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Global research trends on computational thinking in mathematics education: A bibliometric analysis (2000–2025)

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Abstrak: This study aims to identify global trends, scientific collaborations, and developments in computational thinking topics in the context of mathematics education through bibliometric analysis. The method refers to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to improve transparency and quality of reporting. Data were taken from the Dimensions database for the period 2000–2025 and analyzed using VOSviewer software. The results show a significant increase in publications and citations since 2016, with the peak of publications occurring in 2023 and the highest citations in 2024. SDG 4: Quality Education is the theme most often associated with computational thinking, although contributions to Mathematics Education are still limited. The journal Education and Information Technologies is the most dominant publication medium, with researchers such as Weipeng Yang and Gary Ka Wai Wong as the main contributors. The visualization of the keyword network highlights the large focus on computational thinking skills, while mathematics education is in a peripheral position, indicating a suboptimal relationship. The visualization of co-authorship also shows the formation of strong global collaborations. The positive correlation between the number of publications and citations indicates that scientific productivity plays a major role in research visibility. These findings provide an important basis for developing further research into the integration of computational thinking into 21st century mathematics learning.

Kata Kunci: Computational Thinking, Bibliometric, Mathematics Education, VOSviewer

Tren penelitian global tentang pemikiran komputasi dalam pendidikan matematika: Analisis bibliometrik (2000–2025)

Abstract: Penelitian ini bertujuan mengidentifikasi tren global, kolaborasi ilmiah, dan perkembangan topik berpikir komputasi dalam konteks pendidikan matematika melalui analisis bibliometrik. Metode mengacu pada Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) untuk meningkatkan transparansi dan kualitas pelaporan. Data diambil dari basis data Dimensions pada rentang tahun 2000–2025 dan dianalisis menggunakan perangkat lunak VOSviewer. Hasil menunjukkan peningkatan signifikan publikasi dan sitasi sejak 2016, dengan puncak publikasi terjadi pada 2023 dan sitasi tertinggi pada 2024. SDG 4: Quality Education menjadi tema yang paling sering dikaitkan dengan berpikir komputasi, meskipun kontribusi terhadap Mathematics Education masih terbatas. Jurnal Education and Information Technologies menjadi media publikasi paling dominan, dengan peneliti seperti Weipeng Yang dan Gary Ka Wai Wong sebagai kontributor utama. Visualisasi jaringan kata kunci menyoroti fokus besar pada keterampilan berpikir komputasi, sementara pendidikan matematika berada di posisi periferal, menunjukkan keterkaitan yang belum optimal. Visualisasi co-authorship juga memperlihatkan terbentuknya kolaborasi global yang kuat. Korelasi positif antara jumlah publikasi dan sitasi mengindikasikan bahwa produktivitas ilmiah berperan besar dalam visibilitas riset. Temuan ini menjadi dasar penting bagi pengembangan riset lanjutan dalam integrasi berpikir komputasi ke pembelajaran matematika abad ke-21.

Keywords: Berpikir Komputasi, Bibliometrik, Pendidikan Matematika, VOSviewer

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INTRODUCTION

The rapid advancement of information technology in the 21st century has prompted the educational sector to incorporate various higher-order thinking skills, among which is Computational Thinking. The concept of computational thinking was first introduced by Jeannette Wing in 2006 as a problem-solving approach that utilizes principles from computer science to comprehend phenomena (Wing, 2008). Wing emphasizes that Computational Thinking is a fundamental skill on par with reading, writing, and arithmetic, making it essential to teach this skill to all learners from an early age (Grover & Pea, 2013). Computational Thinking extends beyond programming skills; it encompasses analytical thinking abilities such as decomposition, pattern recognition, abstraction, and algorithm formulation, which align with the cognitive characteristics found in mathematics (Angraini et al., 2024; Ferreira et al., 2023; Yadav et al., 2016).

In the realm of Mathematics Education, the integration of Computational Thinking (CT) has been shown to positively impact students' conceptual understanding and problem-solving abilities. Supiarmo et al. (2022) discovered that CT enhances mathematical problem-solving skills, while Kannadass et al. (2023) identified a strong correlation between CT and critical thinking, which influences students' modeling capabilities. This approach is further supported by the Merdeka Curriculum, which provides ample opportunities for the development of 21st-century skills through student-centered and contextual learning (Maharani et al., 2023). Additionally, technologies such as augmented reality contribute to the reinforcement of CT in mathematics education, particularly in grasping abstract concepts (Hanid et al., 2022).

As attention towards CT increases, mapping literature through bibliometric analysis has become essential for understanding the dynamics of knowledge and the global development of research (Maharani et al., 2023; Zakaria et al., 2023). This approach can reveal patterns of international collaboration, citation trends, and keyword relationships within scientific publications (Li et al., 2020; Park & Kwon, 2022). However, most previous bibliometric studies have limitations, particularly because they only cover a narrow time frame and have not specifically highlighted the connections between CT and Mathematics Education. Therefore, a comprehensive and historical analysis is necessary to trace the development of CT in mathematics education since its inception.

The time frame of 2000–2025 has been selected as it reflects the comprehensive evolution of CT from its initial introduction, through the strengthening of its concepts, to its widespread adoption in education. The period from 2000 to 2009 represents the early phase when CT began to be introduced, although publications in Mathematics Education during this time were still limited. The phase from 2010 to 2016 marks the formal adoption of CT through global policies such as those from OECD (2016) and UNESCO (2018), which integrated CT into digital literacy and 21st-century competencies. Meanwhile, the period from 2017 to 2025 demonstrates an extraordinary expansion in CT research, both in terms of the number of publications and citations, resulting from the penetration of digital education policies across various countries. Therefore, an analysis spanning this quarter-century provides a longitudinal perspective that has not been offered in previous studies, such as the research conducted by

(Maharani et al., 2023), which is limited to the period of 2013–2023 and does not encompass the early stages of CT development. This long-term analysis is crucial for illustrating the historical evolution of the CT topic, observing shifts in research themes, and assessing the position of Mathematics Education within the global development of CT.

Based on the identified gap, this research not only concentrates on the identification of publication and citation trends but also explores the contributions of researchers, clusters of keywords, temporal developments of research themes, areas of research intensity, and patterns of author collaboration. This study also integrates inferential analysis through linear regression to examine the relationship between the number of publications and citation rates, thereby providing a more comprehensive understanding of the impact of scientific productivity on the visibility of CT research within Mathematics Education. Consequently, the research problem formulation centers on how publication and citation trends evolve during the period from 2000 to 2025; how research contributions relate to the Sustainable Development Goals (SDGs); how publication distribution varies by journal category and researcher productivity; how conceptual interconnections manifest through network, overlay, and density visualization; how global author collaboration patterns emerge; and how the relationship between publications and citations can be statistically analyzed.

In alignment with these objectives, bibliometric analysis plays a crucial role not only in identifying trends and the distribution of publications but also in providing opportunities to gain a deeper understanding of the dynamics of scientific collaboration and the evolution of research themes. In this context, the use of tools such as VOSviewer is highly beneficial for mapping and visualizing collaboration networks and thematic clusters, thereby facilitating broader knowledge transfer and enhancing integration among researchers within the same field. The application of tools like VOSviewer enables the visualization of collaboration networks and thematic clusters, which can improve knowledge transfer among researchers (Hwang & Tu, 2021; Raman et al., 2021). Consequently, a more in-depth and systematic bibliometric analysis is required to bridge these gaps and strengthen the foundation for the development of CT in Mathematics Education in the future.

