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Computational thinking in mathematics education: A systematic review of research trends and pedagogical implementations

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Abstract
Although computational thinking has become a key competency in mathematics education, a comprehensive understanding of research trends in this field remains limited. This study examines research trends on computational thinking in mathematics education published between 2019 and 2024. A Systematic Literature Review (SLR) was conducted using qualitative studies retrieved through systematic searches in the Scopus bibliographic database and the Google Scholar academic search engine. The review followed predefined inclusion criteria and the PRISMA protocol. The analysis examined publication year, research design, educational level, research location, mathematical topics, instructional models, and computational thinking indicators. The findings show that publications increased substantially between 2021 and 2023, peaking in 2023 (48%). Most studies employed qualitative methods (56%), focused on junior high schools (44%), and investigated number patterns and two-variable linear systems of equations. Problem-Based Learning and Project-Based Learning were the dominant instructional models, while decomposition, pattern recognition, abstraction, and algorithmic thinking were the most frequently examined indicators of computational thinking. These findings provide an updated synthesis of current research trends and offer valuable references for future research and instructional development in mathematics education.

Keywords: computational thinking; mathematics education; systematic literature review

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I. Introduction

Serving as a universal medium that outlines patterns, structures, and relationships, mathematics is crucial for driving scientific and technological progress. In addition to its conceptual significance, this discipline provides people with the practical skills needed to tackle daily challenges. According to Cockcroft (1982), the ability to function successfully in today's world relies heavily on mathematics, highlighting the critical need for robust mathematical proficiency amidst rapid technological advancements.

The rapid advancement of science and technology has transformed the competencies required in the twenty-first century. Educational systems are therefore expected to develop essential skills such as communication, collaboration, critical thinking, creativity, and problem solving (Widodo & Wardani, 2020). Mathematics plays a central role in fostering these competencies by developing logical reasoning and analytical thinking that support learning across disciplines (Siagian, 2016).

Despite the importance of mathematics, Indonesian students continue to demonstrate relatively low achievement in international assessments (Ansori, 2020). According to the OECD (2023), although Indonesia's PISA 2022 ranking improved compared with 2018, the average mathematics score declined to 366, indicating that most students remain at Level 1 proficiency. These findings suggest that Indonesian students still face substantial challenges in developing higher-order mathematical competencies required to compete in an increasingly technology-driven world.

The mathematics performance of Indonesian students in the Program for International Student Assessment (PISA) remains below the OECD average, indicating persistent challenges in mathematical literacy (OECD, 2023). Consistent with these findings, several studies conducted in Indonesia have reported that students' mathematical problem-solving abilities are still relatively low (Mawardi, Arjudin, Turmuzi, & Azmi, 2022; Rizki, Prayitno, Hikmah, & Turmuzi, 2021; Utami & Wutsqa, 2017; Ratna & Yahya, 2022). These studies suggest that students often experience difficulties in understanding mathematical concepts and selecting appropriate solution strategies, resulting in errors during the problem-solving process (Rizki et al., 2021).

Improving students' problem-solving abilities requires higher-order thinking skills that enable them to analyze problems, recognize patterns, and develop effective solution strategies. One approach increasingly adopted to support these skills is computational thinking (Anggriani, 2023). Computational thinking is a problem-solving approach rooted in computer science that involves decomposition, pattern recognition, abstraction, and algorithmic thinking to generate logical, efficient, and effective solutions (Megawati, Sholihah, & Limiansih, 2023). Beyond computer science, computational thinking has become an essential competency for developing logical reasoning, mathematical thinking, and digital literacy, while also fostering positive dispositions such as confidence, openness, and collaboration (Kalelioğlu, 2018). Consequently, it is widely recognized as a fundamental 21st-century skill that students should master (Ansori, 2020; Doleck, Bazelais, Lemay, Saxena, & Basnet, 2017)

The importance of computational thinking is further reflected in the OECD PISA 2022 Mathematics Framework, which emphasizes it as an integral component of mathematical literacy and mathematical problem-solving in technology-rich environments. The framework highlights the need for students to integrate mathematical and computational thinking when solving complex real-world problems, underscoring the importance of strengthening computational thinking skills to prepare students for the demands of the digital era (OECD, 2023).

