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Advancing Computational Thinking in Mathematics Education: a Systematic Review of Indonesian Research Landscape

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ABSTRACT

Computational Thinking (CT) has emerged as a crucial and foundational skill in the 21st century, capturing the attention of researchers across various domains, including mathematics education in Indonesia. This research identifies and analyzes trends, themes, focuses, and research findings on CT through mathematics learning in Indonesia. This Systematic Literature Review (SLR) adheres to the PRISMA guidelines, encompassing three stages: search, selection, and data analysis. The search process on the Scopus database, utilizing queries aligned with the research objectives, yielded 31 articles related to CT and mathematics education authored by Indonesian researchers. Subsequent selection involved criteria such as research focus, study type, document availability, and intervention differences, resulting in 14 articles. Data analysis employed Bibliometrix and NVivo 14 Plus software. The findings reveal a significant increase in research on CT in mathematics education from Indonesian researchers over the past two years, with an annual growth rate of 5.74%. This publication landscape involves contributions from 39 authors affiliated with 16 higher education institutions in Indonesia. Researchers have delved into diverse themes, including the analysis of CT skill achievement, the development of CT-oriented instructional models and media, and the creation of assessment tools to measure CT skills. These findings underscore the broad relevance of CT in the realm of mathematics education. As a burgeoning field of study, numerous aspects of CT remain open for further research, development, and exploration, especially those related to mathematics. To enhance the impact and implementation of Computational Thinking (CT) within the context of Indonesian education, future research may consider investigating innovative pedagogical approaches, assessing the long-term impact of CT interventions, and exploring the potential integration of CT across various educational levels.

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A. INTRODUCTION

Computational thinking (CT) has emerged as a critical concept within modern mathematics education, given the technological transformations reshaping the landscape of education and the professional world. Amidst the ever-deepening integration of technology, CT is no longer merely an optional skill; instead, it stands as a fundamental competency that everyone should possess alongside reading, writing, and arithmetic (Weintrop et al., 2021; Wing, 2006, 2017). CT entails the thought process involved in formulating problems and articulating their solutions in a manner that both humans and machines (computers) can effectively undertake (Wing, 2017). Integrating CT into mathematics education goes beyond comprehending algorithms and programming; it encompasses recognizing patterns, formulating problems, and solving intricate mathematical challenges (Drijvers et al., 2009). As such, a deep understanding of the application and evolution of CT in mathematics education becomes an imperative concern within the educational sphere.

As a nation characterized by its distinctive educational and cultural dynamics, Indonesia faces unique challenges and opportunities in fostering and advancing CT through mathematics instruction. As a country with the fourth-highest population in the world, Indonesia grapples with the reality that students' mathematical literacy skills are relatively low (Dewi & Maulida, 2023). Amidst the rapid surge of technological advancement, there exists an imperative to ensure that the integration of CT not only aligns with global trends but also remains contextually pertinent (Yadav et al., 2017). A comprehensive analysis concerning the evolution and research contributions of CT within the realm of mathematics education becomes profoundly essential (Chan et al., 2023; Ye et al., 2023). Gaining a profound understanding of how CT evolves within Indonesia's research landscape will provide invaluable guidance in shaping practical approaches to mathematical instruction. Hence, this is a promising initial step towards realizing Indonesia's more advanced and highly competitive educational landscape.

At present, many systematic literature reviews (SLR) have been conducted on research about CT. These studies encompass diverse areas, including the integration of CT in mathematics instruction (Barcelos et al., 2018; Chan et al., 2023; Irawan & Herman, 2023; Isharyadi & Juandi, 2023; Khoo et al., 2022; Subramaniam et al., 2022; Ye et al., 2023), CT integration through programming (Agbo et al., 2019; Fagerlund et al., 2021; Y. I. Maharani et al., 2023; Montiel & Gomez-Zermeño, 2021; Tikva & Tambouris, 2021; Zhang & Nouri, 2019), CT integration in STEM (science, technology, engineering, and mathematics) education (Braun & Huwer, 2022; I. Lee et al., 2020; Wang et al., 2022), CT integration in primary and secondary education (S. J. Lee et al., 2022; Quiroz-Vallejo et al., 2021, 2021), and CT integration in early childhood education (Bati, 2022; Su & Yang, 2023). Despite the numerous SLRs conducted across various facets of CT, a specific exploration regarding CT in mathematics education within the Indonesian context, particularly utilizing the Scopus database as a primary source, has yet to be found. This situation is inseparable from the limited number of researchers in Indonesia who concentrate on studies related to CT.

Through a comprehensive analysis of various discovered literature, this article aims to uncover trends, themes, focal points, and diverse research findings concerning CT in mathematics education in Indonesia. Anticipate that a profound understanding of this research landscape will offer profound insights into the development and prospects of CT in mathematics education within Indonesia. Specifically, four research questions (RQ) guide the implementation of this systematic review.

RQ1: What are the trends in research related to CT in mathematics education in Indonesia?

RQ2: What themes and research focuses have emerged in Indonesia, particularly those related to CT in mathematics education?

RQ3: Which CT components are the focus of research in Indonesia?

RQ4: What are the primary findings from various research studies concerning CT in mathematics education in Indonesia?

B. METHODS

This study constitutes a systematic literature review (SLR), which aims to dissect many research outcomes concerning CT in mathematics education within Indonesia. The review procedure adheres to the guidelines of the Preferred Reporting Items for Systematic Review (PRISMA) (Page et al., 2021). From a technical standpoint, the execution of the review encompasses the stages of search, selection, and data analysis (Ye et al., 2023).