METHOD

This study employs bibliometric analysis to identify global research trends concerning Computational Thinking in Mathematics Education from 2000 to 2025. Bibliometric analysis is a pertinent and effective approach for recognizing publication trends, researcher collaboration patterns, and the evolution of research themes in this domain (Aulia & Rusli, 2020; Tupan et al., 2018). As the primary database, this research utilizes Dimensions, a bibliometric platform developed by Digital Science. Dimensions integrate various types of scientific information, including publications, citations, research funding, patents, clinical trials, and policy documents into a single, comprehensively connected system (Herzog et al., 2020). The strengths of this platform lie in its extensive multidisciplinary coverage, open access, and its ability to facilitate transparent scientific analysis, high replicability, and contextual understanding.

The selection of Dimensions over Scopus or Web of Science is based on scientific and methodological considerations to ensure the credibility and completeness, as well as its relevance for long-term longitudinal research (2000–2025). First, Dimensions encompasses over 135 million publications, including open access articles and institutional publications that are not always fully included in Scopus or Web of Science (Herzog et al., 2020). Second, Dimensions offer direct links between data entities (publications, funding, citations, and patents) which enrich the context of bibliometric analysis. Third, its system is open and accessible without commercial licensing restrictions, thereby ensuring transparency and the replicability of research (Szomszor et al., 2021).

In alignment with the perspective of Glänzel & Chi (2020), which underscores the significance of integrating data from various sources to produce comprehensive bibliometric analyses, as well as the recommendations of Szomszor et al. (2021) regarding the value of data openness as a crucial factor in enhancing the reliability and credibility of scientific analysis, the utilization of Dimensions in this research not only offers advantages in terms of the depth and breadth of data but also reinforces the transparency of methodologies and the scientific validity of the research outcomes.

The publication data was extracted from the Dimensions database on April 23, 2025. The extraction and selection process of articles was conducted using the PRISMA flow diagram (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Page et al., 2021), as illustrated in Figure 1. The application of the PRISMA flow diagram has been utilized in prior research, as demonstrated (Damayanti et al., 2024; Santosa & Damayanti, 2024).

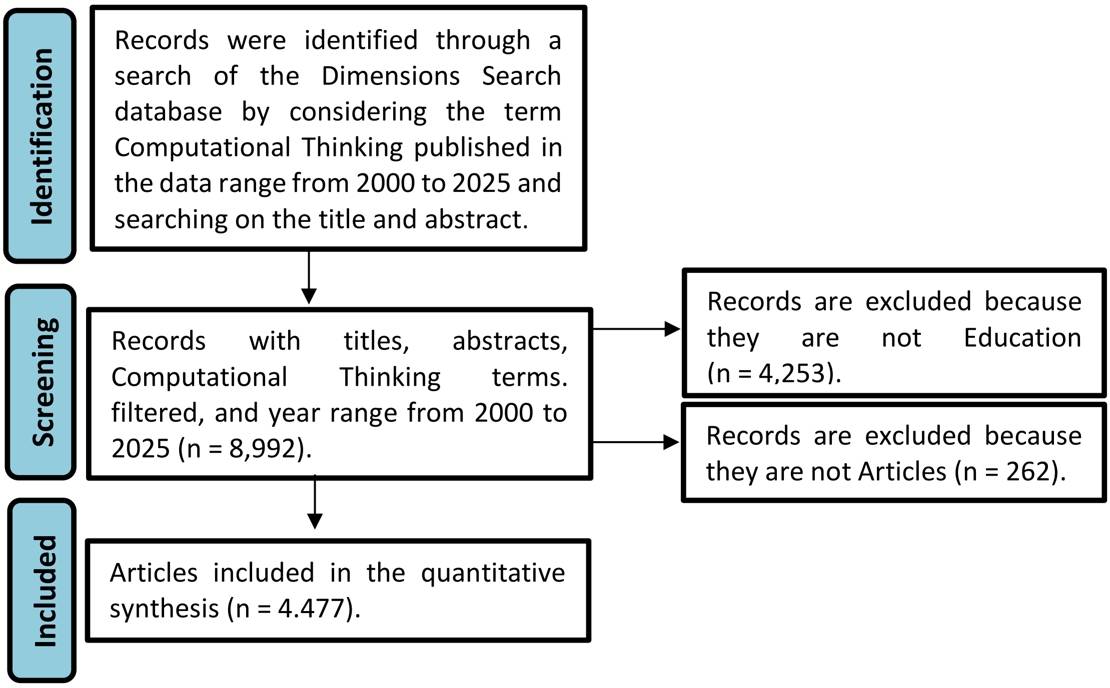

Figure 1. PRISMA flowchart

Based on the PRISMA flowchart, it describes the process of selecting articles in bibliometric research using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach. In the Identification stage, the initial record was identified

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through a search of the Dimensions database using the term Computational Thinking, which was published in the time range from 2000 to 2025. The search is focused on the title and abstract sections. Furthermore, at the Screening stage, a total of 8,992 records were obtained containing the term Computational Thinking in the title or abstract. However, a number of records were later excluded because they were not relevant to the educational context as many as 4,253 records and were not scientific articles as many as 262 records.

After the screening process, a total of 4,477 articles were declared to meet the inclusion criteria and included in the quantitative synthesis for further analysis in this bibliometric study. Furthermore, the filtered data will be analyzed using the VOSviewer software to visualize the relationships between authors, keywords, and emerging research trends in Computational Thinking topics in Mathematics Education. VOSviewer is a software that excels in the analysis and visualization of bibliometric data due to its ability to construct and examine detailed network maps of the retrieved data, in this case through the Dimensions database (Sumarno & Suparman, 2024).

RESULTS AND DISCUSSIONS

This section presents the findings from a bibliometric analysis of publications discussing Computational Thinking within the context of Mathematics Education from the year 2000 to 2025. The analysis encompasses several key aspects, including the number of publications per year, citation trends, the distribution of publications according to the Sustainable Development Goals (SDGs) fields, journal categories, researcher productivity, and the patterns of conceptual relationships and author collaboration through network visualization, overlay visualization, density visualization, and co-authorship networks. Furthermore, a correlational analysis between the number of publications and citations is conducted using linear regression with SPSS to examine the relationship between the two.

The search conducted from the year 2000 to 2025 yielded a total of 4,477 scholarly articles. Furthermore, the annual publication count of articles related to Computational Thinking within the domain of Mathematics Education is illustrated in Figure 2.

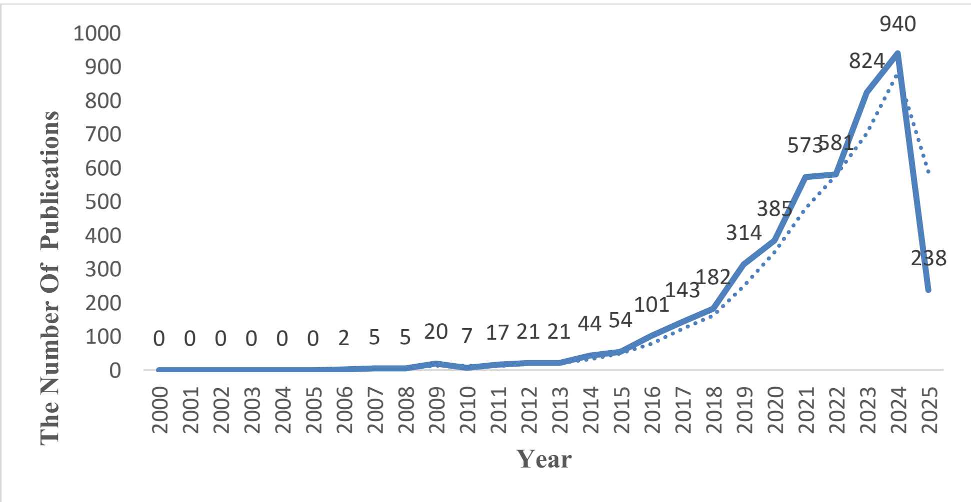

Figure 2. The number of Computational Thinking publications every year

Based on Figure 2, it is evident that the trend in publications has experienced a significant increase starting from the year 2016. In that year, the number of publications rose to 101 articles, nearly doubling from the previous year's total of 54 publications. This upward trend has continued consistently throughout the period from 2017 to 2024, with the most substantial surge occurring between 2022 and 2023, where the number of publications increased from 581 to 824. This sharp rise is not only quantitative in nature but also reflects changes in policy and a global shift towards computational literacy.

