RANGE : Jurnal Pendidikan Matematika
e-ISSN :2685-2373

Volume 7, Nomor 1, Juli 2025, pp. 172-186

A Systematic Literature Review of: Computational Thinking in Mathematics Classrooms

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Received: April 20th 2025. Accepted: June 10th 2025. Published: July 30th.2025

ABSTRACT

In today's rapidly evolving digital era, the ability to think computationally is no longer confined to computer science it has become essential across disciplines, including mathematics. This study integrates computational thinking (CT) into mathematics learning by analyze its development, benefits, and implementation challenges. Computational thinking which includes abstraction, algorithms, decomposition, and pattern recognition, is considered a crucial component in improving students' mathematical learning. These insights are intended to inform educators, policymakers, and researchers seeking to align mathematics instruction with contemporary technological and pedagogical advancements. Utilizing a systemic literature review as a qualitative method, by 37 peer-reviewed articles published between 2019 and 2024 in the Scopus database were examined. Through qualitative thematic analysis, key insights were identified across cognitive and affective dimensions. The review suggests that CT may support students' development in problem-solving, logical reasoning, and conceptual abstraction, while also contributing to affective aspects such as motivation, self-confidence, and self-regulated learning. However, several barriers hinder its effective implementation, including insufficient teacher training, limited infrastructure, and curricular constraints. The study highlights the necessity for targeted teacher training initiatives and institutional support to facilitate CT integration.

Keywords: computational thinking, mathematics classrooms, mathematics education, mathematics learning

How to Cite: Pramesti, S. L. D., Mariani, S., Hendikawati, P., Wardono, Waluya, S. B., Pujiastuti, E., & Dewi, H. L. (2025). Template untuk publikasi naskah di Jurnal Range. *RANGE: Jurnal Pendidikan Matematika*, 7(1). 172-186.

Introduction

Mathematics plays a crucial role in developing logical reasoning and structured problem-solving, which are essential components of Computational Thinking (CT). CT is a fundamental skill in the digital era, enabling students to break down complex problems, recognize patterns, and develop step-by-step solutions—abilities that are deeply rooted in mathematical learning. However, many students struggle with mathematics and show a lack of interest in engaging with its concepts (Aftina et al., 2024). This disinterest not only affects their mathematical performance but also hampers the development of CT skills that are vital for success in academics and future careers. While various mathematics learning and teaching approaches is continued to be explored, the computational thinking (CT) is incorporated into educational framework for improving the efficacy of mathematics learning.

Computational thinking refers to a cognitive process that emphasizes structured, analytical, and algorithm-based manner to problem-solving (Wing, 2006). The main indicator of CT e.g. abstraction, algorithm, decomposition, and pattern recognition. It is related into mathematics learning, because mathematics is a form of structured thinking and based on systematic logic (Pramesti et al., 2024). The incorporation of computational thinking into mathematical learning goes beyond understanding of algorithms and programs, and CT also includes pattern recognition, problem formulation, and solving complex mathematical challenges (van Borkulo et al., 2019). Therefore, a comprehensive grasp of how CT contributes to mathematical development represents a significant priority in contemporary education.

Since 2018, Indonesia has initiated to implement computational thinking (CT) into its national education system. As stipulated in Minister of Education Regulation No. 37 (Menteri Pendidikan dan Kebudayaan Republik Indonesia, 2018), CT has been designated as a core competency to be developed at elementary until high school levels. The adoption of CT has occurred in several countries e.g. the UK (Brown et al., 2014), Finland (Mannila et al., 2014), Australia (Falkner et al., 2015), the United States (Fisher, 2016), and Sweden (Bråting et al., 2022).

Due to rapid technological advancements, it has grown in importance to ensure that the integration of CT is both contextually appropriate and aligned with global educational trends (Yadav et al., 2016). Consequently, a detailed assessment of the advancement and implications of CT in math education is essential (Ye et al., 2023). Although interest in computational thinking (CT) is steadily growing within the mathematics education community, the literature between 2019 and 2024 reflects an evolving but still developing field—particularly regarding its practical application in diverse classroom settings and the challenges encountered during implementation. This highlights the need for a systematic review to synthesize current insights and guide future research and practice.