1. Search Process

The data sources employed for this study consist of the Scopus database, downloaded as of August 17, 2023. Inclusion and exclusion criteria were determined to achieve the research objectives as listed in Table 1. Based on these inclusion criteria, a literature search was conducted within the Scopus database using the query: "TITLE-ABS-KEY ("computational thinking" AND (mathematics OR mathematical)) AND (LIMIT-TO (AFFILCOUNTRY, "Indonesia"))". This query indicates a search for articles containing the terms "computational thinking" and either "mathematics" or "mathematical" appearing within titles, abstracts, or keywords. The search was also specifically restricted to publications authored by individuals affiliated with Indonesia. However, the search was conducted across the entire temporal spectrum without imposing publication date constraints to attain comprehensive data. The search yielded 31 pieces of literature related to CT and mathematics, authored by Indonesian researchers, as depicted in Figure 1.

Table 1. Inclusion and Exclusion Criteria

Indicators	Inclusion	Exclusion
Publication Type	Journal Articles and Proceedings	Books, Book Chapters, Reviews, Conference Reviews, Editorials, Erratum, Notes, and Short Surveys
Database Indexing	Articles indexed in Scopus	Articles not indexed in Scopus
Language	Articles written in English	Articles written in other languages
Author's Country of Origin	Indonesian	Outside Indonesia
Types of Research	Research Studies	Bibliometric analysis, systematic literature review, and meta-analysis
Focus of study	Computational thinking through learning mathematics	Computational thinking unrelated to mathematics
Publication Year	All years published	No exclusion

2. Selection Process

The selection of literature for analysis was guided by the inclusion and exclusion criteria presented in Table 1. The actual process of screening commenced with the search in the Scopus database, entailing the restriction to authors affiliated with Indonesia. Subsequent screening was conducted based on the focus and research type, determined by titles and abstracts. As a result, five articles primarily unrelated to CT were identified, alongside six articles encompassing bibliometric analysis, systematic literature review, and meta-analysis. Following this, the pursuit of complete manuscripts for each publication ensued. Full texts were successfully obtained out of the fifteen articles, while the remaining five could not be located. The subsequent step involved a swift analysis of these full texts, revealing one article as irrelevant due to intervention dissimilarity having no direct relevance to mathematics. Hence, following these several screening stages, fourteen articles were obtained for in-depth analysis, as shown in Figure 1.

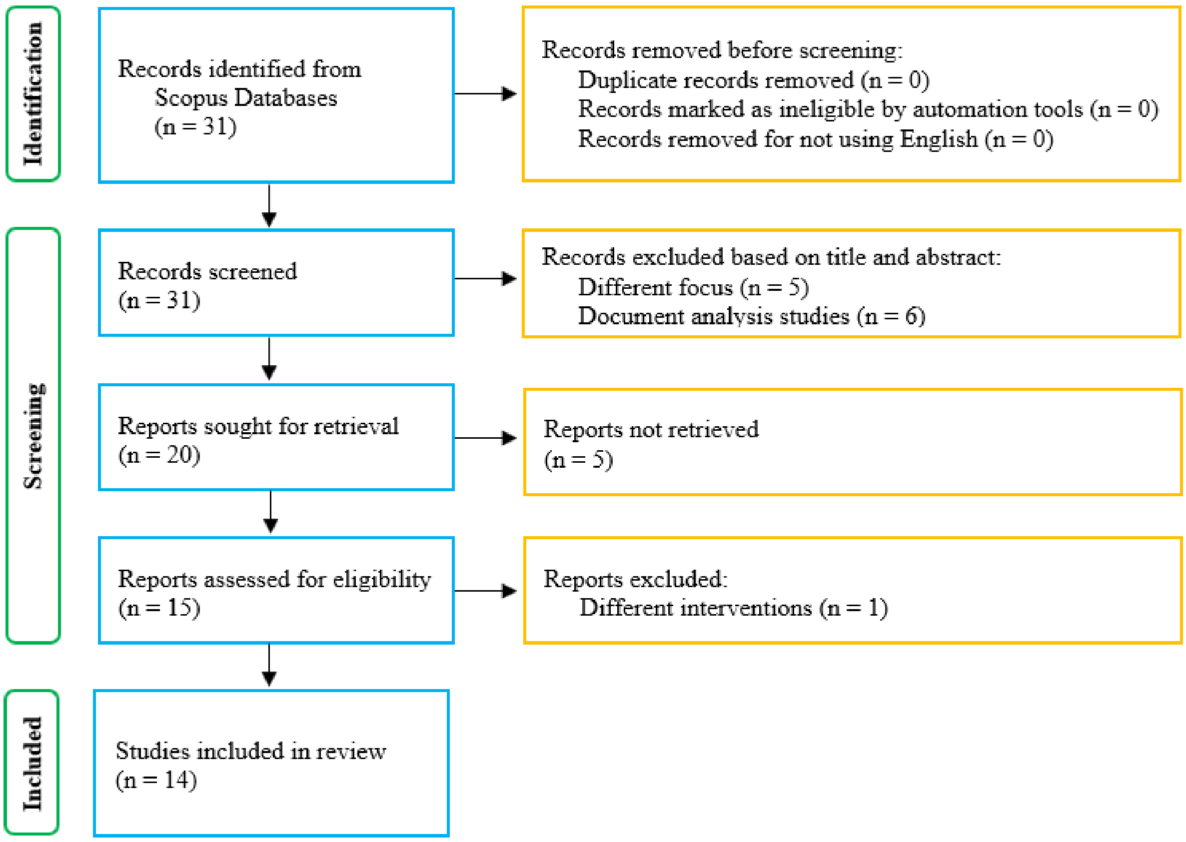


Figure 1. Literature Identification Process Using PRISMA Procedures

3. Data Analysis

This research's data analysis was conducted through quantitative and qualitative approaches. Quantitative analysis was performed using Bibliometrix software, while qualitative analysis was carried out using NVivo 14 Plus software. Bibliometrix is one of the tools used to aid in trend analysis of publications (Aria & Cuccurullo, 2017). In this study, Bibliometrix was employed to unveil essential information concerning publications, encompassing timespan, sources (journals, books, etc.), number of documents, annual growth rate, document average age, average citations per document, number of references, number of authors, number of affiliations, co-authors per document, international co-authorships, number of articles, and number of conference papers. On the other hand, NVivo 14 Plus represents one of the software solutions designed to identify research themes and attributes, simultaneously enabling their visualization per the researchers' needs (Amrutha & Geetha, 2020). A distinct advantage of NVivo 14 Plus lies in its ability to perform automatic theme coding through the

