al., 2020), needs to adapt to a new approach that emphasizes the development of computational thinking skills.

Although the importance of computational thinking in mathematics education is increasingly recognized globally, the application of this concept in Indonesia still faces various challenges. One of the main problems is the lack of integration of computational thinking in the formal mathematics curriculum in Indonesian schools (Purwasih & Dahlan, 2024). The existing curriculum does not fully support the development of computing skills, which can limit students in developing logical thinking and algorithm-based problem-solving (Rahmawati et al., 2024). In addition, limited understanding and experience among teachers regarding how to integrate computational thinking into mathematics learning further complicates this situation (Lin et al., 2021). Many educators have not received adequate training to apply this approach in the classroom, so students do not get optimal benefits from computing-based learning. Furthermore, awareness of the importance of these skills is still low among education stakeholders, including teachers, students and parents, which adds complexity to implementation at the school level (Satria, Hendrizal, et al., 2023). Therefore, this research aims to identify these problems and provide solutions that can support the integration of computational thinking in mathematics learning in Indonesia, in order to strengthen the educational foundation for the ever-growing digital era.

This research aims to review existing literature to understand how computational thinking has been integrated into mathematics learning, especially in Indonesia. By conducting a comprehensive study, this research seeks to explore strategies that have been used in various educational contexts to develop computational thinking skills among students. Through literature analysis, this research also aims to evaluate the potential for implementing a similar approach in Indonesia, taking into account the specific challenges that exist in the national education system. Specifically, this research will identify various learning methods and approaches that have proven effective in encouraging the development of computational thinking through mathematics teaching. Thus, it is hoped that the results of this research can provide practical guidance for educators and policymakers in designing educational strategies that are innovative, relevant, and in line with the needs of technological developments in the digital era.

Although there are a number of studies exploring the integration of computational thinking in mathematics learning, especially abroad, research that specifically focuses on the Indonesian context is still very limited (Helsa et al., 2023). This gap indicates an urgent need to understand how such approaches can be implemented effectively in Indonesian schools, given differences in culture, curriculum and educational infrastructure. Additionally, the existing literature tends to focus on the development of computational skills in general, without paying sufficient attention to how computational thinking can be applied specifically in mathematics teaching. This creates a gap in the literature that hinders progress in our understanding of the full potential of this approach in the mathematics classroom. Furthermore, existing research often does not provide clear and practical guidance for teachers in integrating computational thinking into teaching and learning activities. Therefore, this study aims to fill this gap by providing a comprehensive analysis of global trends in computational thinking research and assessing their suitability for adoption in the mathematics education system in Indonesia.

Currently, there is great interest in CT from key stakeholders (teachers, policymakers, educators, researchers, and so on) (Satria, Hendrizal, et al., 2023). Several studies focus on the explanation of CT and how CT is used (Ersozlu et al., 2023). Our research is directed at providing a practical perspective and bibliography on CT that we believe will be useful to research journal editors and researchers. The following research questions were investigated and guided this study:

1. How is the implementation of various mathematics teaching methods in improving students' Computational Thinking (CT) in mathematics in Indonesia at various levels of education (elementary school, middle school, high school and college)?

2. How is the effectiveness of teaching methods in building Computational Thinking (CT) skills compared to conventional mathematics learning methods in Indonesia?

3. What are the main challenges and obstacles in implementing Computational Thinking (CT) methods in schools in Indonesia?

In this paper, we acknowledge that CT is still relatively new and how relation to mathematics education. This was done to foster and build further interest in the implications of CT and its place in mathematics classrooms and the school curriculum more broadly. Classroom teachers need to understand CT processes and how they can assist students when learning mathematics in making the necessary connections required across numerical and conceptual processes. Much of this is about helping students use CT when solving math problems with the ultimate goal being the development of independent students.

This research presents an innovative contribution in developing computational thinking skills through mathematics learning in Indonesia, an approach that has not been widely explored in local literature. The successful implementation of computational thinking in mathematics education in developed countries shows the great potential of this approach to improve students' computational thinking and problem-solving skills, however, adoption in Indonesia is still limited. The novelty of this research lies in its attempt to reveal a model or way of teaching mathematics to improve CT in the Indonesian educational context, providing a strong scientific basis for integrating computational thinking into the national mathematics curriculum. In addition, this research provides a clear justification for the importance of introducing computing skills in the digital era as an integral part of mathematics education. Thus, this research not only offers theoretical insights but also practical guidance that can support educators and policymakers in designing more adaptive and innovative teaching strategies, to prepare students to face the global challenges of the future.

Method

This literature uses evaluative scientometric mapping to answer the research questions in this study. The scientometric analysis is used to map data originating from scientific literature based on various types of published research (Rivera et al., 2024). Analysis via scientometrics using VOSviewer software uses network and density analysis based on term occurrence maps in text data together with evaluative systematic review analysis (Kuzior & Sira, 2022).