Specifically, the surge in publications following 2016 is closely linked to the introduction of global digital literacy frameworks such as the OECD Digital Skills Framework (OECD, 2016) and the UNESCO Digital Literacy Global Framework (UNESCO, 2018), which position Computational Thinking as a core competency of the 21st century. These frameworks encourage countries to integrate CT into their mathematics and science curricula, thereby stimulating an increased demand for pedagogical research in these fields (Grover & Pea, 2013; Kallia et al., 2021). Consequently, the rise in publications during this period is not a random phenomenon, but rather a part of the academic response to international policy trends and the digital transformation of education. Conversely, the period from 2000 to 2003 exhibited a complete absence of publications, with only a very slow growth observed until 2010. This situation suggests that at the beginning of the 2000s, the topic of Computational Thinking had not yet garnered significant attention within Mathematics Education. This aligns with Wing (2008) findings, which indicate that CT only gained widespread popularity after the mid-2000s.

Overall, the trend data indicates that interest in research on this topic has progressively increased, peaking in 2024. The decline in the number of publications in 2025 (288 publications) is likely attributed to the fact that the data for that year was still ongoing at the time of data collection, thus not fully reflecting the total number of publications. Following the analysis of this dynamic publication, the next step is to review citation development as an indicator of scientific contribution, considering that citations provide insight into the quality and impact of research within the domain of Computational Thinking, as illustrated in Figure 3.

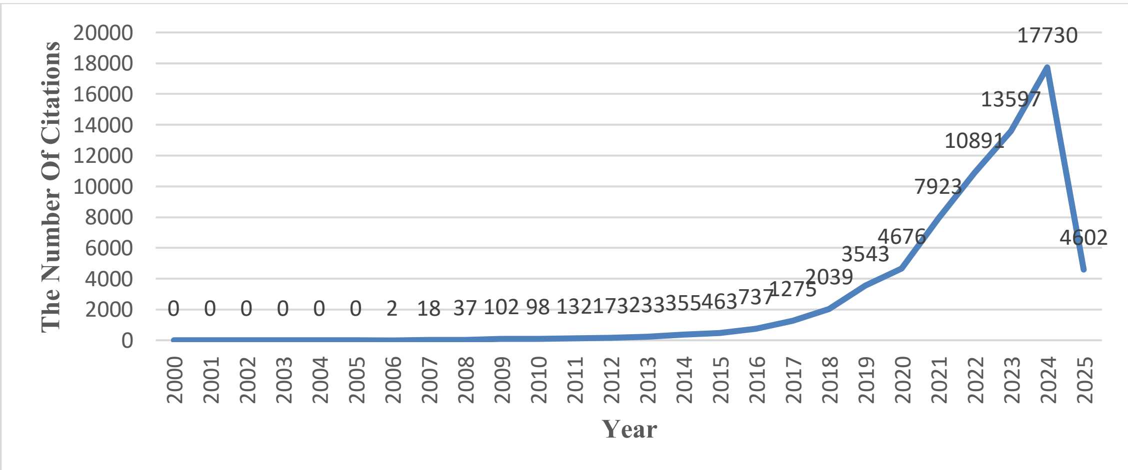

Figure 3. Number of citations on the topic of Computational Thinking Every Year

According to Figure 3, the citation trend exhibits a significant increase starting from the year 2017. In that year, the number of citations rose to 1,275 from 737 in the previous year. This sharp increase continued until 2024, reaching a total of 17,730 citations. This surge in citations not only reflects the growing volume of publications but also indicates that research in Computational Thinking is increasingly recognized as making a vital contribution to the advancement of theory and practice in education, particularly in the field of Mathematics Education.

Conceptually, this increase in citations can be linked to the growing global recognition of Computational Thinking as a vital competency in modern education, as emphasized (OECD, 2016; Wing, 2008). Various international reports and standards encourage researchers to establish CT as the foundation for developing digital literacy and 21st-century skills. This recognition also underscores that CT is not only pertinent within the realm of computer science but also plays a significant role in mathematics education, particularly in enhancing problem-solving abilities, abstraction, and algorithms (Helsa et al., 2023b; Kallia et al., 2021).

The low citation rates during the period of 2000–2004 indicate that Computational Thinking (CT) had not yet garnered significant scholarly attention. However, following the incorporation of CT into curriculum policies across various countries (such as Singapore, South Korea, and Finland), research on CT has gained international focus, thereby enhancing its visibility within the field of Mathematics Education. This aligns with the findings of Grover & Pea (2013), which assert that conceptual understanding in mathematics can be bolstered through the development of CT. Based on the research domain, publications on the topic of Computational Thinking can be categorized under the Sustainable Development Goals, as illustrated in Figure 4.

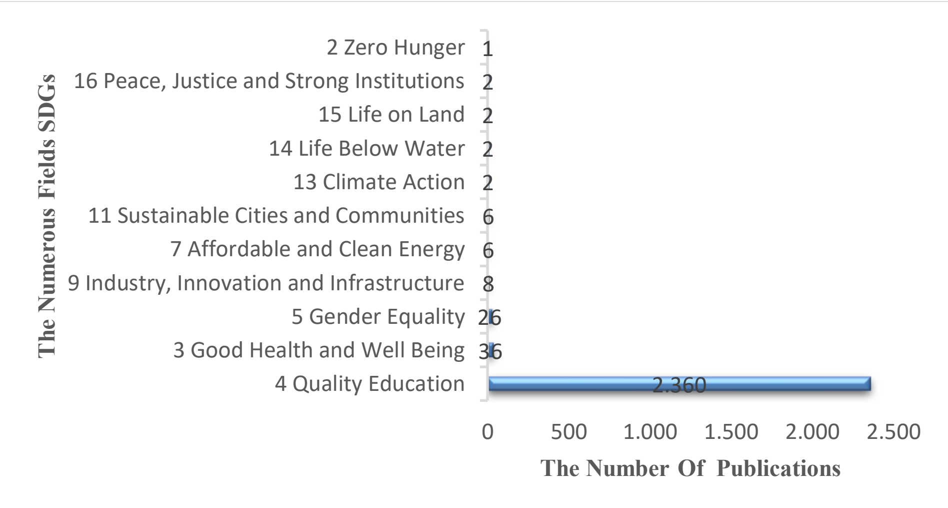

Figure 4. The number of Computational Thinking publications reviewed from the field of Sustainable Development Goals

According to the graph depicting the volume of publications on the topic of Computational Thinking in relation to the Sustainable Development Goals (SDGs), it is evident that SDG 4: Quality Education is the most extensively researched area, with a total of 2,360 publications. This figure is significantly higher compared to other SDGs, which have only a limited number of publications, such as SDG 3: Good Health and Well-Being with 36 publications, SDG 5: Gender Equality with 26 publications, and SDG 9: Industry, Innovation and Infrastructure with 8 publications. Several other SDGs are recorded to have merely 1 to 6 publications. This finding indicates that the development of Computational Thinking is predominantly focused on the educational context, particularly in enhancing access, quality, and relevance of learning in the digital age (Agbo et al., 2019; Knie et al., 2022).