"Autocode Wizard" feature. Of the 14 articles meeting the inclusion criteria, NVivo 14 Plus was employed to subject them to thematic and attribute coding, whether automated or manual. Subsequently, data, coding, and cases were visualized through hierarchy charts, bar charts, and concept maps.

C. RESULTS AND DISCUSSION

1. Results

a. RQ1: Trends in CT Research through Mathematics Education in Indonesia

The outcomes of identifying publications concerning CT in mathematics education, authored by researchers from Indonesia, have been evident since 2019. The research trend spanning five years, from 2019 to 2023, is depicted in Figure 2.

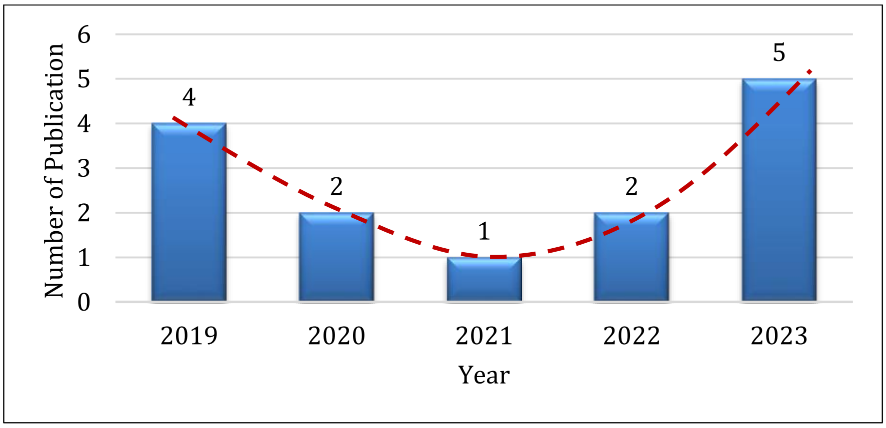


Figure 2. Trend in the Number of CT-Related Publications in Mathematics Learning in Indonesia

Figure 2 illustrates that a total of four articles were produced in the year 2019. However, in 2020 and 2021, there was a decline, with only two and one articles found, respectively. The momentum of publications experienced a resurgence in 2022 with two articles, and up to August 2023, five articles were recorded. These findings indicate an uptick in the development of CT-related research in mathematics education in Indonesia over the past two years. The diverse research outcomes have been disseminated through Scopus-indexed journals and conference papers. At least nine journals and one proceeding have showcased articles authored by Indonesian researchers.

The research trends regarding the integration of Computational Thinking (CT) into mathematics education in Indonesia, especially those published in Scopus-indexed journals, diverge from the global trend, which has shown a significant increase in the last five years (Irawan & Herman, 2023). This discrepancy can be attributed to the limited number of institutions and researchers in mathematics education innovating by incorporating CT into mathematics learning. From 2019 to 2021, research was relatively limited to a specific group responsive to global research trends. Additionally, several CT-related publications by other Indonesian researchers were only disseminated in national and international journals that were not indexed in Scopus. However, in 2023, there was a noteworthy increase in publications. This trend is closely linked to the government's policy of integrating CT into the independent curriculum, implemented in

2022 (Badan Standar, Kurikulum, dan Asesmen Pendidikan Kemendikbudristek, 2022). Further comprehensive insights obtained from the analysis employing Bibliometrix software are presented in Table 2.

Table 2. Main Information Publications Related to CT in Mathematics Learning in Indonesia

Description	Results
Timespan	2019 : 2023
Sources (Journals, Books, etc)	10
Documents	14
Annual Growth Rate	5.74%
Document Average Age	1.79
Average citations per doc	2.143
References	587
Authors	39
Affiliations	16
Co-Authors per Doc	3.79
International co-authorships	7.143%
Article	11
Conference Paper	3

Above, Table 2 provides a wealth of information concerning the trends and progress of CT research within mathematics education in Indonesia. A total of 14 articles generated by researchers from Indonesia between 2019 and 2023 were published across nine journals and one conference paper. These articles have an average age of 1.79 years, with an average of 2.143 citations per article and an annual growth rate of 5.74%. There is a recorded co-authorship average of 3.79 per document, with an international co-authorship percentage of 7.143%. A collective of 39 authors affiliated with 16 Indonesian universities collaboratively produced these diverse articles. The distribution and network of universities and the articles they have generated are depicted in Figure 3.