The articles analyzed are articles published in journals from 2014 to 2024 in Indonesian and English. The article collection technique uses Google Scholar and Scopus as search engines connected to various journal portals and indexing institutions. This strategy is used to collect data as widely as possible to obtain a lot of data so that it can represent conditions in Indonesia comprehensively and avoid bias.

The inclusion criteria in this study based on articles published from 2014 to 2014 are: i) Articles published in Indonesian and English; ii) The article discusses experimental studies of various mathematics learning methods to improve computational thinking skills in Indonesia; iii) Articles are analyzed qualitatively; iv) Articles published in journals indexed in Google Scholar which are listed in the Science and Technology Index (SINTA) and Scopus indexed articles. Articles that do not meet the four inclusion criteria will be included in the collection of articles included in the exclusion criteria. Articles that fall within the exclusion criteria will not be included in the meta-analysis process.

2. Results

1. Series of Research Publications Aiming at Teaching CT through Mathematics

Searches via Google Scholar and Scopus produced 918 publications classified by author, title, keywords, abstract and source title. In addition, to control for study outcomes, we used the preferred reporting items for systematic reviews and meta-analyses (PRISMA) protocol technique. The

PRISMA stages can be seen clearly in Figure 1. Meanwhile, this research uses the Scopus and Sinta databases as data sources.

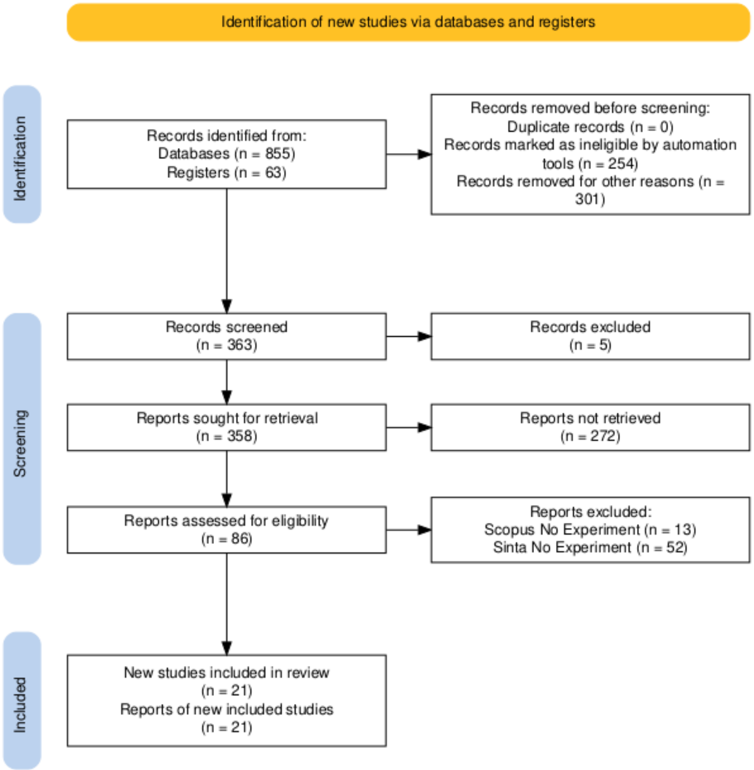

Figure 1. Diagram PRISMA

The PRISMA diagram presented shows a systematic flow in identifying, filtering, and including relevant studies related to the development of Computational Thinking (CT) in mathematics learning. This process begins with identification where there are 918 records taken from databases (855) and registers (63). This represented a broad search to ensure all relevant research related to the development of CT in mathematics could be covered.

However, before the screening process, 301 records were removed for various reasons, such as duplication, or not meeting the initial criteria set. In this context, many studies may have mentioned CT or mathematics education but were not specifically relevant to the aims of this research, so they were excluded from the initial stage.

Furthermore, in the screening stage, 363 studies were examined, of which only 5 studies were excluded, indicating that the majority of studies identified met the criteria to proceed to a further review stage. This shows that most of the studies are indeed relevant and related to the development of CT in the context of mathematics education. However, when proceeding to the retrieval stage, 272 reports were not obtained, possibly due to limited access to the full text or articles that were not publicly available. This is one of the significant limitations in this process because potential research contributions cannot be analyzed.

Of the 86 reports that were successfully accessed and assessed for suitability, there was a significant reduction at the feasibility assessment stage, where 65 reports were excluded, mostly because they did not involve experiments (13 from Scopus and 52 from Sprott). This indicates that research that is theoretical or conceptual, without empirical or experimental evidence, is considered less relevant to the research focus. This also shows that an empirical approach is prioritized in evaluating the real impact of CT in mathematics learning.