Despite the growing attention on computational thinking (CT) in various educational domains, there remains limited consolidated evidence on how CT specifically contributes to both cognitive and affective aspects of students in mathematics learning. This study addresses that gap by providing a comprehensive synthesis of recent literature (2019–2024), offering an up-to-date perspective on the integration of CT in mathematics education. The utilization of CT in mathematics education offers a means to enhance students' critical thinking abilities via a technology-driven methodology. It can enhance students' comprehension of mathematical ideas in a more organized and engaging manner. It also aids students in recognizing patterns, deconstructing complex problems into simpler components (decomposition), and abstracting and visualizing challenging mathematical concepts. The researchers attempt to examine and evaluate the development, benefits, and challenges of integrating Computational Thinking (CT) into mathematics learning, focusing on both students' cognitive and affective aspects through a comprehensive review of the literature. The researchers believed this study would offer insightful information for educators, policymakers, and researchers who interested in advancing CT in mathematics learning which relevant into current technological developments.

Methods

The study takes a qualitative, using a Systemic Literature Review (SLR) methodology. Classifying, choosing, evaluating, or critically calculating important studies, along with collecting and assessing data from the results for review, are the main focuses of this methods (Aliyu et al., 2021; Irshad & Yasmin, 2022; Robinson & Lowe, 2015). This method used three components:

1.Identification

The procedure for selecting relevant papers for this study involved three main stages (identification, screening, and eligibility) in systematic literature review method. The first step was determining the keywords and looking up its related using dictionaries, encyclopedia and earlier studies. After identifying the relevant terms, a search string was then generated in scopus database (See table 1). This research project successfully retrieved 551 articles from the database during the first stage of the SLR method.

Table 1. *String*

Scopus	TITLE-ABS-KEY (computational AND thinking AND mathematics AND mathematics learning AND mathematics education) Access Date: 5 March 2025

1.2 Screening

According to previous phase, 128 articles were excluded based on the various inclusions and exclusions of the researcher (Table 2). Research papers were the main focus and were selected using the initial selection criteria. In this phase, systematic reviews, narrative reviews, meta-syntheses, meta-analysis, monographs, books, chapters, and conference proceedings were excluded. Consequently, the scope is restricted to English-written articles to years 2019-2024. A total of 128 articles were checked after the predefined criteria were used. In the second stage, 50 articles were identified as duplicates and were systematically excluded from selected articles.

Table 2. *Selection Criteria*

Criteria	Inclusion	Exclusion
Language	English	Non-English
Time Range	2019-2024	<2019
Type of Literature	Journal	Conference, Book, Review

1.3 Eligibility

Following the second screening, 43 articles qualified for third phase, termed the eligibility stage. The titles and contents of the selected articles were carefully examined. So, 6 articles were excluded due to irrelevance to the research field, titles and abstracts that lacking significant connection to the study's focus. Finally, 37 articles were selected.

The settings used after structure are improvement settings. Improvement can be an attitude that involves implementing a systematic literature overview. This environment relies on Preferred Details for Efficient Surveys and Meta-Analyses (PRISMA). A structured approach for peer-reviewed studies has been formulated, incorporating a ranking framework to ensure consistency and standardized value in the transformation process (Conde et al., 2020). Core components of the PRISMA method is identification, screening, eligibility, and included. The flow of the PRISMA can be seen in Figure 1.

This final organization of SLR testing includes methodological testing and a discussion of detailed results based on the research questions posed. This leads to the SLR conclusion. Additionally, SLR inspections also provide data on related and encouraged inspections of patterns that take into account defects and recommendations. This arrangement also adequately assesses the importance of each stage in Figure 1 which highlights research limitations that cannot be excluded by the SLR.