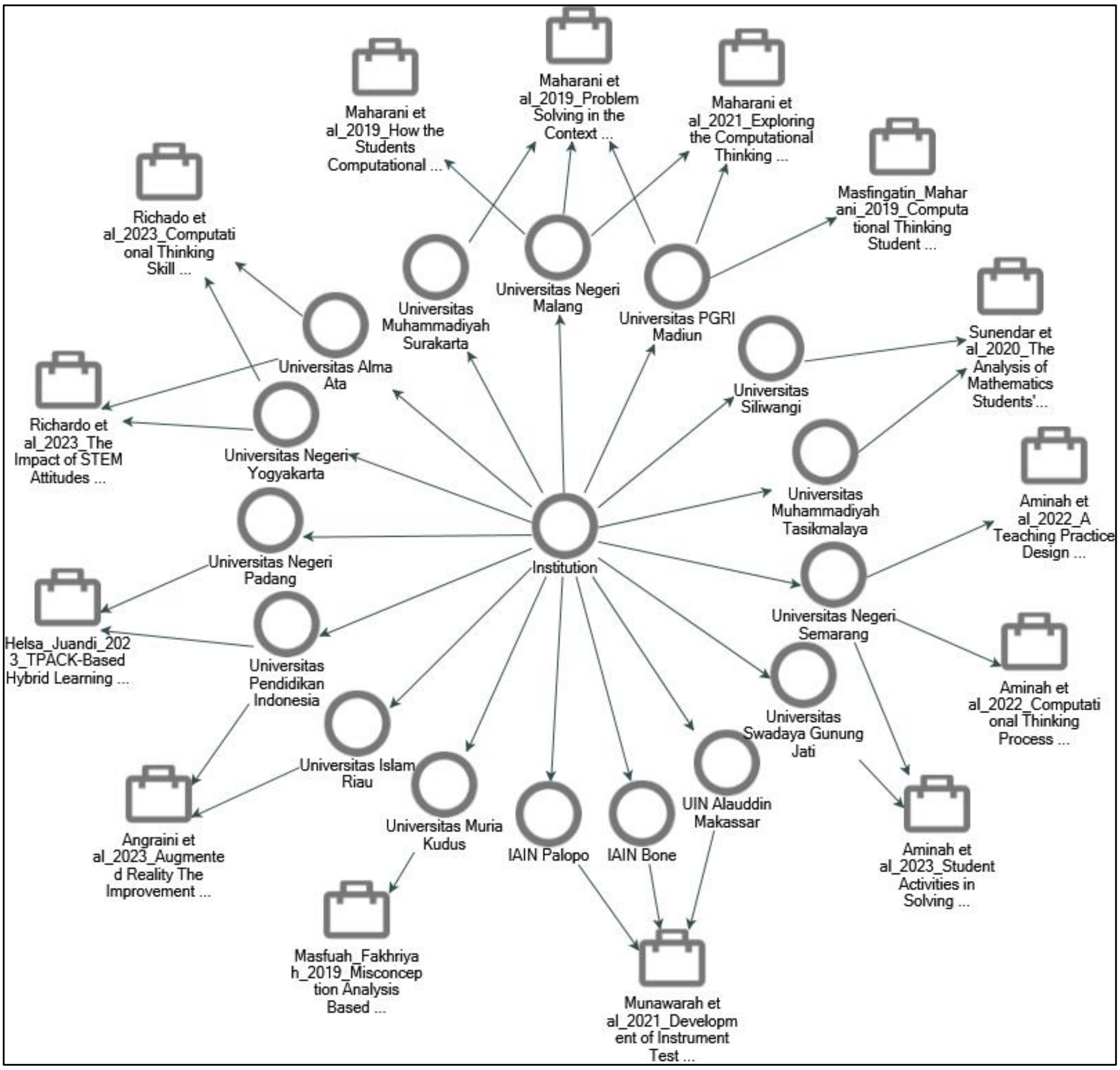
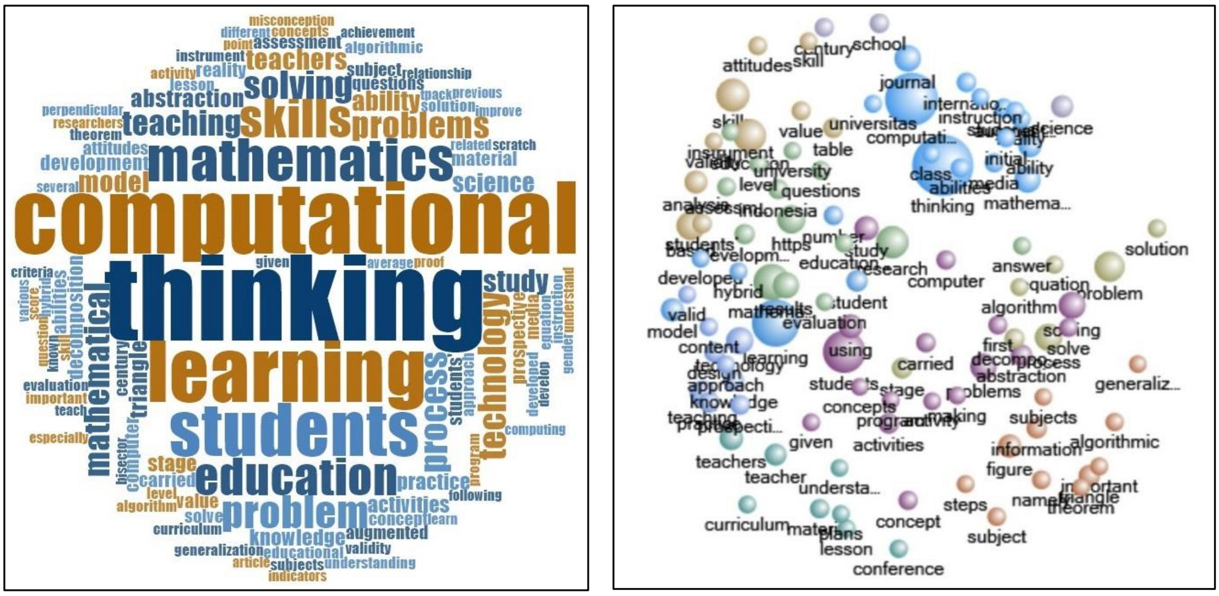


Figure 3. Distribution of Article Publications Based on Author Affiliation

b. RQ2: Themes and Research Focus on CT through Mathematics Education in Indonesia
   Identifying emerging and evolving themes in research related to CT in mathematics education in Indonesia was conducted using the "Word Cloud" feature in NVivo 14 Plus. Additionally, NVivo 14 Plus was employed to facilitate the recognition of various thematic clusters present in the analyzed articles. The outcomes of the word cloud and cluster map identification concerning CT in mathematics education in Indonesia are presented in Figure 4.