Initially conceptualized by Wing (2006), computational thinking is a problem-solving methodology that uses foundational computer science principles to develop efficient, structured solutions. While it originally emerged in the computing domain, this approach is now widely regarded as a versatile cognitive ability spanning multiple fields. According to Barr and Stephenson (2011), its applicability extends far beyond computer science, significantly enhancing educational outcomes across different subjects. Furthermore, as highlighted by Maharani, Nusantara, As'ari, & Qoha (2020), this mindset is no longer exclusive to tech professionals but is a crucial, universal skill for all students, underscoring the need to embed it in modern educational curricula.

Computational thinking, first introduced by Jeannette Wing, is a problem-solving process that applies fundamental concepts from computer science to formulate effective, systematic solutions (Wing, 2006). Although initially associated with computer science, computational thinking has gradually been recognized as a transferable cognitive skill applicable across various disciplines. Barr & Stephenson (2011) argue that computational thinking is relevant beyond computing and can support learning in diverse subject areas. Likewise, Wing emphasizes that computational thinking is a fundamental competency for all learners, not a skill limited to computer scientists, underscoring the importance of integrating it into school curricula (Maharani et al., 2020).

In mathematics education, computational thinking provides a structured approach that supports students in analyzing mathematical problems, identifying patterns, constructing abstractions, and developing logical solution procedures. Consequently, the integration of computational thinking not only strengthens mathematical problem-solving skills but also cultivates positive learning dispositions, including self-confidence, perseverance in solving challenging problems, the ability to cope with ambiguity and open-ended tasks, collaborative problem solving, and awareness of individual strengths and limitations when working with others (Barr & Stephenson, 2011). The growing recognition of these benefits has positioned computational thinking as an essential component of mathematics education and influenced international educational policies and assessment frameworks, including the OECD's PISA.

Prior studies have extensively investigated computational thinking in mathematics education (Doleck et al., 2017; Zahid, 2020; Augie, Fatimah, & Prabawanto, 2023; Megawati et al., 2023; Silvia, Pramasdyahsari, & Nizaruddin, 2023; Mukhibin & Juandi, 2023). These studies have contributed substantially to the understanding of computational thinking by examining its implementation, students' computational thinking abilities, learning models, instructional media, and learning outcomes across various educational contexts.

However, despite the growing body of literature, a comprehensive synthesis of recent research trends in computational thinking within mathematics education remains limited. Existing review studies have generally focused on particular aspects, such as instructional implementation or learning outcomes, rather than providing an integrated overview of publication trends and research characteristics. Moreover, limited attention has been paid to the simultaneous examination of publication year, research design, publication sources, educational levels, research locations, mathematical topics, instructional models, and computational thinking indicators in a single review. Such a synthesis is important for identifying current research patterns, revealing underexplored areas, and providing evidence-based directions for future research and instructional practice. Although this review was designed without geographical restrictions, the final dataset was dominated by studies conducted in Indonesia, reflecting the characteristics of the available literature rather than an intended national focus.

To address these gaps, this study conducts a Systematic Literature Review (SLR) of studies published between 2019 and 2024. Unlike previous reviews, this study provides a comprehensive synthesis of publication trends and pedagogical characteristics of computational thinking research in mathematics education by analyzing publication year, research design, publication source, educational level, research location, mathematical topics, instructional models, and computational thinking indicators. Accordingly, this study addresses the following research questions:

1. What are the publication trends and research characteristics of computational thinking studies in mathematics education between 2019 and 2024 in terms of publication year, research design, publication source, educational level, research location, sample characteristics, and mathematical topics?

2. Which instructional models, approaches, and methods have been employed to facilitate computational thinking in mathematics education across different educational levels?
3. Which computational thinking indicators are most frequently adopted in mathematics education research?

Thus, this research aims to describe the results of research regarding the ability of computational mathematical thinking in mathematics learning based on the criteria of year of research, type of research, journal index, sample size, place of research, level of study, research material, learning model used, indicators or aspects of Computational ability, and the most relevant thinking used in mathematics learning.