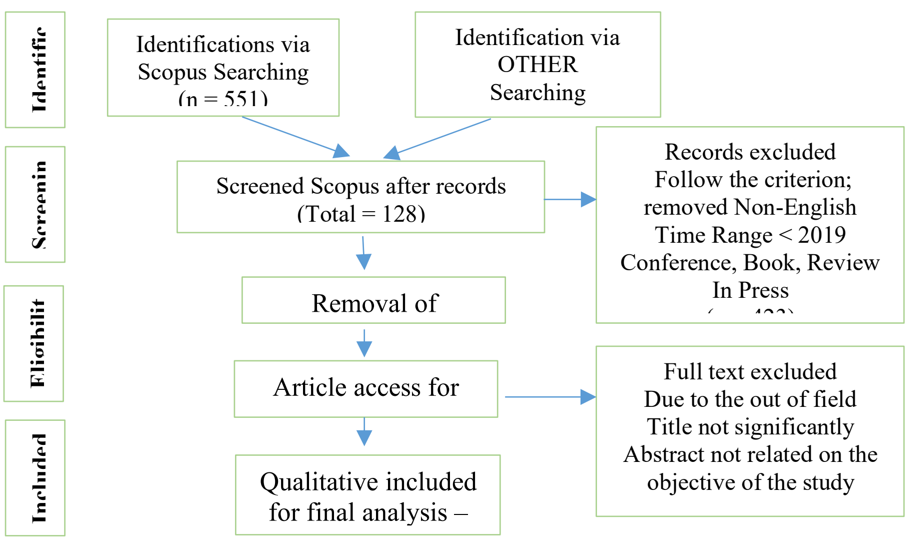

Figure 1. *Procedure PRISMA*

Results and Discussion

The 37 articles presented below, which fulfil the criteria outlined in the research questions, have been selected for further analysis and review.

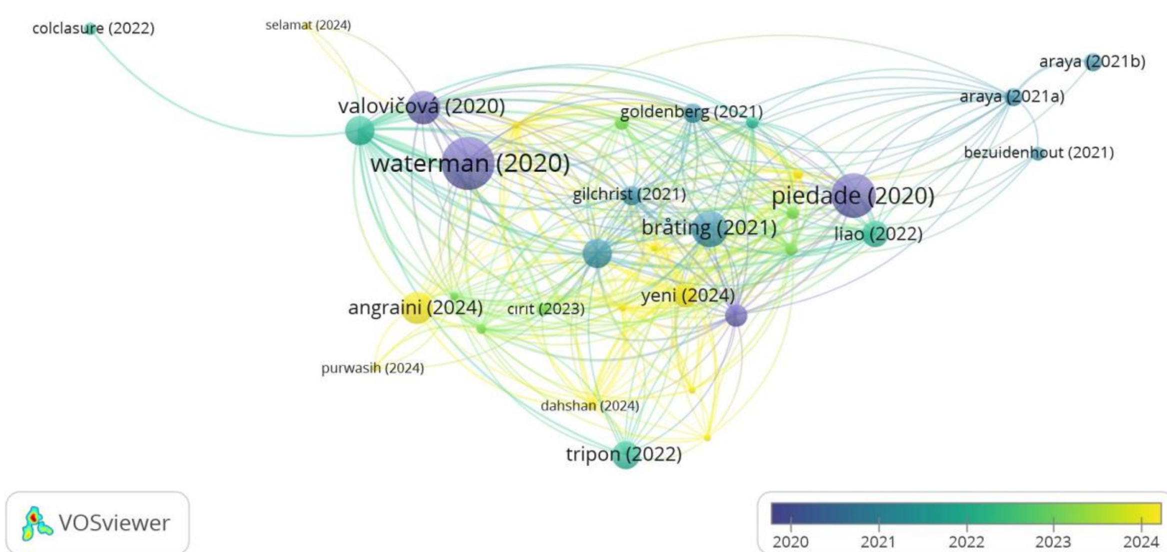

Figure 2. *Distribution of Articles by Author and Year of Publication*

Based on the PRISMA structure, the researchers analyse all articles (n = 37) to collect the data needed to answer research questions, allowing us to achieve this SLR exam goal for results and reality. Discussions of this consideration are categorized into three that correspond to the indication of the question. The table below presents the research questions, along with insights that guided the formulation:

Table 3. *Research Question*

Code	RQ	Motivation
RQ1	How has CT developed in math learning based on years and research topics?	Knowing the year of publication and research topics related to CT offers a clear overview of the progression of CT-related studies. It can be a reference for further research.
RQ2	What is the impact of the Application of CT in Math Learning?	Providing insight into the impact of the Application of CT in Math Learning
RQ3	Challenges of Implementing CT in Math Learning	Providing an overview of the challenges of implementing CT in math learning

Development of CT in Mathematics Learning by Year and Research Topic

According to Scopus database spanning the years 2019 to 2024, the incorporation of CT research in math learning showed diverse developments. Table 4 presents a classification of the selected computational thinking (CT) studies into distinct research clusters. This categorization supports the PRISMA procedure by systematically organizing the diverse body of literature, facilitating a clear overview of research trends and thematic focus areas. By grouping studies into categories such as basic research, applications, ability analysis, supporting tools, and multidisciplinary approaches, this table aids in the transparent screening and synthesis process, ensuring that the review comprehensively addresses different facets of CT in mathematics education.