It is important to note that the scope of SDG 4: Quality Education remains quite broad, encompassing all aspects of education across various levels and fields of study. This implies that the figure of 2,360 publications does not specifically illustrate the extent of Computational Thinking's contribution to Mathematics Education in particular. A more detailed mapping is necessary to ascertain the proportion of publications that genuinely focus on Mathematics Education. Consequently, research opportunities around Computational Thinking in Mathematics Education remain abundant, not only to support quality education but also to enhance its impact on other SDGs. To examine how these research findings are disseminated, the subsequent discussion will explore the categories of journals in which these publications appear, reflecting their credibility and the scope of their scientific dissemination.

According to the journal, publications on the topic of Computational Thinking within the realm of Mathematics Education can be categorized. The number of publications from the 11 largest journals is presented in Figure 5.

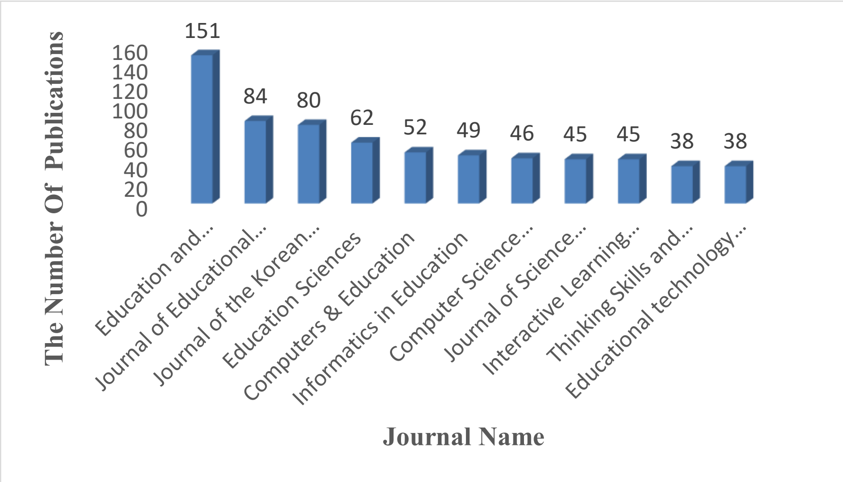

Figure 5. The number of publications on the topic of Computational Thinking is reviewed from the journal

The graphical representation of the number of publications on the topic of Computational Thinking, as reviewed from various journals, indicates that the journal Education and Information Technologies is the most prominent publication medium, with a total of 151 articles published. This journal is followed by the Journal of Educational Computing Research, which has 84 publications, and the Journal of the Korean Association of Computer Education, with 80 publications. These journals primarily concentrate on the integration of technology in education and the development of computational skills across different levels of learning.

Furthermore, there are several other journals that consistently publish research on Computational Thinking, including Education Sciences with 62 publications, Computers & Education with 52 publications, Informatics in Education with 49 publications, and Computer Science Education with 46 publications. This is followed by the Journal of Science Education and Technology with 45 publications, Interactive Learning Environments with 45 publications, Thinking Skills and Creativity with 38 publications, and Educational Technology Research and Development with 38 publications. This distribution indicates that the topic of Computational Thinking is broadly interconnected, not only within the realm of technology education but also in the development of creativity, higher order thinking skills, and the teaching of science and computer subjects (Aytekin & Topcu, 2024; Tian, 2024; Wiryasaputra et al., 2022). Based on an analysis of existing publications, the contributions of researchers can be categorized, with an emphasis on five prominent researchers who have significantly influenced this field. The volume of publications attributed to these top five researchers is illustrated in Figure 6.

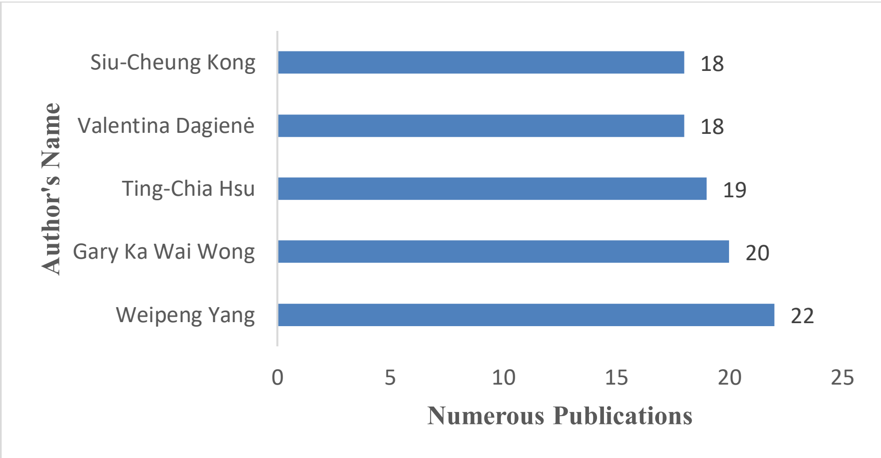

Figure 6. The number of publications on the topic of Computational Thinking from researchers

The illustration depicts the volume of publications on the topic of Computational Thinking by various researchers, revealing that Weipeng Yang is the leading author with a total of 22 publications. He is followed by Gary Ka Wai Wong with 20 publications, and Ting-Chia Hsu with 19 publications. Additionally, Valentina Dagienė and Siu-Cheung Kong each have 18 publications. This data indicates that these five researchers have made significant contributions to the development and dissemination of the topic of Computational Thinking through their scholarly publications. To further explore the relationships among these publications and the frequently occurring terms within this context, one can utilize the network visualization tool provided by VOSviewer, which offers a clearer representation of the co-occurrence of terms related to Computational Thinking. The network visualization illustrating the co-occurrence of Computational Thinking terms is presented in Figure 7.

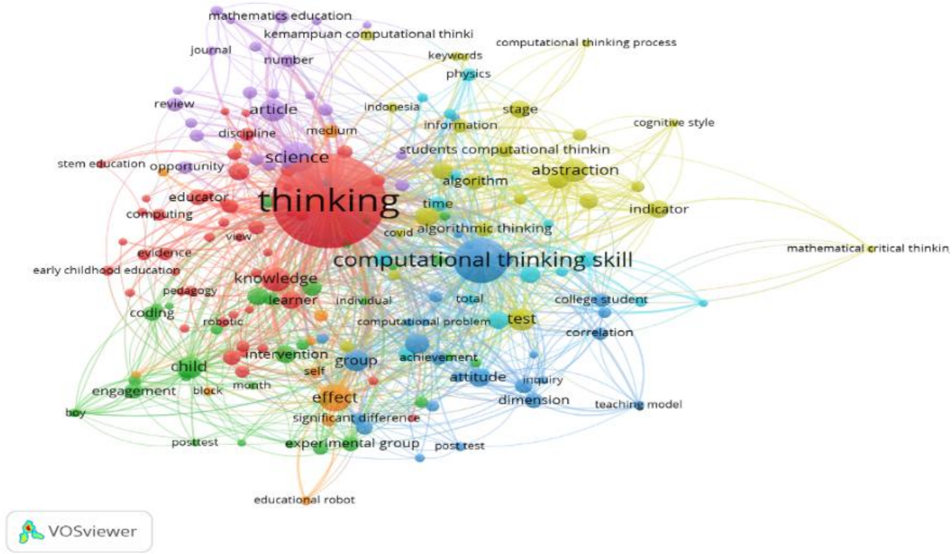

Figure 7. Network visualization on the topic of Computational Thinking

The illustration depicts conceptual relationships among various keywords in scientific publications, primarily emphasizing computational thinking skills. It encompasses 185 terms, 7 clusters, 7.919 links, and a link strength of 60.775. Notably, cluster 5 reveals a direct connection between computational thinking skills and mathematics education. This cluster is represented in purple, indicating that while the topic of computational thinking is broadly distributed across multiple fields, it is specifically the element of computational thinking skills that is closely associated with mathematics education.