II. Research Methods

Research design

This study employed a Systematic Literature Review (SLR) to systematically identify, evaluate, and synthesize research on computational thinking in mathematics education. According to Snyder (2019), a literature review is a research methodology that systematically integrates existing knowledge to develop a comprehensive understanding of a particular research field and identify directions for future studies. More specifically, Kitchenham & Charters (2007) define an SLR as a rigorous review method that identifies, critically evaluates, and synthesizes relevant studies using transparent and reproducible procedures to answer predefined research questions.

The SLR approach was considered appropriate for this study because the objective was not to evaluate the effectiveness of a specific intervention but to provide a comprehensive synthesis of recent research trends in computational thinking in mathematics education. Specifically, this review examines publication trends, research characteristics, instructional models, mathematical topics, educational levels, research locations, and computational thinking indicators reported in studies published between 2019 and 2024. By applying a systematic and transparent review process, the study minimizes selection bias while providing a reliable overview of the current state of research in this field (Kitchenham & Charters, 2007).

To ensure methodological transparency and consistency, the review process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines proposed by Moher et al. (2009). PRISMA provides a structured framework for identifying, screening, assessing eligibility, and selecting relevant studies, thereby enhancing the transparency, reproducibility, and credibility of systematic review findings.

Inclusion criteria

To ensure that the selected studies were relevant to the research objectives, the following inclusion criteria were established: (1) Only studies published between 2019 and 2024 were considered because this period captures recent developments in computational thinking research following its increasing recognition in mathematics education and its inclusion in the OECD PISA 2022 framework; (2) The publication was a peer-reviewed journal article; (3) The article was retrieved through systematic searches in the Scopus bibliographic database and the Google Scholar academic search engine; (4) The study focused on computational thinking in mathematics education; (5) The article was published in English or Indonesian; (6) The study involved participants from primary school to university level; (7) The article reported sufficient information on the research design, educational level, research location, mathematical topic, and computational thinking indicators to support the review objectives.

Review Protocol

To systematically review the literature, this study utilized the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. As outlined by Moher et al. (2009), PRISMA provides a rigorous, evidence-based framework that ensures the accuracy and reliability of systematic review findings. The analysis specifically used empirical data extracted solely from published academic journals to address the defined research questions. By adopting this protocol, the study successfully mitigates potential bias while maintaining a highly organized and transparent reporting standard.

Study Selection

Studies were identified through systematic searches of the Scopus bibliographic database and the Google Scholar academic search engine, based on predefined inclusion and exclusion criteria. Study selection followed the PRISMA framework, consisting of four stages: identification, screening, eligibility assessment, and inclusion. The complete selection process is presented in Figure 1.

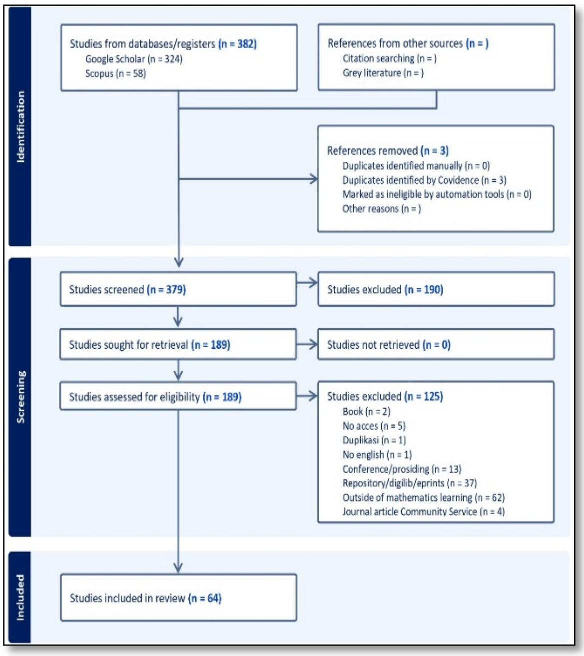

Figure 1. PRISMA protocol diagram

As illustrated in Figure 1, the initial search yielded 382 records, comprising 324 records retrieved from Google Scholar and 58 records from the Scopus database. After removing three duplicate records, 379 studies remained for title and abstract screening. During this stage, 190 studies were excluded because they did not satisfy the predefined inclusion criteria. The remaining 189 full-text articles were subsequently assessed for eligibility.