Tabel 4. *CT Research Classification*

Cluster	Research
Basic research on computational thinking	(Araya, 2021; Araya et al., 2021; Bezuidenhout, 2021; Fang et al., 2023; Humble & Mozelius, 2023; Krakowski et al., 2024; Liao et al., 2022; Piedade et al., 2020)
Application or Case Study of Computational Thinking	(Angraini et al., 2024; Bråting & Kilhamn, 2021; Chan et al., 2021; Cırıt & Aydemir, 2023; Molina-Ayuso et al., 2022; Moon et al., 2023; Mumcu et al., 2023; Purwasih et al., 2024)
Computational Thinking Ability Analysis	(Al-Nawaiseh et al., 2024; Bianco et al., 2024; Dahshan & Galanti, 2024; Nordby et al., 2024; Reichert et al., 2020; Tripon, 2022)
Application of Computational Thinking with supporting tools	(Abramovich, 2023; Barana et al., 2023; Gilchrist et al., 2021; Goldenberg & Carter, 2021; Musaeus & Musaeus, 2024; Waterman et al., 2020)
Computational Thinking and STEM/STEAM	(Colclasure et al., 2022; Knie et al., 2022; Rajapakse-Mohottige et al., 2024; Selamat et al., 2024; Valovičová et al., 2020)
Computational thinking research in multidisciplinary sciences	(Khuda et al., 2024; Kong & Wang, 2024; D. Wang et al., 2022; Yeni et al., 2024)