Ultimately, only 21 studies made it into the final review. These studies are likely to provide deeper insight into the application of CT in mathematics, whether through classroom experiments, curriculum trials, or teaching methods that integrate CT elements such as abstraction, algorithmic thinking, and decomposition in the context of mathematical problem-solving. From these 21 articles it can be concluded through the following graph:

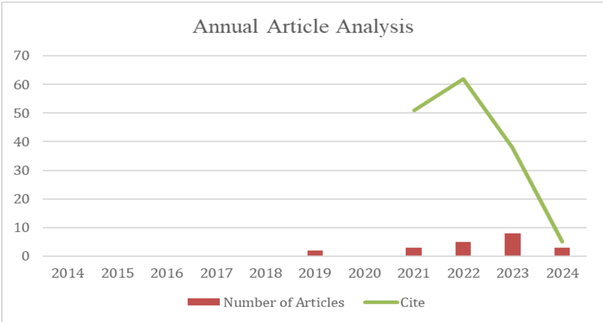

Figure 2. Annual Article Analysis

Based on the Annual Article Analysis graph above, there are two main indicators analyzed: the number of articles published each year and the number of citations received each year. The graph shows that the number of articles published from 2019 to 2024 shows that there are few articles published in the context of developing computational thinking skills. Even from 2014 to 2018 and 2020 there were none. That year does not mean there were no articles about computational thinking, but there were relatively few in terms of developing and using appropriate methods to improve computational thinking skills in mathematics. There will be a spike in 2023 and a decline in 2024, so computational thinking skills in mathematics learning are relatively new.

2. Concepts and Topics used in Mathematics learning

In the process of compiling bibliometric data, the first step taken is to collect literature related to the topic being researched, in this case, Computational Thinking (CT) in mathematics learning. This data is then analyzed using bibliometric tools such as VOSviewer to map relationships between concepts based on the co-occurrence of keywords. The results of this visualization show a network of interrelated concepts in the form of clusters, which represent the main topics discussed in related literature. The following is data analysis through bibliometric analysis:

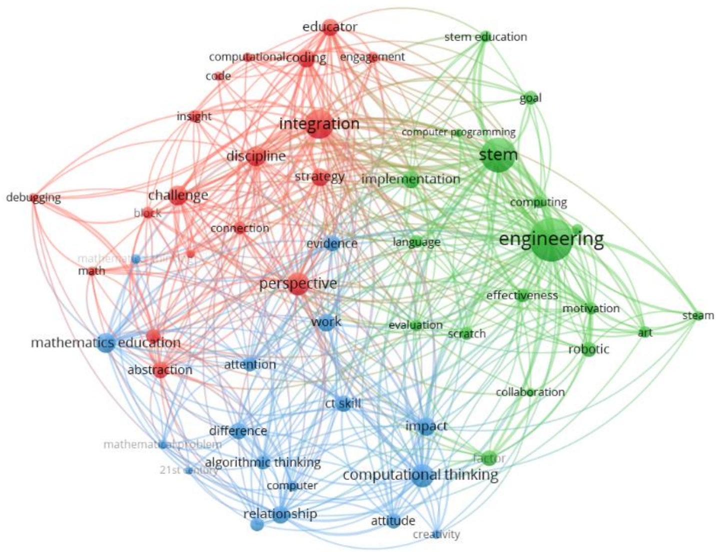

Figure 3. Bibliometric analysis of three clusters

The bibliometric visualization above displays three main clusters depicted in different colors, Red Cluster (Integration and Challenges), Green Cluster (STEM and Engineering), Blue Cluster (Mathematics and Computational Thinking). Each cluster has a main theme that dominates, with different connections between them. The following is an analysis of the relationships and differences between the three clusters. The following is an explanation of the three clusters.

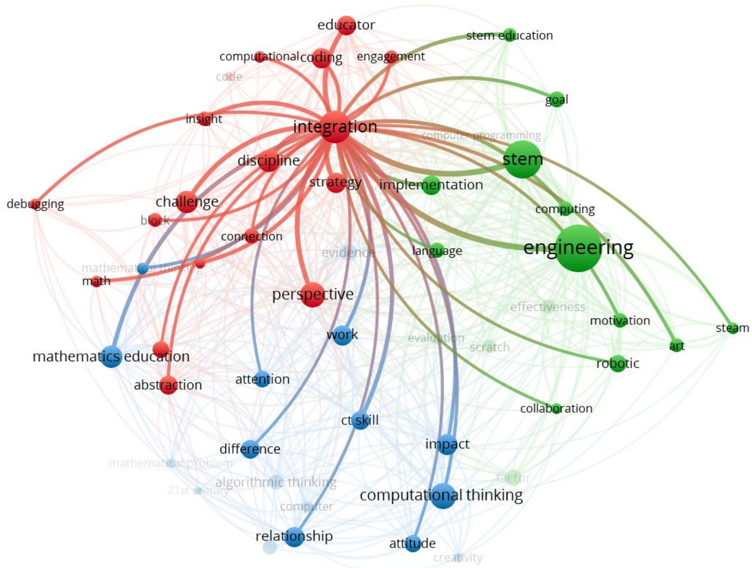

Figure 4. Red Cluster

Red Cluster - Integration and Challenges, the red cluster focuses on the integration of Computational Thinking in education and the challenges that come with it. Keywords such as “integration,” “discipline,” “challenge,” and “strategy” dominate. This suggests that one of the main areas of research is how CT can be integrated into various disciplines, especially mathematics, and what challenges are faced in the process. There are also concepts such as “educator” and “engagement,” which emphasize the importance of teacher training as well as student involvement in the implementation of CT in the classroom. The challenges and debugging that arise in this cluster show the technical challenges that are often faced during implementation, both in educational and programming contexts.