During the eligibility assessment, 125 studies were excluded for predefined reasons, including publication type (books, conference proceedings, repositories, and preprints), inaccessible full texts, studies conducted outside the scope of mathematics education, and articles that did not provide sufficient information required for data extraction. Following this selection process, 64 peer-reviewed journal articles met all inclusion criteria and were included in the final review.

The final dataset comprised articles published in Indonesian and English. Although the review imposed no geographical restrictions during the literature search, most of the included studies were conducted in Indonesia, reflecting the current distribution of research on computational thinking in mathematics education during the review period. These studies constituted the evidence base for addressing the research questions and conducting the descriptive synthesis.

III. Results and Discussion

Analysis of research characteristics

The characteristics of studies examining computational thinking skills in mathematics education were analyzed based on several aspects, including publication year, research design, journal indexing, educational level, research location, and learning materials, as presented in Table 1.

Table 1. Research data based on criteria

Characteristics	Criteria	Frequency
Year of research	2019	1
	2020	2
	2021	8
	2022	16
	2023	31
	2024	6
Types of research	Qualitative Research	36
	Quantitative Research	17
	Development Research	9
	Mixed Research	1

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	Classroom action research	1
Journal index	Scopus	1
	Copernicus	3
	Internasional	2
	Sinta 1	1
	Sinta 2	7
	Sinta 3	16
	Sinta 4	19
	Sinta 5	9
	Sinta 6	0
	Not accredited	6
Educational level	SD	14
	SMP	28
	SMA	14
	College	8
Research location	Aceh	1
	Bali	1
	Banten	2
	Jakarta	2
	Jambi	1
	Jawa barat	11
	Jawa Tengah	7
	Jawa timur	16
	Kalimantan	1
	Maluku Utara	2
	Riau	7
	Sulawesi Selatan	1
	Sumatera barat	1
	Sumatera Selatan	1
	Sumatera Utara	5
	Yogyakarta	4
	Not mentioned	1
Research material	Algebra	1
	Social arithmetic	1
	Two-dimentional figure	2
	Geometry	2
	Sequence and series	4
	Fractional numbers	1
	Lines and angles	1
	Geometry	4
	Graph	1
	Opportunity	1
	Measurement	1
	Addition of numbers	1
	Comparison	3
	Comparison of numbers	1
	Quadratic equation	2
	One variable linear equation	1
	Number patterns	7
	Binomial probability	1
	Linear programming	1
	Pythagorean Theorem	1
	System of linear equations in two variables	5
	Systems of Linear Equations in Three Variables	2
	Statistics	1
	Algebraic structure	2
	Number theory	1
	Not mentioned	14

Studies Based on Research Year

The studies used as data for this research were published between 2019 and 2024. Details of the distribution of primary studies from 2019 to 2024 are presented in Figure 2 below.

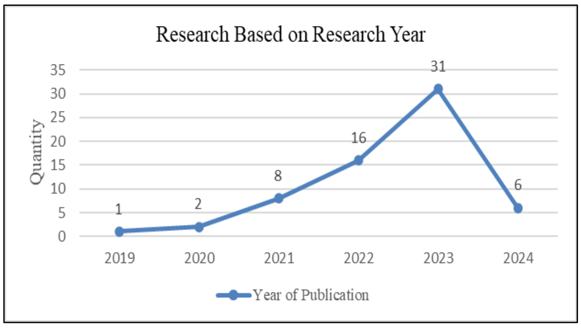

Figure 2. Distribution of studies by publication year

Based on Figure 2, the number of studies addressing computational thinking in mathematics learning published between 2019 and 2024 shows a generally upward trend. The highest number of publications appeared in 2023, while only a limited number of studies were published in 2019 and 2020. However, in 2024, the number of publications on this topic declined by 80.6% compared with the previous year.

Studies Based on Research Type

The distribution of studies on computational thinking in mathematics learning, by research design, is illustrated in Figure 3.