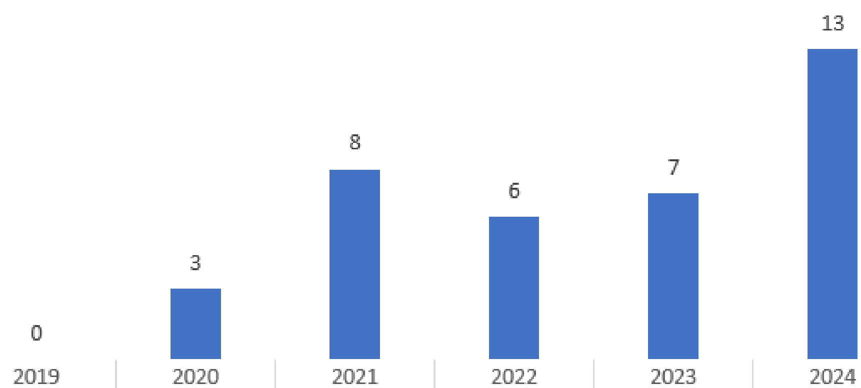

Figure 3. *Distribution of Articles Based on Year of Publication*

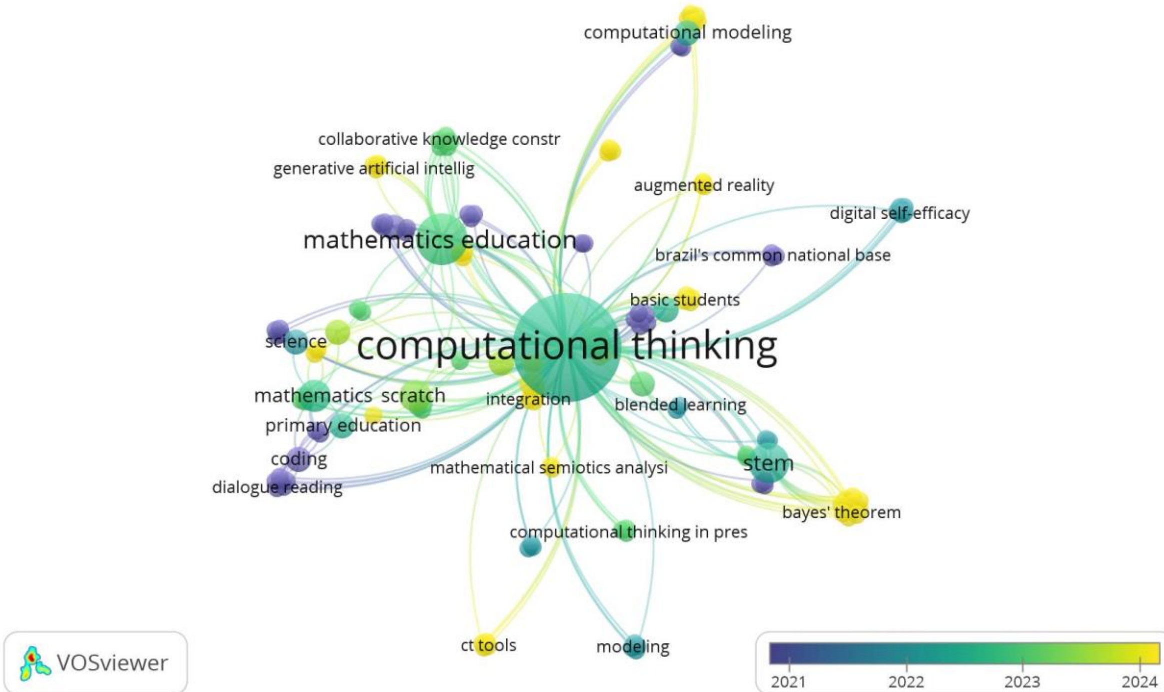

Figure 4. *Research Keywords related to math and CT learning*

The combination of CT and educational innovation is a solution to CT improvement (Voskoglou & Salem, 2020). Thus, CT examinations and agreements were improved by integrating the CT and education modules (Voogt et al., 2016; Weintrop et al., 2016) as was done by Asian countries e.g. Hong Kong, Taiwan and China (Subramaniam et al., 2022). Based on figure 3, CT continues to grow with mathematics. Development of CT in mathematics has evolved significantly since 2021 to 2024. Initially, research emphasized to introducing CT in primary education, often through tools like Scratch. Over time, the scope expanded to include blended learning, STEM integration, and mathematical semiotics analysis. By 2023, advanced technologies e.g. artificial intelligence, augmented reality, and digital self-efficacy became central topics, highlighting the contribution of technology to enhance mathematical understanding. In 2024, research further broadened to explore computational thinking modelling and the incorporation of CT in basic and preschool levels, indicating a shift towards integrating CT into various educational contexts.

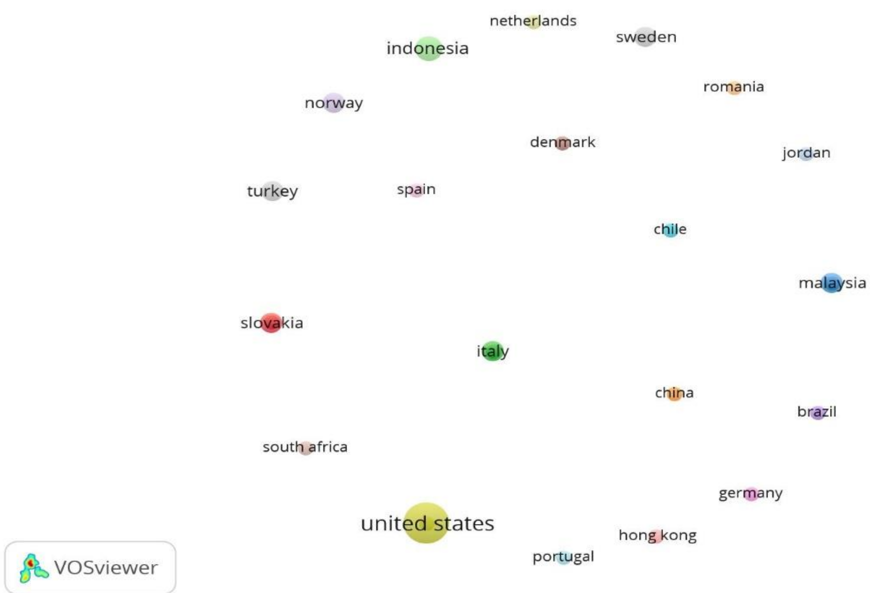

Figure 5. *Distribution of CT research from various countries*

Exploration of the Impact of Computational Thinking Application in Mathematics Learning