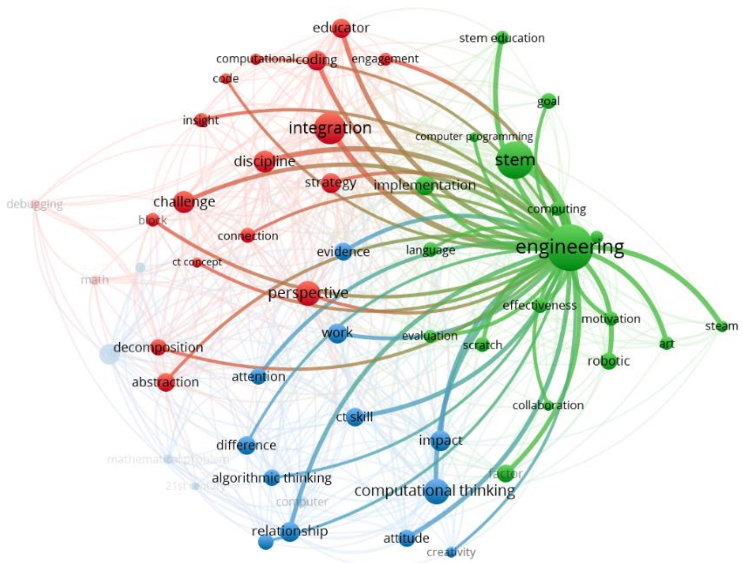

Figure 5. Green Cluster

Green Cluster - STEM and Engineering. The green cluster is closely related to STEM (Science, Technology, Engineering, Mathematics) and engineering. Keywords such as “STEM,” “engineering,” “robotic,” “motivation,” and “collaboration” indicate that there is a large body of research focused on the application of CT in engineering and science contexts. The relationship between STEM and computing emphasizes that Computational Thinking has an important role in supporting innovation in engineering and technology. The use of robotics and computer programming is an integral part of the STEM learning process that combines CT concepts. There is a link to the evaluation and effectiveness of CT implementation in this context, indicating that research should not only focus on implementation but also on measuring success and its impact on students.

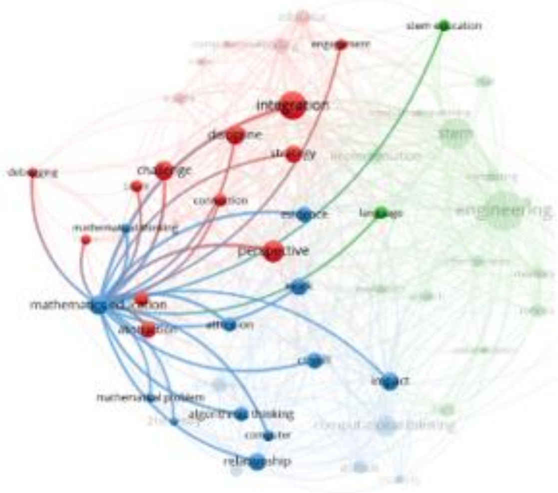

Figure 6. Klaster Biru 1

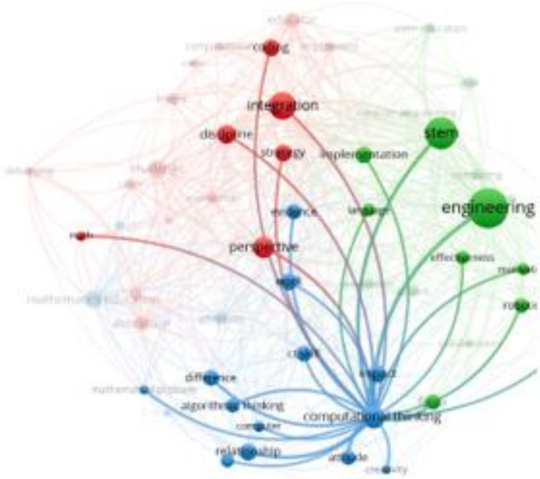

Figure 7. Klaster Biru 2

Blue Cluster - Mathematics and Computational Thinking: The blue cluster is the center of the discussion of mathematics education and computational thinking. Keywords such as “algorithmic thinking,” “abstraction,” “problem-solving,” and “relationship” indicate that this cluster includes research on how CT can be used to improve students' math skills. Algorithmic thinking and abstraction are main concepts in Computational Thinking which are closely related to the way students understand and solve mathematical problems. This cluster focuses on the cognitive and methodological aspects required in mathematics education. The impact and relationships connected in this cluster demonstrate the importance of evaluating the impact of CT on mathematics learning, as well as how these skills can build deeper connections with traditional mathematics concepts.