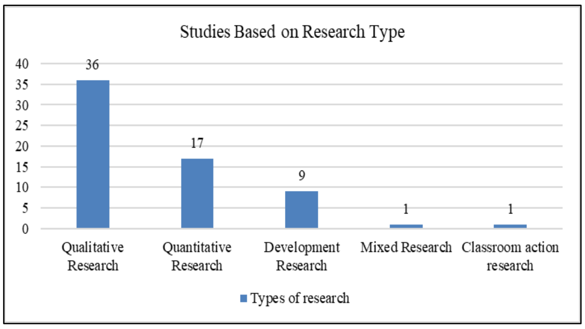

Figure 3. Distribution of studies by research type

Based on Figure 3, studies on computational thinking in mathematics learning are predominantly conducted using qualitative methods, accounting for 56% of publications. In contrast, mixed-methods research and classroom action research (CAR) are still relatively limited. This condition indicates potential opportunities for future researchers to explore computational thinking in mathematics education using mixed-methods and CAR approaches.

Studies Based on Journal Indexers

The distribution of studies on computational thinking in mathematics learning, by journal indexing, is illustrated in Figure 4.

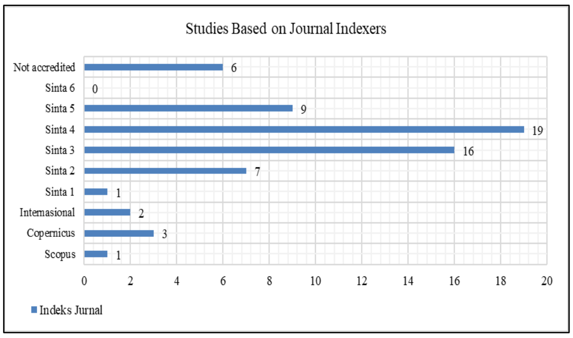

Figure 4. Distribution of studies by journal index

Figure 4 presents the distribution of publications according to their publication sources. Most studies were published in nationally accredited Indonesian journals, particularly those classified as SINTA 3 (16 articles), SINTA 4 (19 articles), SINTA 5 (9 articles), and SINTA 2 (7 articles). A smaller number of studies appeared in SINTA 1 (1 article), while six articles were published in non-accredited journals. Internationally, only a limited number of studies were published in Scopus-indexed journals (1 article), other international journals (2 articles), and Copernicus-indexed journals (3 articles).

The distribution of publication sources does not indicate differences in research quality; rather, it provides an overview of where research on computational thinking in mathematics education has predominantly been disseminated during the review period. The predominance of nationally accredited journals suggests that this research area is actively developing within the Indonesian academic community, whereas its representation in internationally indexed journals remains relatively limited. Consequently, the findings should be interpreted with consideration of the publication profile of the available literature included in this review.

Study Based on Education Level

The distribution of studies on computational thinking in mathematics learning by educational level is shown in Figure 5.

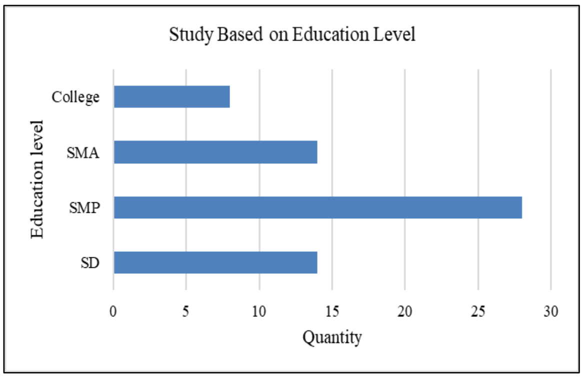

Figure 5. Distribution of studies by educational level

Based on Figure 5, the distribution of studies on computational thinking in mathematics learning varies across different educational levels. The majority of studies were conducted at the junior high school (SMP) level (28 studies), indicating that this level has received the greatest attention from researchers. In contrast, studies conducted at the elementary school (SD) and senior high school (SMA) levels show a similar pattern, each accounting for 14 studies. Meanwhile, research focusing on the college or

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university level is relatively limited, with only 8 studies identified. These findings suggest that research on computational thinking in mathematics education is predominantly concentrated at the junior high school level, while investigations at the elementary, senior high school, and higher education levels remain comparatively fewer.

Study Based on Research Place

Figure 6 illustrates the distribution of studies on computational thinking in mathematics learning by research location.