The interconnectedness is illustrated by the link that associates computational thinking skills with mathematics education, indicating that in research, the development of CT skills is a primary focus when this topic is addressed within the context of Mathematics Education (Angraini et al., 2024). This suggests that the approach to mathematics education places greater emphasis on the concrete application of skills such as abstraction, algorithms, decomposition, and logical reasoning, which are fundamental components of computational thinking skills (Helsa et al., 2023a; Huda & Ikhsan, 2024).

Furthermore, the visualization illustrates the connection between mathematics education and the concept of Systematic Literature Review (SLR). Numerous studies on computational thinking within Mathematics Education have been conducted using SLR (Agbo et al., 2019; Mohmad & Maat, 2023; Refvik & Bjerke, 2022). The presence of SLR within the same cluster indicates that it is a predominant strategy for understanding and formulating the integration of computational thinking into Mathematics Education. However, an analysis of the circle sizes and the number of link strengths reveals that the keyword 'mathematics education' appears to have a lower frequency and connectivity compared to other keywords such as thinking and science.

Furthermore, it has been found that computational chinking is closely related to abstraction skills, cognitive styles, and mathematical critical thinking. This finding encourages further research to explore how individual characteristics, such as students' cognitive styles, can contribute to the effectiveness of computational thinking implementation in mathematics education, particularly in enhancing higher order thinking skills such as modeling, problem-solving, and critical thinking. Explicit research on computational thinking within the context of mathematics education remains relatively scarce compared to other fields. The enhancement of 21st-century skills necessitates the integration of computational thinking abilities across various subjects (Knie et al., 2022; Maharani et al., 2019; Putri et al., 2024; Wiryasaputra et al., 2022).

It is essential for researchers to broaden their studies on how mathematics education can be specifically designed to enhance computational thinking through learning models and the utilization of technology (Manullang & Simanjuntak, 2023). Furthermore, VOSviewer offers an overlay visualization map that enables the visualization of how terms related to computational thinking interact and evolve over time within scientific publications. Additionally, the overlay visualization for the co-occurrence of the term Computational Thinking is presented in Figure 8.

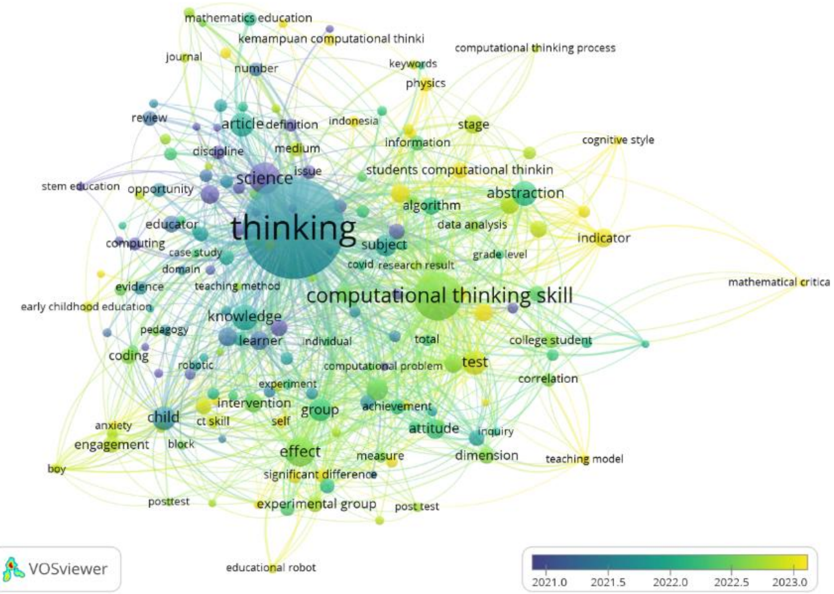

Figure 8. Overlay visualization on the topic of Computational Thinking

The Overlay Visualization image from VOSviewer illustrates the temporal development in research related to the topic of computational thinking, with colors indicating the year of publication, ranging from dark blue representing 2021 to yellow representing 2023. The keyword computational thinking skill serves as the central node of the network, connecting to various concepts such as test, group, and abstraction. Although the keyword mathematics education is also present, its position at the periphery, indicated by a bluish-green color, suggests that its relevance has not yet become a primary focus in current research.

Numerous studies have confirmed that computational thinking is highly relevant to Mathematics Education, particularly because both emphasize logical reasoning, analytical skills, pattern recognition, and problem-solving abilities. Helsa et al. (2023a) and Kallia et al. (2021) discovered that computational thinking significantly enhances mathematical

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understanding through abstraction and algorithmic processes. However, the marginal position of mathematics education within the network indicates a gap between the theoretical potential of computational thinking and its application in contemporary mathematical research.

The lack of connection presents significant opportunities for further research, particularly in the development of innovative learning models that explicitly integrate CT into mathematics education. Recent studies indicate that the use of interactive technologies, such as GeoGebra and visual programming, can enhance the development of CT while also aiding in the mastery of mathematical concepts (Manullang & Simanjuntak, 2023). Furthermore, project-based approaches and Problem-Based Learning that incorporate CT have proven effective in improving students' mathematical reasoning and problem-solving skills (Agbo et al., 2019; Refvik & Bjerke, 2022).

Thus, the findings of this overlay visualization underscore the necessity to expand research that examines the integration of Computational Thinking (CT) within Mathematics Education, whether through the design of digital learning media, the development of new pedagogical approaches, or the analysis of CT-based mathematical representations (Huda & Ikhsan, 2024). To enhance this understanding, the next step involves analyzing density visualization to identify the areas that have been most intensively researched and the themes that exhibit the strongest connections within the conceptual map of computational thinking research, as presented in Figure 9.