The relationship between clusters is that there is a strong relationship between the red and blue clusters through keywords such as "mathematics education" and "integration", indicating that the integration of CT in mathematics learning is still the main focus and challenge discussed in the literature. The green cluster is related to the other two clusters through STEM, which implies that many studies try to integrate CT not only in mathematics learning but also across STEM disciplines.

3. Tools and Methods/Ways of Teaching CT through Mathematics

In the process of collecting data from indexed academic sources such as Scopus and Sprott, it is very important to ensure that each publication selected meets the inclusion criteria that are relevant to the research topic. In this case, the literature review on Computational Thinking (CT) in mathematics learning is mapped through tools such as PRISMA, which highlights the stages of article selection, starting from identification, screening, and eligibility assessment, to final article inclusion. Data obtained from indexes such as Scopus (which is an international database) and Sprott (which is a national database) helps provide a broader perspective, both nationally and internationally. To make it easier to analyze validated articles, it is necessary to extract data from the articles into the following table:

Table 1. Article data extraction table

Code	Author	Tools Used	Site of placement	Cite	Index
1D	(Satria et al., 2022)	Scratch Programming Interactive Animation	SD	20	Feel
2D	(Prahmana et al., 2024)	Cross-cultural insights into computational thinking	SD	0	Scopus
3D	(Khoirinisah et al., 2024)	E-LKPD Based on Wizer.Me	SD	0	Feel
1P	(Aminah et al., 2023)	Scratch Application	JUNIOR HIGH SCHOOL	4	Scopus
2P	(Maharani, Nusantara, et al., 2019)	PBL (Problem Based Learning)	JUNIOR HIGH SCHOOL	1	Scopus
3P	(Salwadila, 2024)	PBL (Problem Based Learning)	JUNIOR HIGH SCHOOL	0	Scopus
4P	(Angraini et al., 2023)	Augmented Reality	JUNIOR HIGH SCHOOL	6	Scopus
1A	(Richardo et al., 2023)	STEM	SMA	3	Scopus
2A	(Pertiwi et al., 2023)	School Culture and ICT Use Capabilities	SMA	0	Feel
3A	(Cahyo, 2021)	Effectiveness of the ITM Learning Model (Inquiry Training Model)	SMA	1	Feel
4A	(Batul et al., 2022)	SSCS Model Learning Tools Using the Rme Approach	SMA	16	Feel
5A	(Fauzi et al., 2022)	Digibook Anyflip Based Sequences and Series	SMA	14	Feel
6A	(Supiarmo et al., 2021)	Scaffolding	SMA	50	Feel
1M	(Maharani, Kholid, et al., 2019)	PBL (Problem Based Learning)	Student	25	Scopus
2M	(Aminah et al., 2022)	PBL (Problem Based Learning)	Student	5	Scopus
3M	(Budiyanto et al., 2022)	Educational Robotics in STEM Teaching	Student	7	Scopus
4M	(Helsa & Juandi, 2023)	Design of a TPACK-based hybrid learning model	Student	1	Scopus
5M	(Satria et al., 2024)	Magnet Interactive Learning Media (MANIAKNET)	Student	5	Feel
6M	(Satria, Efendi, et al., 2023)	Development of Interactive Media for Computational Thinking Programming	Student	10	Feel

7M	(Marom, 2023)	Wolframs Mathematica	Student	7	Feel
1G	(Satria, Hendrizal, et al., 2023)	Scratch app for teachers	Educator	7	Feel

Based on table 1, there are several publications indexed in Scopus and Sprott, each of which has its own advantages and challenges in the context of relevance, coverage and citation level. Data from the table above shows various approaches, teaching tools, and where they are implemented, which are linked to the number of citations to evaluate the impact and relevance of each research.

Based on the table, the following are several key points that can be identified:

a. Index Differences: Scopus vs Sprott

1) Publications indexed in Scopus tend to have more citations than publications indexed in Sinta. For example, the publication by Maharani, Kholid, et al., 2019 regarding PBL (Problem Based Learning) has 25 citations and is indexed in Scopus, while the publication by Batul et al., 2022 which is indexed in Sinta has 16 citations.

2) Even though Scopus has a wider reach internationally, Sinta remains relevant in a local or national context because it presents research that is more focused on the problems and context of education in Indonesia.

b. Tools Used:

1) Scratch as a learning tool is very popular in computational education. Examples of publications such as Satria et al., (2022) and Aminah et al., (2023) which use Interactive Animation Programming Scratch and Scratch Application show that Scratch is one of the most commonly used tools at various levels of education, including elementary and middle school.

2) Apart from Scratch, PBL (Problem Based Learning) is also an approach that is often used, especially in middle and high schools, as reported by Maharani and Nusantara, et al., (2019) and Salwadlia, (2024), which is indexed both in Scopus and Sinta.

c. Implementation at Various Education Levels:

1) Implementation of Computational Thinking is widely applied at the Elementary School (SD) and Junior High School (SMP) levels, with several publications focusing on students and educators. For example, Budyanto et al., (2022)'s research on Educational Robotics in STEM Teaching focuses on students and is indexed in Scopus, while Satria, Hendrizal, et al., (2023)'s study focuses on the use of Scratch for teachers with the Sinta index.