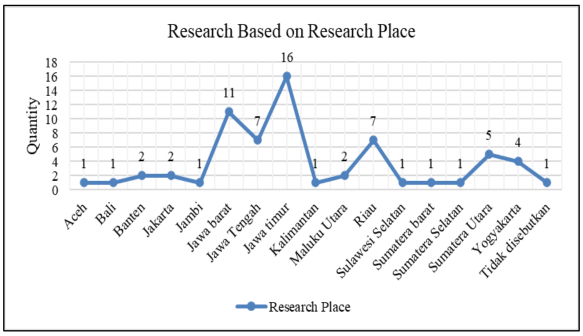

Figure 6. Distribution of studies by research location

Figure 6 presents the geographical distribution of the reviewed studies by research location. Although this review employed an international search strategy using Scopus and Google Scholar, the final dataset was dominated by studies conducted in Indonesia. East Java contributed the highest number of studies (16), followed by West Java (11), Central Java (7), and Riau (7), while only one or two studies were conducted in most other provinces. This finding indicates that research on computational thinking in mathematics education remains geographically concentrated, particularly on Java Island.

The uneven distribution of studies suggests that the current evidence is largely derived from regions with stronger research capacity and educational infrastructure, whereas many provinces remain underrepresented. As a result, the existing literature may not fully capture the diversity of educational contexts across Indonesia. Future research should therefore expand to include underrepresented regions and broader international contexts to provide a more comprehensive understanding of the implementation of computational thinking in mathematics education.

Study Based on Research Material

Figure 7 illustrates the distribution of studies on computational thinking in mathematics learning by mathematical topic.

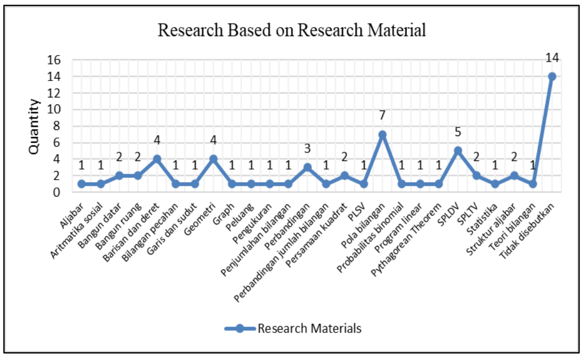

Figure 7. Distribution of studies by mathematics topic

Figure 7 presents the distribution of the reviewed studies according to the mathematics topics in which computational thinking was implemented. Although 14 studies did not explicitly report the mathematics topic, among the identified topics, number patterns were the most frequently investigated (7 studies), followed by two-variable linear equation systems (SPLDV) (5 studies). In comparison, most other topics appeared in only one to four studies. This distribution suggests that computational thinking has primarily been explored in mathematical topics that emphasize pattern recognition, logical reasoning, and problem solving. In contrast, its integration across other areas of the mathematics curriculum remains limited. Moreover, the large proportion of studies with unspecified mathematics topics reflects inconsistencies in research reporting, which may reduce the comparability of findings across studies. Therefore, future research should investigate computational thinking in a wider range of mathematics topics and provide clearer descriptions of instructional contexts to strengthen the evidence base and improve the generalizability of research findings.

Study Analysis Based on Learning Models

The analysis of research on computational thinking in mathematics learning, organized by the instructional models, methods, and approaches used, is summarized in Table 2.