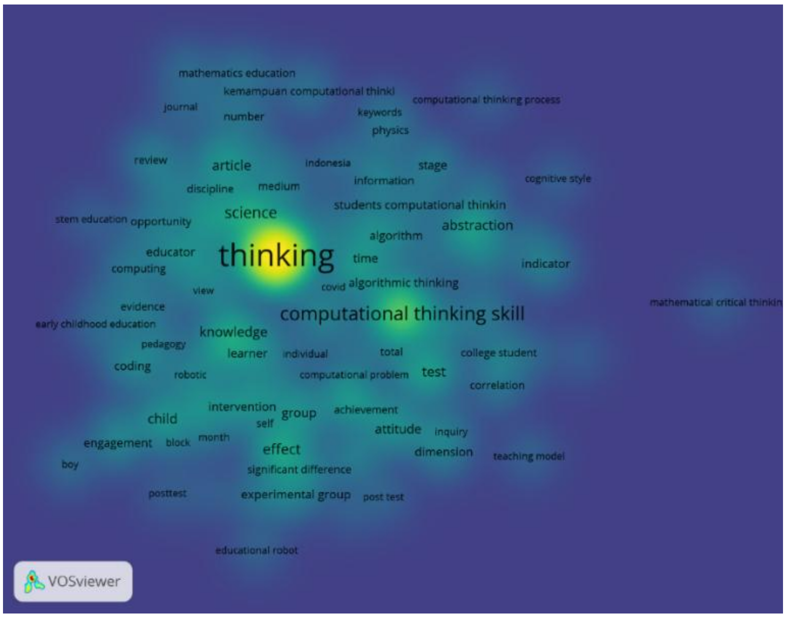

Figure 9 Density visualization on the topic of Computational Thinking

The Density Visualization image from VOSviewer illustrates the distribution of keyword intensity in research focused on computational thinking. The term 'thinking' is prominently featured, highlighted in bright yellow to indicate its high frequency and central position within the research (Sumarno & Suparman, 2024). In contrast, the keyword 'computational thinking skill' is also noticeable, albeit with a less vibrant color, suggesting that researchers' attention to this topic is still evolving and not as substantial as the broader concept of thinking itself.

The term mathematics education appears to occupy a less prominent position on the periphery of the network, indicating that its connection to computational thinking remains limited in current research. Strengthening computational thinking within Mathematics Education is crucial for enhancing students' logical reasoning, systematic thinking, and problem-solving skills (Kaswar & Nurjannah, 2024; Pajow et al., 2024). This visualization illustrates significant opportunities for researchers to further explore the integration of computational thinking skills and mathematics education as a contribution to the advancement of 21st-century learning. To deepen the understanding of collaboration in this research, VOSviewer also offers network visualization for co-authorship, providing insights into the relationships among authors involved in publications related to this topic. The network visualization for co-authorship involving 132 authors is presented in Figure 10.

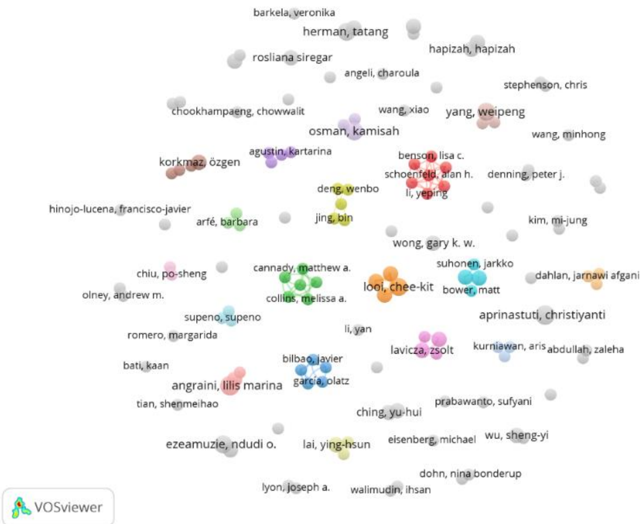

Figure 10. Network visualization for co-authorship on the topic of Computational Thinking

The visualization of the co-authorship network illustrates collaborative relationships among researchers in the field of Computational Thinking within Mathematics Education. This visualization was generated using VOSviewer software, where each node represents an individual researcher, and the lines connecting the nodes indicate collaborative efforts in scientific publication (Cheng et al., 2019). The different colors within the network signify clusters or groups of researchers who frequently collaborate, thereby forming specific research communities within the same topic. The image reveals that certain researchers play a prominent role in this network. For instance, Looi, Chee-Kit appears in the orange cluster and possesses extensive connections, indicating his active involvement in research collaboration.

Benson, Lisa C., Schoenfeld, Alan H., and Li Yeping are also situated in the red cluster, indicating their central positions and significant contributions to the advancement of Computational Thinking studies within Mathematics Education. Other researchers such as Aprinastuti, Christiyanti, Angraini, Lilis Marina, and Ezeamuzie, Ndudi O. also appear to be actively engaged in their respective clusters, demonstrating involvement in cross-author collaborations. Furthermore, the partnership between Cannady, Matthew A. and Collins, Melissa A. in the green cluster illustrates a robust research collaboration. Overall, this visualization depicts the emergence of a global collaboration network in Computational Thinking research, with several researchers playing pivotal roles in the development and dissemination of knowledge in this field.

The visualizations obtained through VOSviewer reveal an intriguing conceptual relationship between computational thinking skills and mathematics education; however, this connection requires a deeper analysis within the framework of mathematics education theory. This interrelation can be elucidated through the constructivist theories of (Bruner, 1961; Piaget, 1970), which emphasize that mathematics learning occurs when students actively construct meaning through thinking processes and exploration. This aligns with the perspective of Grover & Pea (2013), who assert that computational thinking serves as a conceptual thinking tool that aids students in comprehending mathematical ideas through processes of decomposition and abstraction. The findings from the visualizations also correspond with DuVal (2006) representation theory, which underscores the significance of the ability to transition between symbolic, graphic, and algorithmic representations in understanding mathematical concepts, a process that is further facilitated by CT skills. Additionally, the framework of conceptual understanding articulated by Hiebert & Carpenter (1992) indicates that deep understanding emerges when students can connect various representations within the context of problem-solving, as pursued through the integration of computational thinking. Therefore, these bibliometric results not only display statistical patterns of relationships among keywords but also reinforce the theoretical foundation for the development of a computational thinking-based mathematics learning paradigm (Helsa et al., 2023a).

From a practical perspective, the findings of this analysis can serve as a foundation for the development of policies and learning strategies in secondary and higher education, particularly regarding the integration of computational thinking into the digital mathematics curriculum. Educators and curriculum developers may utilize these findings to design learning activities that foster decomposition, abstraction, and algorithmization through interactive media such as GeoGebra or Articulate Storyline (Helsa et al., 2023b; Manullang & Simanjuntak, 2023). Consequently, this research not only contributes to academic discourse but also has direct implications for technology-based educational practices.

Next, to conduct a deeper analysis of the impact of this collaboration, the relationship between publications and citations can be explored using a simple linear regression method implemented in the SPSS program. To analyze the relationship between the variables of Publications and Citations, a simple linear regression method is employed using SPSS (Wufron, 2020). The aim of this test is to measure the extent of the influence of Publications on Citations and to determine the significance level of the relationship between these two variables. Figure 11 illustrates the coefficient output from the data processing conducted with SPSS.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	23.695	10.585		2.239	.035
	Publikasi	.056	.002	.985	28.414	.000

a. Dependent Variable: Sitasi

Figure 11. Relationship between publications and citations on the topic of Computational Thinking

Based on the output from the Coefficients table resulting from regression analysis conducted using SPSS, a positive constant value of 23.695 was obtained, indicating a positive influence of the independent variable (number of publications) on the dependent variable (number of citations). This implies that an increase of one unit in the number of publications will lead to an increase in the number of scientific citations received. The publication coefficient is 0.056, with a Standard Error of 0.002, a t-value of 28.414, and a significance level of 0.000 ($p < 0.05$), demonstrating that this relationship is statistically significant. Furthermore, the standardized beta coefficient of 0.985 indicates that the publication variable has a very strong impact on the citation variable. In other words, the higher the productivity of scientific publications, the greater the influence and visibility of Computational Thinking research in the field of Mathematics Education on a global scale.