2) Widespread implementation from elementary school to college students shows the flexibility of Computational Thinking and the importance of tools and strategies appropriate for each level of education.

d. Citation Rate and Influence:

1) Research using Scaffolding in education at the high school level by Sujiarmo et al., (2021) has the highest number of citations with 50 citations, indicating that this approach has a significant influence on learning Computational Thinking at the high school level.

2) On the other hand, several publications indexed in Scopus or Sinta still have low citations, such as the publications of Prahmana et al., (2024) and Salwadlia (2024), which may indicate that the research is still new or has not been received widespread attention.

Use of Technology in Teaching:

Several studies focus on innovative technology such as Augmented Reality (AR) and interactive learning media, such as research by Angraini et al., (2023) which used AR in junior high schools and received 6 citations. This shows that new uses of technology are being explored and starting to gain attention in the educational community.

Data from this table shows that Computational Thinking and its approaches through various tools (such as Scratch and PBL) have been applied at various levels of education with varying results, depending on the tools and strategies used. The Scopus and Sprott indexes each make important contributions in mapping national and international literature, with research indexed in Scopus tending to have more citations. Publications that focus on innovative technologies, such as Augmented Reality and Robotics, as well as established approaches such as PBL and Scaffolding, continue to play an important role in improving Computational Thinking skills among students.

4. Analysis of Results and Article Limitations

In extracting research data and limitations from various scientific articles, it is important to analyze in depth both the positive findings and limitations encountered during the research. The results of the study provide insight into the effectiveness of the methods used in improving computational thinking skills, while the limitations of the study reveal challenges and barriers that need to be overcome for further improvement. This analysis includes how different tools and approaches are applied in the context of mathematics education, as well as their impact on students' computational thinking abilities. However, despite the positive results, limitations such as lack of instrument validation, sample limitations, and technical obstacles must be addressed to provide a more balanced perspective on the effectiveness and generalizability of the findings.

Table 2. Results and limitations of each author

Code	Result	Limitations
1D	1. The Scratch application for science material shows positive results. 2. demonstrate its effectiveness for elementary school students and teachers.	Since this paper focuses on the positive outcomes and outcomes of interactive animation media development, it does not discuss any limitations encountered during the research or implementation process.
2D	1. Students understand the concept 2. Computational thinking is influenced by factors such as age, previous exposure to technology, and educational context.	This research highlights obstacles to integrating computational thinking into educational frameworks due to outdated curricula, inadequate teacher training, and lack of resources.
3D	The development of E-LKPD based on Wizer.me makes students enthusiastic and effective in improving computational thinking	One of the limitations highlighted was a lower score in the presentation aspect of the material, especially because the material presented only consisted of instructional videos, lacking other forms of content such as textual explanations.
1P	1) learning to use computational thinking through the Scratch program. 2) Demonstrate the positive impact of the intervention on their problem-solving skills.	The research paper does not explicitly mention any limitations in the research or its findings. The focus is primarily on exploring how learning with computational thinking concepts using the Scratch program can

		improve students' mathematical problem solving abilities.
2P	Research findings can be used as benchmarks in developing mathematics materials and guide future advances in curriculum, assessment methods, and learning approaches	The research team has carefully considered alternative possibilities and contradictory evidence to reduce bias resulting from the limited sample size.
3P	Media can provide significant benefits in improving computational thinking abilities	Limitations mentioned in this paper include students' lack of familiarity with CT-based problems which affects their ability to achieve CT indicators below 50%
4P	1) Utilizing augmented reality media with Unity 3D to improve students' mathematical computational thinking skills 2) Students who receive instruction using augmented reality media and Unity 3D have mathematical computational thinking skills	1) Limitations of the study include a relatively small sample size due to the impact of Covid, with only 15 students consistently participating in offline learning, affecting the generalizability of the findings. 2) Another limitation is the need for further validation of the computational thinking ability test instrument used in this research
1A	1) Research findings show a positive and significant effect between STEM Attitudes on computational thinking skills and 21st century skills in vocational school students. 2) STEM attitudes have a positive and significant effect on computational thinking.	1) Limitations mentioned in this paper include a dearth of studies related to STEM attitudes, computational thinking, and their impact on 21st century skills, indicating a gap in the existing research literature. 2) This study focuses on the affective domain of STEM attitudes, thinking computing, and 21st century skills, emphasizes the importance of understanding the affective aspects in relation to these skills.
2A	1) Research findings show that habits of mind have a positive and significant impact on students' computational thinking abilities, 2) Research results show that school culture does not have a positive and significant influence on ICT use	Limitations of the study include the lack of consideration for external factors that may influence the variables studied, such as socioeconomic background or access to technology. 2 Another limitation is the focus on a specific geographic area, which may limit the generalizability of the findings to a broader population.
3A	1. The ITM model was found to improve students' computational mathematical thinking skills 2. The ITM model facilitates students in developing skills such as formulating problems, representing data mathematically, determining algorithmic instructions, automating algorithms, and generalizing problem solving approaches.	The research paper does not explicitly mention any limitations in its content.