(a) (b)

Figure 4. (a) Word Cloud and (b) Cluster Map Research Related to CT in Mathematics Learning in Indonesia

Figure 4 presents keywords encountered in all articles: a word cloud (Figure a) and a cluster map (Figure b). The font size in the word cloud illustrates their occurrence frequency. The more frequently a word appears, the larger it is displayed in Word Cloud above. Meanwhile, the cluster map involves grouping keywords into distinct clusters. The use of the same color indicates identical clusters. Next, the results of identifying various themes using the "Auto Code" feature on NVivo 14 Plus are displayed in Figure 5.

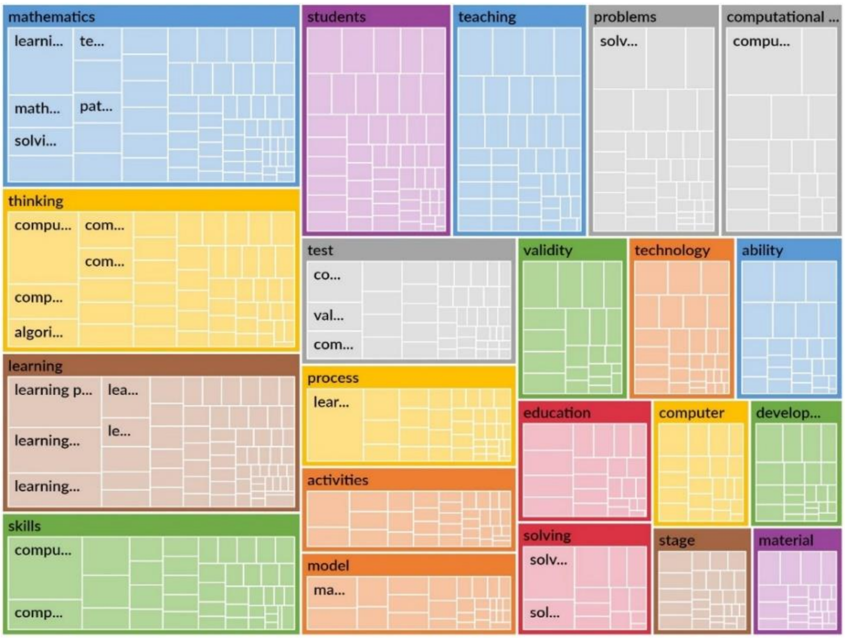


Figure 5. Comparison Between CT-Related Themes in Mathematics Learning in Indonesia

Figure 5 illustrates the presence of at least 21 research topic clusters. These clusters encompass keywords such as mathematics, thinking, learning, skills, students, problems, teaching, test, computational, process, activities, ability, model, technology, validity, education, solving, development, computer, material, and stage. Each cluster comprises several keywords, and the size of each cluster depicts the number of keywords identified from all the articles.

c. RQ3: CT Components in Mathematics Learning in Indonesia

Furthermore, a subsequent identification was conducted on the CT components employed as the focal points in each article. The identification process was performed manually by reading and applying coding to the articles. As a result, eight CT components were identified, as presented in Figure 6.

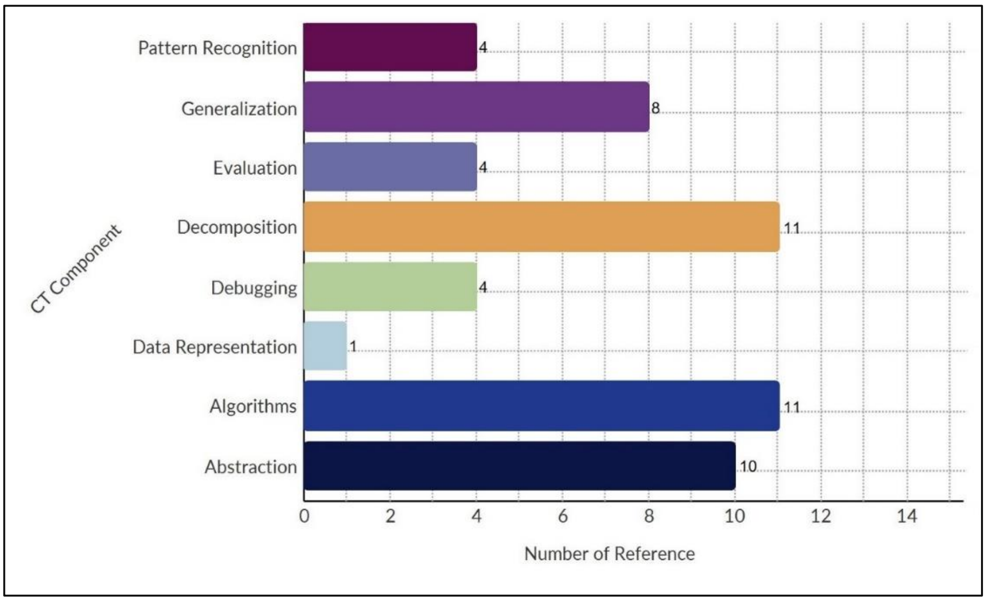


Figure 6. CT Components that are the Focus of Research Studies

Figure 6 presents a list of CT components, the research focus across all the articles, along with their frequencies. Decomposition and algorithm are the most frequently utilized CT components in eleven articles. The subsequent CT component is abstraction, used ten times, followed by generalization, employed eight times. The remaining components, pattern recognition, evaluation, and debugging, appear four times each. Meanwhile, the CT component data representation is used in only one article. The prevalence of employing decomposition, algorithms, and abstraction arises due to their status as pivotal elements constituting CT (Dong et al., 2019). The mapping of CT components with the respective articles that employ them is depicted in Figure 7.