This result indicates that the productivity of publications not only affects the increase in the quantity of literature but also directly contributes to the strengthening of scientific influence through high citation rates. Inferentially, this relationship reflects the dynamics of interconnections among research activities, researcher collaboration, and academic recognition within the global research ecosystem. These findings reinforce the previous research conducted by Li et al. (2020), which also identified a positive correlation between the growth in the number of publications and citation rates as indicators of the development of specific scientific fields. However, in contrast to those studies, this research offers a more profound analytical dimension by linking regression results with the context of global policies such as OECD (2016) and UNESCO (2018), which emphasize the importance of computational literacy and higher-order thinking skills in 21st-century mathematics education.

Thus, this analysis is not merely a visual descriptive study as typically conducted in bibliometric research, but also possesses a comparative and inferential nature, as it links quantitative results with shifts in paradigms and global policies that influence the trajectory of research in Computational Thinking. This approach enriches the interpretation of bibliometric outcomes with broader conceptual meanings and scientific implications, while simultaneously reinforcing the position of this research as a systematic effort to comprehend the relationship between scientific productivity, global collaboration, and the impact of citations in the advancement of Mathematics Education grounded in Computational Thinking.

CONCLUSION

This study employs bibliometric analysis utilizing VOSviewer software to identify global trends in Computational Thinking research within Mathematics Education from 2000 to 2025. The data was sourced from the Dimensions database, selected based on specific criteria. The analysis results indicate a significant surge in publications and citations since 2017, peaking in 2023 for publications and in 2024 for citations. The topic of CT is predominantly examined in the context of SDG 4: Quality Education, with the leading journal being Education and Information Technologies. Weipeng Yang is identified as the researcher with the highest number of publications, and the co-authorship visualization reveals a robust collaboration network among several key researchers. Keyword visualization indicates that computational thinking skills are central to the research, while the connection to mathematics education remains relatively weak.

This finding indicates that despite the rapid advancement of CT, its application within the realm of Mathematics Education has not yet become a primary focus. This situation presents significant opportunities for further research that is more in-depth and specific, particularly in the development of CT-based learning models that are pertinent to supporting 21st-century education. However, this study does have several limitations. Firstly, the data sources utilized are exclusively from a single database, namely Dimensions, which means that the coverage of publications from other databases such as Scopus or Web of Science is not fully represented. Secondly, the analysis conducted remains descriptive and has not explored the deeper conceptual relationships between Computational Thinking and mathematics education theory. Thirdly, this research has not included content analysis to investigate the pedagogical context and implementation strategies within the publications reviewed.

Consequently, it is recommended that future research combine bibliometric analysis with a systematic content analysis approach to reveal the thematic directions, learning theories, and pedagogical approaches underlying CT research in mathematics education. Further studies could also compare the analytical results from various databases such as Scopus, Web of Science, and Dimensions to enhance the validity and reliability of the findings. Moreover, it is crucial to explore the relationship between publication trends and global educational policies, ensuring that research outcomes are not merely descriptive but also provide strategic recommendations for the development of a Computational Thinking-based curriculum in mathematics education. Thus, the results of this study not only illustrate the existing research landscape but also strengthen the conceptual, practical, and policy-oriented development of Computational Thinking in the future.

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REFERENCES

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Adewumi, S. (2019, 2019). *A Systematic Review of Computational Thinking Approach for Programming Education in Higher Education Institutions* Proceedings of the 19th Koli Calling International Conference on Computing Education Research, https://doi.org/10.1145/3364510.3364521

Angraini, L. M., Kania, N., & Gürbüz, F. (2024). Students' Proficiency in Computational Thinking Through Constructivist Learning Theory. *International Journal of Mathematics and Mathematics Education*, *2*(1), 45–59. https://doi.org/10.56855/ijmme.v2i1.963

Aulia, E. S., & Rusli, R. P. (2020). Manfaat Kajian Bibliometrik Sebagai Penunjang Analisis Kebutuhan Kurikulum Program Studi Ilmu Perpustakaan dan Informasi. *Inovasi Kurikulum*, *17*(2), 59–68. https://doi.org/10.17509/jik.v17i2.36827

Aytekin, A., & Topcu, M. S. (2024). Improving 6th Grade Students' Creative Problem Solving Skills Through Plugged and Unplugged Computational Thinking Approaches. *Journal of Science Education and Technology*, *33*(6), 867–891. https://doi.org/10.1007/s10956-024-10130-y

Bruner, J. S. (1961). The act of discovery. *Harvard educational review*.

Cheng, F. F., Huang, Y. W., Tsaih, D. C., & Wu, C. S. (2019). Trend analysis of co-authorship network in Library Hi Tech. *Library Hi Tech*, *37*(1), 43–56. https://doi.org/10.1108/LHT-11-2017-0241

Damayanti, F. N., Lutfitasari, A., Santosa, B., Prakasiwi, S. I., Suparman, & Anggraini, N. N. (2024). Bibliometric Analysis of Research Trends and Novelty of Midwifery Policy. *Africa Journal of Nursing and Midwifery. repository. unimus. ac. id*. https://doi.org/10.25159/2520-5293/14031

DuVal, K. (2006). *The native ground: Indians and colonists in the heart of the continent*. University of Pennsylvania Press.

Ferreira, T. D., Santos, J. S., Araújo Medeiros, R. d., Andrade, W. L., Brunet, J., & Araujo Melo, M. R. (2023). Exploring the Relationship of Mathematical Reasoning and Computational Thinking. In *Workshop de Informática na Escola (WIE* (pp. 583–591). https://doi.org/10.5753/wie.2023.235113

Glänzel, W., & Chi, P. S. (2020). The big challenge of Scientometrics 2.0: exploring the broader impact of scientific research in public health. *Scientometrics*, *125*(2), 1011–1031. https://doi.org/10.1007/s11192-020-03473-x

Grover, S., & Pea, R. (2013). Computational Thinking in K-12. *Educational Researcher*, *42*(1), 38–43. https://doi.org/10.3102/0013189x12463051

Hanid, A., Fadzil, M., Said, H., Nihra, M., Yahaya, N., & Abdullah, Z. (2022). The Elements of Computational Thinking in Learning Geometry by Using Augmented Reality Application. *International Journal of Interactive Mobile Technologies (IJIM*, *16*(02), 28–41. https://doi.org/10.3991/ijim.v16i02.27295

Helsa, Y., Turmudi, & Juandi, D. (2023a). *Computational Thinking dalam Pembelajaran Matematika (Cetakan Pertama*. Deepublish Publisher.

Helsa, Y., Turmudi, & Juandi, D. (2023b). TPACK-based hybrid learning model design for computational thinking skills achievement in mathematics. *Journal on Mathematics Education*, *14*(2), 225–252. https://doi.org/10.22342/jme.v14i2.pp225-252

Herzog, C., Hook, D., & Konkiel, S. (2020). Dimensions: Bringing down barriers between scientometricians and data. *Quantitative Science Studies*, *1*(1), 387–395. https://doi.org/10.1162/qss_a_00020

Hiebert, J., & Carpenter, T. P. (1992). Learning and teaching with understanding.

Huda, N., & Ikhsan, J. (2024). *Computational Thinking Skills: Definisi, Kontroversi, dan Integrasinya dalam Pendidikan* (D. R. P. Cetakan Pertama, S. Khoriyati, & Eds, Eds.). Bumi Aksara.