4M	Learning tools show significant effects on students' computational thinking abilities based on experimental research conducted.	the learning process with the SSCS model requires a lot of time, which may be challenging due to the short time allocated in the curriculum 2. Low mathematics achievement in schools, indicating problems in mathematics learning components such as interactive learning processes, monotonous strategies, and uninteresting teaching methods.
5M	The result of the research and development process is the development of valid and usable digibooks in sequences and series based on Anyflip, which have a strong effect on exploring students' computational thinking skills.	The research paper does not explicitly mention any limitations in the study or development process.
6M	helps and enhances computational thinking processes among students by making their computational thinking optimally active, leading them to progress from pattern recognition to abstraction and algorithmic thinking in solving mathematical problems.	Limitations mentioned in this paper include the fact that students in this study were only able to reach the stages of pattern recognition, abstraction, and algorithmic thinking after scaffolding, indicating initial limitations in their computational thinking abilities.
1M	The research results show that the relationship between problem solving and computational thinking is evident when defining the problem, planning the solution process, implementing the plan, and evaluating the solution. Stages of decomposition, abstraction, generalization, debugging, and algorithmic steps are observed during the problem solving process.	As per the context provided, there is no direct reference to the limitations discussed in the paper regarding research on problem solving in the context of computational thinking.
2M	This study highlights that errors in solving the problem occur when the decomposition process is disrupted, leading to incomplete substitution.	1) This study focuses on the description of thought processes based on prospective teachers' answers, limiting the scope to non-routine problems in Linear Diophantine Equations. 2) This research does not extend to other fields outside the specific context of solving Diophantine linear equation problems using components of computational thinking.
3M	1) Participants show behavior consistent with the abstraction and generalization components from the beginning of learning. 2) Participants gain knowledge based on learning results and observing robot test results. 3) STEM learning using robotics provides new experiences for	Limitations of the research paper include the fact that it was conducted as a case study, focusing on a particular context, which may not fully represent broader knowledge dynamics outside that setting.

	participants, helping them adapt to gain relevant knowledge	
4M	The research results show that the TPACK-based hybrid learning model designed for achieving computational thinking skills in mathematics was found to be very valid, practical, and effective in improving students' computational thinking skills.	1) The limitations mentioned in this paper include the fact that almost all students are wrong in finding the solution to a particular problem due to misunderstanding the given image and failing to observe it. 2) students have difficulty in recognizing patterns and tracking emerging patterns accurately, which leads to errors in problem solving and incomplete answers, indicating the need for further development in computational thinking skills, especially in pattern recognition.
5M	Provides positive responses and is effectively used for mathematics learning and can improve computational thinking skills	Limitations of the study include the lack of detailed discussion of the challenges faced during the development of interactive learning media, which could provide valuable insight into the process
6M	1) The application of interactive learning media shows positive feedback and effectiveness in improving students' computational thinking skills. 2) This study emphasizes the importance of using interactive media to improve computational thinking learning outcomes.	1 Limitations of the study include the lack of detailed discussion of the challenges faced during the development of interactive media for computational thinking. 2 Another limitation is the absence of a comprehensive analysis of the impact of interactive media on the actual improvement of students' computational thinking skills 3 This study did not investigate potential barriers or difficulties faced by students when using interactive media to learn computational thinking.
7M	The use of Wolframs Mathematica was found to be effective in increasing students' understanding of computational thinking.	The research paper does not explicitly mention any limitations or constraints related to the research conducted on the effectiveness of using Wolframs Mathematica in injecting computational thinking in mathematical modeling.
1G	1) Participants engage in hands-on activities to create interactive simulations to teach basic science concepts using Scratch programming. 2) The overall response to the training was positive, with teachers showing interest in applying computational thinking skills through programming in their classrooms.	1) Limitations of the study include the need for further evaluation of the effectiveness of Scratch programming training for improving computational thinking skills, 2) Additionally, this study did not investigate the long-term retention of computational thinking skills acquired through Scratch programming training.

From the data displayed in the table, the results of research that focuses on Computational Thinking (CT) show various tools and strategies that have been implemented at elementary, middle school, high school, and student levels. Some significant results include the use of Scratch and PBL (Problem-Based Learning) which have proven effective in improving students' problem-solving and computational thinking skills.

Some examples of results from research that support this conclusion:

a. Satria et al., (2022) found that Interactive Scratch Animation was effective for science material, especially for elementary school students, by obtaining 20 citations, indicating positive results in related literature.

b. Angraini et al., (2023) show that the use of Augmented Reality in mathematics learning in junior high schools has a positive impact on computational thinking skills, with 6 citations confirming the widespread acceptance of these findings.

c. Research by Sujiarmo et al., (2021) on the use of scaffolding in high schools succeeded in obtaining 50 citations, showing the effectiveness of this method in helping students understand CT concepts in more depth.