Computational Thinking (CT) is increasingly recognized as having a meaningful influence on students’ cognitive and emotional development in mathematics education. Various studies indicate that CT contributes to the enhancement of students’ problem-solving and logical reasoning skills, while also supporting affective domains such as motivation, persistence, and engagement in learning. For example, Purwasih et al. (2024) demonstrated that through the integration of semiotic analysis in mathematical and computational thinking, students could more effectively identify and generalize patterns—thereby sharpening their cognitive abilities. Similarly, Araya (2021) and Fang et al. (2023) reported that CT-based instruction helped students develop more efficient problem-solving strategies, improve their understanding of complex mathematical concepts, and foster critical thinking skills.

Furthermore, Bråting and Kilhamn (2021) emphasized the intersection between algebraic and computational thinking, revealing that the mastery of both forms of reasoning enhances students’ abstraction and generalization capabilities in mathematics. Additional studies by Khuda et al. (2024) and Mumcu et al. (2023) also highlighted that CT not only promotes cognitive improvement but also strengthens students’ emotional involvement, helping them stay focused and motivated when tackling more complex mathematical problems.

Notably, Yunianto et al. (2024) illustrated the use of GeoGebra in CT-oriented learning activities, showing how such tools enhance both conceptual understanding and programming-related skills like debugging—further boosting students' cognitive performance and confidence. These findings collectively suggest that the integration of CT in mathematics education supports students' holistic development, both cognitively and affectively, and prepares them for future academic and professional challenges in increasingly technology-driven environments.

Development of problem-solving abilities: The key findings showed that students more engage in logical thinking when solving mathematical problems. Students acquired enhanced problem-solving skills particularly in areas such as programming (e.g., scratched), abstraction, and debugging (Prahmana et al., 2024).

Understanding of algorithms and mathematical logic: the application of CT, which involves programming and algorithms, is closely related to improved understanding of algebra and mathematical logic. In several studies, such as those involving the use of programming in algebra, it was found that programming helps students improve their algebraic thinking, facilitating the understanding of the relationships between symbols in mathematics (Reichert et al., 2020). Improved abstraction skills: In a broader context, abstraction as one component of CT allows students to generalize and classify mathematical concepts better. This learning helps students overcome complex mathematical challenges in a more structured and organized way (Goos et al., 2023).

In addition to students' cognitive aspects, computational thinking also affects students' affective aspects. Studies have shown that computational thinking is closely linked to an individual's cognitive style (C. J. Wang et al., 2022). This cognitive style of a student will influence a person's thinking style. Aspects of student engagement and motivation. Research shows that the application of CT can increase student engagement in learning. For example, the use of technologies such as Microsoft Excel and e-Learning has been shown to increase students' motivation to learn mathematics. Students who engage in collaborative problem-solving or use digital tools report a more positive outlook on learning mathematics (Araya, 2021). Increased Self-Efficacy: In several studies, ongoing interaction with a mentor or project-based teaching increases students' confidence in using technology and applying computational thinking to solve mathematical problems (Bråting & Kilhamn, 2021). Kong & Wang, (2024) highlighted a reciprocal dynamic between SRL and CT, suggesting that growth in one foster improvement in the other.

The impact of computational thinking on student engagement is one of the key findings, yet a deeper exploration of this aspect is still lacking. While it is clear that CT applications enhance student's cognitive and emotional skills, particularly in problem solving, abstraction, and understanding mathematical logic, the effects on engagement require more details investigation. Recent literature (Araya et al., 2021) highlights that tools such as learning and collaborative problem solving foster greater students motivation and participation in mathematics learning. However, these studies primarily focus on the correlation between engagement and the use of CT tools without delving into how these tools specifically impact long-term motivation or sustained engagement across different student demographics. Future, research should explore how various CT applications, such as programming or interactive simulations, affect student engagement in diverse learning contexts and over time, considering factors like teaching style, curriculum integration, and technological infrastructure.