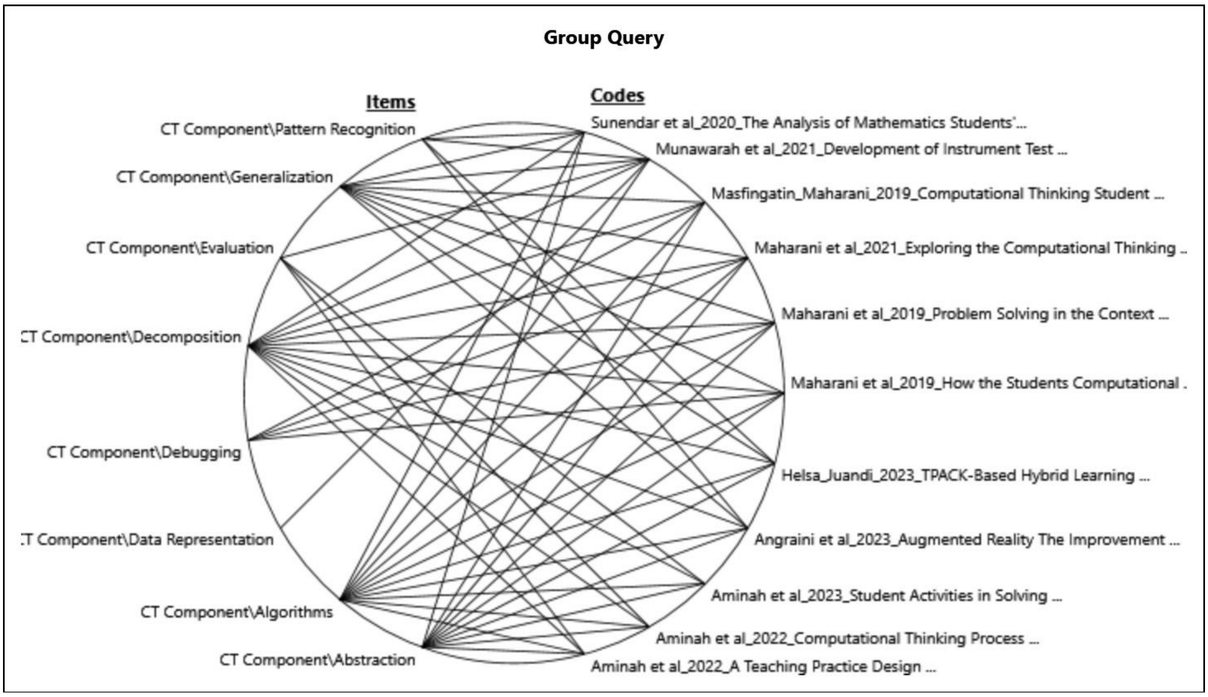


Figure 7. Use of CT Components in Each Article

Figure 7 provides information that each article utilizes four to six CT components. Researchers who employed six CT components include Munawarah et al. (2021). Meanwhile, researchers who employed five CT components include: Sunendar et al. (2020), Masfingatin and Maharani (2019), Angraini et al. (2023), Helsa et al. (2023), Maharani et al. (2021; 2019; 2019), Masfuah and Fakhriyah (2019), and Richardo et al. (2023; 2023). On the other hand, researchers who used four CT components are Aminah et al. (2023; 2022; 2022). This result indicates a significant variation in the CT components that are the focus of CT research in Indonesia's mathematics education. The variation in the selection of these CT components occurs due to the absence of a strict sequence within the selection of these elements, and indeed, each element can be taught independently (Dong et al., 2019).

d. RQ4: Main Research Findings

Through meticulous scrutiny of each article, an exhaustive examination yielded profound insights into the employed methodologies, explored subjects, and fundamental discoveries expounded within each research endeavor. The methodologies employed in the research were systematically classified into three discrete categories: qualitative research, quantitative research, and mixed methods. Research subjects can be grouped into four categories: kindergarten, primary school, secondary school, and higher education. The attributes of authorship, publication year, research approach, research subjects, and principal findings are elegantly presented in Table 3.