Research Limitations: However, every study has its limitations. Based on data from documents related to research results, several main limitations faced are:

a. Limitations of Curriculum and Resources: Research by Prahmana et al., (2024) highlighted the challenges in integrating CT due to outdated curriculum and inadequate teacher training, which is also a common issue in many other studies.

b. Small Sample Size: For example, research by Angraini et al., (2023) shows that the small sample size due to the impact of Covid-19 limits the generalizability of the findings, as only 15 students consistently participated in the learning.

c. Limited Learning Content: In Jumadir's (2023) research on Wizer.Me-based E-LKPD, limitations occurred in the presentation of the material which was only in the form of instructional videos without other supporting content such as text or infographics, which limited the students' learning experience.

Conclusions from Limitations: These limitations indicate that although the tools and methods used in CT research have proven effective in a variety of educational contexts, there is still an urgent need to improve curricula, provide further training for teachers, as well as expand the scale of research to be more representative. wider population. Additionally, many studies have not explored the long-term impacts of CT-based teaching, which is an opportunity for further research in the future.

3. Discussion

This research provides a comprehensive overview of various teaching methods used to develop Computational Thinking (CT) skills in mathematics learning, based on bibliometric analysis and literature studies that have been carried out. Through a Systematic Literature Review (SLR) approach analyzed using bibliometric tools, various teaching methods such as Scratch, Augmented Reality (AR), Problem-Based Learning (PBL), and Educational Robotics have been identified as effective methods in improving students' computational skills.

The bibliometric analysis that has been presented provides valuable insights into trends, challenges, and opportunities in integrating Computational Thinking (CT) in mathematics learning. One of the main strengths of this analysis is its ability to identify gaps in the existing literature and reveal patterns and relationships between concepts, which can serve as a basis for further research.

This study found that the use of Scratch is widely used in mathematics learning at various levels of education, especially at the elementary school (SD) and junior high school (SMP) levels. Scratch, as a block-based programming tool, has the advantage of helping students develop algorithmic logic and problem solving through a visual and easy-to-understand environment. The results of research by Aminah et al., (2023) and Satria et al., (2022) show that Scratch-based interactive animation increases student engagement and motivation. This is in line with the findings of Molina-Ayuso et al., (2024) who stated that Scratch is effective in helping students understand basic programming concepts and computational thinking. However, there were limitations identified, such as the lack of development of valid evaluation instruments to measure the direct impact of Scratch use on long-term computational thinking skills. This study suggests the need to develop more comprehensive evaluation instruments so that results can be measured more objectively.

PBL (Problem-Based Learning) has been identified as one of the teaching methods most frequently used to develop Computational Thinking skills at the middle school, high school, and college student levels, as reported in the studies of Masfingatin & Maharani, (2019) and Moreno-Palma et al., (2024). PBL emphasizes problem-based learning which allows students to solve real problems using critical thinking and computing skills, especially algorithmic ones. This study found that PBL had a significant influence on improving students' computational skills, especially systematic problem solving skills. These findings support Hmelo-Silver's (2004) research which shows that PBL is effective in improving students' computational thinking skills through a collaborative learning process. However, our research reveals that obstacles to the use of PBL are limited classroom time and a lack of curriculum adaptation, which is still not designed to optimally support problem-based learning.

The use of Augmented Reality (AR) in computational learning is also a main concern in this study. Angraini et al., (2023) show that AR, when used in mathematics learning in middle school, provides a richer and more interactive experience for students, helping them visualize abstract concepts. These findings support the study of Lampropoulos et al., (2023) which stated that AR enhances students' learning experiences in a more dynamic way, allowing them to interact with learning material in more depth. However, technical limitations and limited resources are still the main obstacles to the widespread implementation of AR in schools. This study suggests the need to improve technology infrastructure in schools to support the development of AR in computational education.

Educational Robotics is an innovative method in supporting Computational Thinking, especially in the context of STEM (Science, Technology, Engineering, Mathematics). Budiyanto et al., (2022) show that the integration of robotics in STEM teaching at the student level has proven effective in improving algorithmic skills and systematic thinking. The use of robots allows students to apply mathematical and logical concepts in real situations, improving their technical skills. This is in line with research by Galanti & Holincheck, (Galanti & Holincheck, 2024) which found that educational robotics helps students develop computational skills through a collaborative exploration process. However, the barriers identified in our research are the limited cost and availability of robotics tools in schools, which limits the adoption of this method in some educational contexts.

4. Conclusion

This research presents a comprehensive review of teaching methods used to integrate Computational Thinking (CT) in mathematics learning, based on bibliometric analysis and literature study. The results show that methods such as Scratch, Augmented Reality, Problem-Based Learning (PBL), and robotics make a significant contribution in improving students' computational skills. However, several limitations need to be considered, such as the lack of valid evaluation instruments, limited technological resources, and implementation challenges at various levels of education. Further research is needed to overcome these barriers as well as explore the long-term impact of CT integration in education. This analysis opens up opportunities for the development of better evaluation instruments, more inclusive technological innovations, and more effective collaborative learning models for the future of computational-based mathematics education.

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