Challenges in Implementing CT in Mathematics Learning

Based on the analysis of 37 articles included in this systematic literature review, 13 studies (approximately 35%) explicitly discuss the challenges involved in integrating Computational Thinking (CT) into mathematics education. These challenges are multifaceted and span across various domains, including teacher preparedness, technological infrastructure, curriculum design, time management, student adaptability, and disparities in digital competence. Most of the studies that highlight these challenges fall under the category of *Computational Thinking and Curriculum Integration*, indicating that while the integration of CT holds great potential, its implementation in mathematics classrooms still faces significant practical and systemic obstacles.

One of the most frequently cited challenges is teacher preparedness. Many teachers lack adequate training in the foundational principles of CT and are often not equipped with the appropriate strategies to integrate CT effectively into mathematics pedagogy (Yunianto et al., 2024; Khuda et al., 2024; Mumcu et al., 2023). This is further supported by Abramovich (2023), who emphasizes that a considerable number of educators still lack sufficient methodological understanding to implement CT consistently. These findings point to the critical need for comprehensive and continuous professional development initiatives to support teachers in this area.

Another major barrier relates to technological infrastructure. In low-resource educational environments, limited access to technology—such as hardware, software, and internet connectivity—significantly impedes the successful implementation of CT in mathematics education (Purwasih et al., 2024; Horton & Hardin, 2021; Bubnic et al., 2024). Such disparities in technological resources not only affect instructional delivery but also exacerbate existing inequalities in educational outcomes between schools or regions.

In terms of curriculum design, several studies report that existing curricula are not adequately structured to support the integration of CT. Teachers often find it challenging to modify traditional mathematics curricula to incorporate CT-based approaches, particularly those that involve programming or the use of digital tools (Bråting & Kilhamn, 2021; Moon et al., 2023). This mismatch between CT goals and current curricular content can hinder both teaching effectiveness and student comprehension.

Time management and the lack of specialized training opportunities are also highlighted as pressing issues. Teachers frequently report feeling overwhelmed by the additional time required to prepare and implement CT-enhanced instructional materials—especially when they lack prior training or support (Ye et al., 2023). Without sufficient time allocation or institutional support, the integration of CT may become an added burden rather than a beneficial innovation.

The issue of student adaptability further complicates the integration process. Students who are used to conventional, procedural-based mathematics instruction may experience confusion or cognitive overload when exposed to CT methods that rely on problem-solving, abstraction, or the use of technology (Khuda et al., 2024; Goos et al., 2023). Without proper scaffolding, these transitions may reduce student engagement and negatively impact learning outcomes.

Finally, disparities in digital literacy and technology access among students present another layer of challenge. While some students adapt quickly to CT-integrated learning environments, others struggle due to limited digital skills or unfamiliarity with the tools being used (Angraini et al., 2024; Prahmana et al., 2024b). These disparities not only affect individual academic performance but also risk intensifying existing inequities within the classroom context.

Overall, the findings suggest that although not all studies in this review focus on these issues, a significant portion of the literature identifies these challenges as critical barriers. Addressing them will require systemic changes, including targeted teacher training, equitable access to technology, curriculum reform, and adaptive instructional design to support both teachers and students in successfully navigating the integration of computational thinking in mathematics education.

Conclusion

The application of computational thinking in mathematics learning significantly enhances students' cognitive and affective abilities. By integrating CT, students show better abilities in solving math problems, improve their greater insight of mathematical concepts e.g. algorithms and logic, and strengthen abstraction skills. In addition, this approach also increases student motivation and engagement, cognitive thinking, thinking style, which leads to increased self-confidence and self-regulated learning in mathematics learning.

However, the challenges in implementing CT remain obstacles that need to be taken into consideration. The lack of initial knowledge of teachers regarding CT, limited technical infrastructure, and difficulties in curriculum adaptation are factors which influence the success of CT incorporation in mathematics learning. As a result, it is crucial to acquire more intensive training for teachers and providing appropriate resources to support effective implementation of CT in mathematics. Overall, despite some challenges, the implementation of CT in mathematics has great potential to improve the relationship between the quality of mathematics' formation and current technological development. Therefore, steps to address these challenges must be taken to ensure optimal implementation of future CTs.

Acknowledgement

The authors wish to convey their heartfelt appreciation to the Department of Math and Sciences at Universitas Negeri Semarang for their provision of the vital resources and scholarly support throughout this research. Grateful acknowledgement is extended to the authors of the articles reviewed, whose work greatly contributed to this study.

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