Table 3. Main Findings of CT Research in Mathematics Education in Indonesia

No	Authors and Year	Research Approach	Research Subject	Course/Material	Software/ Application	Main Findings
1	Maharani et al. (2019)	Qualitative Approach	Higher Education	Graph	Unplugged	According to Polya, there is a connection between the problem-solving steps and computational thinking. During the problem definition phase, students engage in decomposition and abstraction; in the planning phase, they perform generalization; while executing the plan and evaluating the solution, students employ debugging and algorithmic thinking.
2	Maharani et al. (2019)	Qualitative Approach	Higher Education	Algebra	Unplugged	The utilization of computational thinking in solving algebra-related problems begins with abstraction, followed by decomposition generalization, and concludes with algorithmic thinking.
3	Masfingatin and Maharani (2019)	Qualitative Approach	Higher Education	Geometry	Unplugged	The stages of computational thinking utilized by male students in proving geometric theorems start with decomposition, abstraction, generalization, algorithmic thinking, and debugging. For female students, the CT stages initiate with decomposition, abstraction, debugging, and generalization and conclude with algorithmic thinking.
4	Masfuah and Fakhriyah (2019)	Quantitative Approach	Higher Education	STEM	Unplugged	Students' computational thinking lies within the algorithmic stage, and misconceptions arise regarding motion systems. These misconceptions are attributed to textbooks, lecturer explanations, mathematical calculations, formulas, graphical interpretations, peer influence, and everyday experiences.
5	Sunendar et al. (2020)	Qualitative Approach	Higher Education	Mathematics Modeling	Unplugged	A mathematical modeling course effectively enhances the computational thinking abilities of prospective teachers, both in problem decomposition, pattern recognition, abstraction, and creating accurate algorithms to solve real-world problems.
6	Maharani et al. (2021)	Qualitative Approach	Higher Education	Mathematics Lesson Plans	Unplugged	Pre-service teachers' computational thinking skills in lesson planning can be categorized into four groups: Full CT, Partial CT, Incomplete CT, and Non-CT.

No	Authors and Year	Research Approach	Research Subject	Course/Material	Software/ Application	Main Findings
7	Munawarah et al. (2021)	Qualitative Approach	Secondary School	Mathematics	Unplugged	Only two out of 102 students demonstrated high-level computational thinking skills. Most other students displayed good, moderate, low, and feeble CT skills.
8	Aminah et al. (2022)	Mixed Methods	Higher Education	Micro-Teaching	Geogebra, Math Labs, Scratch, SPSS, MathCityMap, Microsoft Math, Point Learning, and Math Expert	A teaching practice design based on a computational thinking approach using Ed-Tech Apps has a positive impact on the knowledge and creativity of prospective teachers in preparing teaching practices during the pandemic, evident in planning, core activities, and evaluation steps.
9	Aminah et al. (2022)	Qualitative Approach	Higher Education	Linear Diophantine Equations	Unplugged	Prospective teachers who successfully solved Diophantine linear equation problems utilized CT components such as reflective abstraction, algorithmic thinking, decomposition, and evaluation.
10	Aminah et al. (2023)	Mixed Methods	Secondary School	Mathematics	Scratch	CT concepts encompassing abstraction, algorithmic thinking, decomposition, and evaluation influence students' mathematical problem-solving abilities.
11	Angraini et al. (2023)	Quantitative Approach	Secondary School	Flat Shapes (Triangles and Quadrilaterals)	Unity 3D	Augmented reality media with Unity 3D can enhance students' mathematical CT abilities, especially for those with lower initial mathematical proficiency levels.
12	Helsa et al. (2023)	Qualitative Approach	Higher Education	Mathematics	Microsoft Excel, Unity, R Studio, Scratch	Around 21.9% of students achieved moderate-level CT skills, 6.3% achieved low-level skills, and a total of 71.9% of students were classified as having very low CT proficiency.
13	Richardo et al. (2023)	Quantitative Approach	Secondary School	STEM	Robotic Coding	A positive STEM attitude positively affects computational thinking, and computational thinking, in turn, positively impacts 21st-century skills.
14	Richardo et al. (2023)	Quantitative Approach	Primary School	Mathematics	Unplugged	Using CT skills to solve mathematical problems among female students is more effective than for male students. CT attitudes among male and female students show no significant differences. Nevertheless, CT attitudes significantly influence CT skills.

Table 3 furnishes insights concerning the methodologies employed, research subjects, and principal findings. The preeminent research approach employed is qualitative. To be precise, eight studies employ a qualitative approach; four embrace a quantitative approach and the remaining two employ mixed methods. The selected research subjects manifest a discernible diversity, with a pronounced emphasis on higher education. Nine articles focalize their research subjects within the domain of higher education. The remainder encompasses four articles that delve into research subjects at the secondary school level, while one article investigates research subjects at the primary school level. The spectrum of research approaches and subjects concomitates a commensurate diversity in the key findings. Another significant revelation pertains to the principal findings from diverse studies concerning CT within Indonesia's mathematics education context. The preponderance of research is centered on scrutinizing the analysis of CT skills among students and learners, particularly among prospective teacher candidates. The covered subjects span various domains, encompassing linear equations, algebra, and geometry. Furthermore, there are endeavors to conceive pedagogical media with a CT orientation, fostering students' cognitive abilities. Ed-Tech Applications and augmented reality utilizing Unity 3D are prominent tools within this ambit. Moreover, extending beyond media integration, certain studies are dedicated to devising instructional models underpinned by CT principles. Concurrently, other scholars focus on identifying factors that theoretically impact students' CT skills. Additionally, research endeavors are channeled into creating instruments to assess CT proficiencies comprehensively.

2. Discussion

a. Discussion of Findings

For RQ1 (trends in research related to CT in mathematics education in Indonesia) we found that CT-related research in mathematics education in Indonesia has significantly increased over the past two years. Although the first articles were found in 2019, there was a decrease in publication count over the following two years. It was not until 2022 and 2023 that a significant increase occurred. These findings align with other research indicating a significant increase in CT-related studies since 2013 (Chen et al., 2023; Tekdal, 2021). However, compared to several other countries, the development of CT research in Indonesia still lags both in terms of time and quantity.

Various studies on CT in mathematics education in Indonesia have been published in various journals and Scopus-indexed conference papers. The success of several articles published in Scopus-indexed journals suggests significant potential and opportunities for Indonesian researchers and authors to contribute to the global advancement of CT studies. The collaborative authorship involving multiple authors from different universities indicates that the study of CT in mathematics education in Indonesia is growing uniformly and not dominated by just one or two institutions. This finding aligns with Grover's (2022) conclusion that the idea of CT is becoming an integral part of mainstream awareness. Therefore, it draws interest from diverse individuals to study, develop, and research further.