Table 2. Research data based on the model/approach/method used

Title	Learning model
The influence of the discovery learning model using the STEAM (science, technology, engineering, art, mathematics) approach on students' computational thinking skills	Discovery Learning
The effectiveness of the scaffolding method in improving junior high school students' computational thinking on comparative material	Scaffolding method
The Effectiveness of the Scaffolding Method in Improving Junior High School Students' Computational Thinking Skills in Comparative Material	Scaffolding method
The Effect of Mind Mapping on Students' Computational Thinking Skills in Fifth Grade Mathematics Learning	Mind mapping model
Development of SSCS Model Learning Tools with the RME Approach and Its Influence on Computational Thinking Skills	Search, Solve, Create, and Share (SSCS) learning model with the RME approach
Implementation of Realistic Mathematics Learning to Improve Students' Computational Thinking Skills	Realistic mathematics learning
The Effectiveness of Realistic Mathematics Learning Approach on Students' Computational Thinking Abilities	Realistic mathematics learning
Improvement of Computational Thinking through Interactive Multimedia Learning Based on Initial Mathematical Ability	Pembelajaran menggunakan bahan ajar berbasis multimedia interaktif
Augmented reality: The improvement of computational thinking based on students' initial mathematical ability	Pembelajaran menggunakan media augmented reality dengan Unity 3D
Implementation of Computational Thinking in Mathematics Learning in Elementary Schools	Learning integrated with computational thinking
Analysis of the need to develop an inquiry-based electronic module to improve computational thinking skills in the sequence and series material of high school students.	Inquiry approach
Students' Proficiency in Computational Thinking Through Constructivist Learning Theory	constructivist learning approach
ZPD Technological Learning Environment In Learning Computational Thinking Skill-Based Mathematics	Zone of Proximal Development (ZPD) approach based on smart technology
The influence of flash card media on students' computational thinking skills in the spatial structures material in grade V of elementary school.	Use of flash card media
Using podcasts to develop students' computational thinking skills during the pandemic disruption	Use of podcast learning media
The Influence of the Problem-Based Learning Model on Computational Thinking Ability Assisted by GeoGebra Media	Problem-Based Learning (PBL)
Elementary school students' computational thinking skills in learning-based 3D geometry problems	Problem-Based Learning (PBL)
Learning Tool Project to Create a PBL Model to Stimulate the Computational Thinking Ability of Students	Problem-Based Learning (PBL)
The Influence of the Problem-Based Learning (PBL) Model on Computational Thinking Skills in Grade IV Measurement Material	Problem-Based Learning (PBL)
Computational thinking profile of students using the problem-based learning (PBL) model in terms of learning styles at SMA N 1 Langsa	Problem-Based Learning (PBL)
Improving Students' Computational Thinking Skills Through the Implementation of Project-Based Learning Models	Project-Based Learning (PJBL)
Development of Project-Based Statistics e-Module with Scratch Assistance to Improve Students' Computational Thinking Skills	Project-Based Learning (PJBL)
The Influence of the Project-Based Learning Model on Computational Thinking Skills in Flat Building Lessons for Fifth Grade Students	Project-Based Learning (PJBL)

Among the 23 reviewed studies that reported instructional approaches (Table 2), Problem-Based Learning (PBL) was the most frequently implemented model (5 studies), followed by Project-Based Learning (PjBL) (3 studies). The predominance of these models suggests that researchers tend to adopt student-centered learning approaches that promote active engagement in solving authentic problems. This finding is consistent with computational thinking, which requires students to decompose complex problems, identify patterns, and develop systematic solution strategies. Previous studies have also highlighted the effectiveness of PBL in fostering computational thinking by encouraging active problem solving and critical thinking (Lye & Koh, 2014).

Study Analysis Based on Computational Thinking (CT) Ability Indicators

In the research analysis that has been reviewed, it can be seen that most researchers use indicators of computational thinking abilities as a reference. These indicators include Decomposition, Recognizing Patterns, Performing Abstractions, and Algorithmic Thinking (Afifah & Apriyono, 2023; Aisy & Hakim, 2023; Angraini, Yolanda, & Muhammad, 2023; Angraini & Muhammad, 2023; Azizia, Kusmaryono, Maharani, & Arifuddin, 2023; Budiarti, Wibowo, T., & Nugraheni, 2022; Candraningtyas & Khusna, 2023; H. L. Dewi & Pramesti, 2023; J. P. Dewi, Lyesmaya, & Maula, 2024; Findayani, Suparta, & Sariyasa, 2023; Kharomah, Fitri, & Cindarbumi, 2023; Lestari & Roesdiana, 2023; Litia, Sinaga, & Mulyono, 2023; Manullang & Simanjuntak, 2023; Marchelin, Hamidah, & Resti, 2022; Mardiah, Ramadoni, & Fitri 2023; Memolo, 2022; Miswanto, Nusantara, As'ari, & Sukoriyanto, 2022; Mubarokah, Pambudi, Lestari, Kurniati, & Jatmiko, 2023; Mukhibin, Herman, & Utomo, 2024; Mustafa, 2023; Mustaqimah & Ni'mah, 2024; Nuraisa, Saleh, & Raharjo, 2021; Nurwita, Kusumah, & Priatna, 2022; Sa'diyyah, Mania, & Suharti, 2021; Safitri, Putra, Alim, & Aljarrah, 2023; Silvia et al., 2023; Siregar & Malay, 2023; Sudadi, Lolang, Ariawan, Kusnadi, & Munir, 2023; Sunendar, Santika, Supratman, & Nurkamilah, 2020; Supiarmo, Mardhiyatirrahmah, & Turmudi, 2021; Syahputra & Sinaga, 2024; Augie, 2021; Veronica, Siswono, & Wiryanto, 2022; Widiyawati, Utari, Aprinastuti, & Setyaningsih, 2022). These findings emphasize the importance of using these indicators in improving analytical and problem-solving abilities in this digital era.