Hwang, G., & Tu, Y. (2021). Roles and Research Trends of Artificial Intelligence in Mathematics Education: A Bibliometric Mapping Analysis and. *Systematic Review. Mathematics*, *9*(6). https://doi.org/10.3390/math9060584

Kallia, M., Borkulo, S. P., Drijvers, P., Barendsen, E., & Tolboom, J. (2021). Characterising computational thinking in mathematics education: a literature-informed Delphi study. *Research in Mathematics Education*, *23*(2), 159–187. https://doi.org/10.1080/14794802.2020.1852104

Kannadass, P., Hidayat, R., Siregar, P. S., & Husain, A. P. (2023). Relationship Between Computational and Critical Thinking Towards Modelling Competency Among Pre-Service Mathematics Teachers. *Tem Journal*. https://doi.org/10.18421/tem123-17

Kaswar, A. B., & Nurjannah, N. (2024). Keefektifan computational thinking dalam meningkatkan kemampuan pemecahan masalah matematika siswa. *SIGMA: JURNAL PENDIDIKAN MATEMATIKA*, *16*(1), 109–120. https://doi.org/10.26618/sigma.v16i1.14574

Knie, L., Standl, B., & Schwarzer, S. (2022). First experiences of integrating computational thinking into a blended learning in-service training program for STEM teachers. *Computer Applications in Engineering Education*, *30*(5), 1423–1439. https://doi.org/10.1002/cae.22529

Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2020). On Computational Thinking and STEM Education. *Journal for STEM Education Research*, *3*(2), 147–166. https://doi.org/10.1007/s41979-020-00044-w

Maharani, S., Kholid, M. N., Pradana, L. N., & Nusantara, T. (2019). Problem solving in the context of computational thinking. *Infinity Journal*, *8*(2). https://doi.org/10.22460/infinity.v8i2.p109-116

Maharani, S., Susanti, V. D., Andari, T., Krisdiana, I., & Astuti, I. P. (2023). Trend Publication of Computational Thinking in Mathematics Education. *Bibliometric Review. Jipm*. https://doi.org/10.25273/jipm.v12i1.17654

Manullang, S. B., & Simanjuntak, E. (2023). Pengaruh Model Problem Based Learning terhadap Kemampuan Computational Thinking Berbantuan Media Geogebra. *Journal on Education*, *06*(01), 7786–7796.

Mohmad, A. F., & Maat, S. M. (2023). Computational Thinking Activities Among Mathematics Teachers: A Systematic Literature Review. *International Journal of Academic Research in Progressive Education and Development*, *12*(3). https://doi.org/10.6007/IJARPED/v12-i3/18988

OECD. (2016). *What is PISA for Development?* OECD.

Page, M. J., McKenzie, J. E., Bossuyt, P., Boutron, I., Hoffmann, T. C., Mulrow, C. D., & Moher, D. (2021). The prisma 2020 statement: An updated guideline for reporting systematic reviews. *Medicina Fluminensis*, *57*, 444–465. https://doi.org/10.21860/medflum2021_264903

Pajow, M. A., Regar, V. E., & Maukar, M. G. (2024). Hubungan Kemampuan Computational Thinking dan Pemahaman Konsep Matematika Siswa Materi Pola Bilangan. *Kognitif: Jurnal Riset HOTS Pendidikan Matematika*, *4*(1), 544–554. https://doi.org/10.51574/kognitif.v4i1.1661

Park, W., & Kwon, H. (2022). Research Trends and Issues Including Computational Thinking in Science Education and Mathematics Education in the Republic of Korea. *Journal of Baltic Science Education*. https://doi.org/10.33225/jbse/22.21.875

Piaget, J. (1970). Inteligencia y adaptación biológica. *Los procesos de adaptación*, *1*(1), 69-84.

Putri, I. A., Tanjung, M. S., & Siregar, R. (2024). Studi Literatur: Pentingnya Berpikir Komputasional dalam Meningkatkan Kemampuan Pemecahan Masalah Matematis Peserta Didik. *Bilangan: Jurnal Ilmiah Matematika, Kebumian Dan Angkasa*, *2*(2), 23–33. https://doi.org/10.62383/bilangan.v2i2.36

Raman, A., Thannimalai, R., Don, Y., & Rathakrishnan, M. (2021). A Bibliometric Analysis of Blended Learning in Higher Education: Perception. *Achievement and Engagement. International Journal of Learning Teaching and Educational Research*. https://doi.org/10.26803/ijlter.20.6.7

Refvik, K. A. S., & Bjerke, A. H. (2022). Computational thinking as a tool in primary and secondary mathematical problem solving: a literature review. *NOMAD Nordic Studies in Mathematics Education*, *27*(3). https://doi.org/10.7146/nomad.v27i3.149191

Santosa, B., & Damayanti, F. N. (2024). Trends in iron deficiency anemia research 2010-2023: a bibliometric analysis. repository.unimus.ac.id.

Sumarno, F., & Suparman, S. (2024). Pemetaan Tren Global Riset Etnomatematika dalam Pendidikan: Analisis Bibliometrik 2000-2023. *JIPM (Jurnal Ilmiah Pendidikan Matematika*, *13*(1), 1–14. https://doi.org/10.25273/jipm.v13i1.19960

Supiarmo, M. G., Hadi, H. S., & Tarmuzi, T. (2022). Studentâ€TMs Computational Thinking Process in Solving PISA Questions in Terms of Problem Solving Abilities. *JIML) JOURNAL OF INNOVATIVE MATHEMATICS LEARNING*. https://doi.org/10.22460/jiml.v5i1.p01-11

Szomszor, M., Adams, J., Fry, R., Gebert, C., Pendlebury, D. A., Potter, R. W. K., & Rogers, G. (2021). Interpreting Bibliometric Data. *Frontiers in Research Metrics and Analytics*. https://doi.org/10.3389/frma.2020.628703

Tian, S. (2024). The Impact and Reconstruction of Computational Thinking on Educational Models in the Era of Artificial Intelligence. *International Journal of Education and Humanities*, *14*(3), 47–50. https://doi.org/10.54097/e2s41q04

Tupan, T., Rahayu, R. N., Rachmawati, R., & Rahayu, E. S. R. (2018). *Analisis Bibliometrik Perkembangan Penelitian Bidang Ilmu Instrumentasi* (Vol. 39). Jurnal Dokumentasi Dan Informasi. https://doi.org/10.14203/j.baca.v39i2.413

UNESCO. (2018). *Global Education Meeting, Brussels Declaration*. UNESCO.

Wing, J. M. (2008, 2008). *Computational Thinking and Thinking About Computing* Proceedings of IEEE International Symposium on Parallel and Distributed Processing, https://doi.org/10.1109/ipdps.2008.4536091

Wiryasaputra, R., Salomo, A., Sevani, N., & Seruni. (2022). Peningkatan Pola Berpikir Komputasi pada Siswa/i SMAK MATER DEI Melalui Bahasa Pemrograman Java dan Python. *Servirisma*, *2*(2), 127–145. https://doi.org/10.21460/servirisma.2022.22.28

Wufron. (2020). Analisis Regresi Linier dengan IBM SPSS Statistics. *OSFPREPRINTS*, 1–10. https://doi.org/10.31219/osf.io/fwex8

Yadav, A., Hong, H., & Stephenson, C. (2016). Computational Thinking for All: Pedagogical Approaches to Embedding 21st Century Problem Solving in K-12 Classrooms. https://doi.org/10.1007/s11528-016-0087-7

Zakaria, P., Djakaria, I., Amin, R. M., Katili, S., Majid, M., & Maharani, S. (2023). The Relationship Between Computational Thinking and Critical Thinking Disposition in Mathematical Problem Solving: Bibliometric Analysis. *AL-ISHLAH: Jurnal Pendidikan*, *15*(3), 2857–2865. https://doi.org/10.35445/alishlah.v15i3.3162