For RQ2 (themes and research focuses have emerged in Indonesia, particularly those related to CT in mathematics education) we found that the themes and focuses of research are diverse, broad, and distributed across several clusters and theme groups. Emerging themes include mathematics, thinking, learning, skills, students, problems, teaching, test, computational, process, activities, ability, model, technology, validity, education, solving, development, computer, material, and stage. These findings indicate that CT research has an extensive scope. As a newly emerging field, the definition of CT varies widely among researchers (Cansu & Cansu, 2019). Therefore, the aspects of CT that can be explored further are still extensive.

For RQ3 (CT components are the focus of research in Indonesia) we found that eight CT components were targeted in the research, including decomposition, algorithm, abstraction, generalization, pattern recognition, evaluation, debugging, and data representation. This finding aligns with some previous research that identified varied CT components. Abstraction, decomposition, and algorithm are CT components also used by Wing (2006, 2008), Grover and Pea (2013), Dong et al. (2019), Angeli and Giannakos (2020), and Grover (2022). Generalization is a CT component also used by Wing (2006, 2008), Angeli and Giannakos (2020), and Grover (2022). Pattern recognition is a CT component also used by Dong et al. (2019) and Grover (2022). Debugging is a CT component that Angeli and Giannakos (2020) also use. Lastly, data representation is a CT component (Grover, 2022). The variation in components used in research is closely related to the primary references chosen as support by each researcher.

For RQ4 (primary findings from various research studies concerning CT in mathematics education in Indonesia) we found that five main categories of findings from these various studies. *First*, research that analyzes students' CT skill achievements. Such research includes the analysis of CT abilities in prospective mathematics teacher students (Aminah et al., 2023; S. Maharani et al., 2021; S. Maharani, Kholid, et al., 2019; Sunendar et al., 2020), analysis of misconceptions based on CT test results (Masfuah & Fakhriyah, 2019), and analysis of CT abilities based on problem-solving processes in linear equation (Aminah, Leonardus, et al., 2022), algebra (S. Maharani, Nusantara, et al., 2019), and geometry (Masfingatin & Maharani, 2019). *Second*, research that develops media to introduce and enhance students' CT. These interventions include the utilization of Ed-Tech Apps (Aminah, Sukestiyamo, et al., 2022) and using augmented reality with Unity 3D (Angraini et al., 2023). *Third*, research that develops CT-oriented teaching models. Such research includes the development of a hybrid TPACK-based model (Helsa et al., 2023). *Fourth*, research examines various factors' impact on students' CT skills. This research includes examining the impact of STEM education on CT (Richardo, Dwiningrum, Wijaya, et al., 2023) and the impact of gender on CT (Richardo, Dwiningrum, & Wijaya, 2023). *Fifth*, research that seeks to develop instruments for measuring CT skills. This research develops a CT test using the realistic mathematics education approach (Munawarah et al., 2021). These five findings indicate the broad scope of CT studies researchers can conduct.

b. Limitations and Future Work

Despite comprehensively exploring the trends, themes, and main findings of CT-related research in mathematics education in Indonesia, this research has at least three limitations. *First*, this research is limited in terms of the data sources of the analyzed articles, which only originate from the Scopus database. *Second*, this research is limited to articles produced by researchers affiliated with Indonesian universities. *Third*, the review was conducted only on articles about mathematics-related CT. These limitations provide opportunities for further research that is more comprehensive.

Regarding future work, we will conduct further Systematic Literature Review (SLR) and meta-analysis to compare the effectiveness of various approaches and software utilization to promote and develop Computational Thinking (CT). Subsequent research should also be expanded to encompass broader data sources for deeper insights. Additionally, we intend to devise a didactic design for integrating CT into mathematics education tailored to the needs of learners. This design will then need implementation to gather information concerning the CT acquisition process among mathematics students. Consequently, researchers can conduct further studies to examine how CT integration impacts mathematics learning and individual achievement.

D. CONCLUSION AND SUGGESTIONS

Studies related to Computational Thinking (CT) in mathematics education in Indonesia have experienced growth over the past two years, with an annual growth rate of 5.74%. The publications involved 39 authors from 16 higher education institutions in Indonesia. While lagging behind some other countries in terms of publication volume, research outcomes by Indonesian authors have gained international recognition through journal publications and Scopus-indexed conference papers. The diverse range of research themes aligns with the evolving nature of CT as a burgeoning field. There are eight frequently utilized CT components by Indonesian CT researchers: decomposition, algorithm, abstraction, generalization, pattern recognition, evaluation, debugging, and data representation. In general, existing research explores students' CT abilities, compares CT skills across groups, develops CT-oriented models and instructional media, and designs assessment instruments to measure CT abilities. These findings reflect the ongoing development of CT as a field significantly impacting mathematics education.

Several suggestions can be provided in light of these conclusions. *Firstly*, there is a need for enhanced collaboration among researchers in the field of CT and its integration with mathematics education to accelerate growth and amplify global impact, fostering domestic and international collaboration. *Secondly*, design research incorporating various expertise areas, such as mathematics education, computer science, and educational psychology, is essential. *Lastly*, there is a call for an increased frequency of national seminars and workshops focused on CT, aiming to facilitate the exchange of ideas and experiences among researchers. These three endeavors will contribute to the augmentation of the quantity and quality of research on the integration of CT, mainly through mathematics education in Indonesia, and broaden its influence within the global community.

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