This is also supported by Lee et al. (2012), who stated that Google demonstrated four indicators of computational thinking capabilities: problem decomposition, pattern recognition, pattern abstraction and generalization, and algorithmic thinking. Further explanation regarding these indicators is provided in Table 3.

Table 3. Explanation of computational thinking ability indicators

Indicators	Explanation
Decomposition	Ability to break down complex math problems into simpler, more manageable parts
Pattern recognition	Ability to identify similarities, differences, and relationships between various mathematical concepts
Abstraction	Ability to ignore irrelevant details and focus on information that is important to solving the problem
Algorithm	Ability to design clear and structured steps or procedures to solve mathematical problems

The findings indicate that decomposition, pattern recognition, abstraction, and algorithmic thinking remain the four computational thinking indicators most frequently adopted in mathematics education research. Their predominance suggests a broad consensus that these indicators represent the core cognitive processes required for effective mathematical problem solving. Specifically, decomposition enables students to break complex problems into manageable components; pattern recognition supports the identification of mathematical regularities and relationships; abstraction facilitates the construction of generalized mathematical representations by focusing on essential information; and algorithmic thinking guides students in developing systematic and logical solution procedures. Collectively, these indicators provide an integrated framework that supports students in solving mathematical problems through structured and analytical reasoning.

This finding is consistent with previous studies that highlight these four dimensions as fundamental components of computational thinking in mathematics education (Lee et al., 2012; Weintrop et al., 2016). It also aligns with the systematic review conducted by Mukhibin and Juandi (2023), which identified decomposition, pattern recognition, abstraction, and algorithmic thinking as the dominant computational thinking dimensions implemented in mathematics learning. However, the present study extends previous reviews by demonstrating that these four indicators have consistently been the primary focus across studies published between 2019 and 2024, while simultaneously synthesizing publication trends, research characteristics, instructional models, mathematical topics, educational levels, and research locations in a single review. This broader perspective provides a more comprehensive understanding of the current landscape of computational thinking research in mathematics education.

The predominance of these four indicators has several important implications. From a theoretical perspective, they may serve as a common conceptual framework for investigating computational thinking across different mathematical topics and educational levels, thereby facilitating greater consistency among future studies. From a practical perspective, these indicators can guide educators in designing learning activities, assessment instruments, and instructional strategies that systematically develop students' computational thinking skills. At the same time, the findings reveal that relatively limited attention has been given to other computational thinking dimensions proposed in the literature. This suggests that future research should explore broader computational thinking frameworks and investigate additional indicators that may better capture the complexity of students' mathematical reasoning and problem-solving processes across diverse educational contexts.

IV. Conclusion

This study provides an in-depth summary of publication patterns on computational thinking in mathematics education from 2019 to 2024. The results highlight a growing academic interest in this area, with qualitative research designs being the most widely applied. A significant portion of the investigations targeted junior high school students, placing special emphasis on specific mathematics topics such as number sequences and two-variable linear systems of equations. Additionally, Problem-Based Learning (PBL) and Project-Based Learning (PjBL) emerged as the preferred teaching frameworks for cultivating these skills. The core dimensions of decomposition, pattern recognition, abstraction, and algorithmic thinking remain the primary metrics used by researchers. Ultimately, this review offers a contemporary snapshot of research dynamics and serves as a foundational guide for future advancements in this field.

For researchers, future studies are encouraged to investigate more diverse instructional approaches and explore broader dimensions of computational thinking, including integrating technology to enhance students' computational thinking in mathematics learning. For educators, the findings highlight the importance of systematically integrating computational thinking into mathematics instruction to better support students' problem-solving and higher-order thinking skills.

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