

Mapping the Landscape of Computational Thinking on Mathematics Learning in Indonesia: A Systematic Literature Review

Isnaeni Umi Machromah*, Bambang Eko Susilo, Wardono

Department of Mathematics Education, Universitas Negeri Semarang, Semarang, Indonesia

*Author to whom any correspondence should be addressed.

E-mail: isnaeniumi@students.unnes.ac.id

Abstract

Computational thinking (CT) is an essential skill of the 21st century and is increasingly relevant in mathematics education. Although many systematizations discuss CT on a global scale, empirical evidence in Indonesia is still limited. Most studies prioritize short-term digital media development (e.g., augmented reality development, e-modules, coding) with a primary focus on cognitive achievement, while the affective domain (such as motivation, attitude, and self-directed learning) is neglected. Meanwhile, the integration of CT in mathematics learning or mathematical literacy, and unplugged activities are rarely studied. This study provides a systematic review of empirical investigations regarding CT in Indonesian mathematics education to produce a comprehensive synthesis. Specifically, it analyzes: (1) theoretical and pedagogical conceptualizations of CT, (2) learning dimensions related to CT (cognitive, affective, and academic outcomes), (3) research methodologies and reported limitations, and (4) applications of plugged (digital/AR/coding) and unplugged (non-digital/game-based) activities. In accordance with the PRISMA protocol, a search was conducted on the national database Scopus. There were 22 published articles in 2018–2025 analyzed. The main findings include: (1) Most studies in Indonesia view CT as a capability with components of decomposition, abstraction, algorithm design, debugging; (2) The dimensions of learning studied are dominated by cognitive dimensions such as problem solving, while the affective dimension is still minimally studied in CT research; (3) The research design used is dominated by qualitative research, while limitations in the research are related to the relatively short research period, limited number of samples, and the absence of standardized instruments; and (4) 85% of the CT studies analyzed tend to use plugged activities by integrating technology.

Keywords: Computational thinking, Mathematics Education, Plugged Activity, Unplugged Activity

1. Introduction

Technological innovation in the 21st century demands that the education system produce a generation equipped with adaptive and critical thinking competencies. Given the complex challenges faced today, this generation requires 21st-century skills that require students to acquire not only basic knowledge but also critical thinking, creativity, collaboration, communication, and digital and information literacy. With the rapid development of technology, computational thinking skills have emerged as one of the basic skills that need to be mastered. Computational thinking involves solving problems

through the basic principles of computer science, which can be applied across various disciplines, including mathematics [1]. The integration of computational thinking into mathematics education not only fosters the development of algorithmic thinking but also enhances students' ability to solve complex problems in a structured manner. This ability is crucial in the 21st century, where students must be able to navigate an increasingly data-focused environment. As illustrated by the International Society for Technology, introducing students to computational thinking skills will equip them to solve real-world problems, thereby strengthening their adaptability and critical thinking skills [2].

The connection between computational thinking and mathematics learning is intimately intertwined, as computational thinking functions as an essential cognitive tool that enhances problem-solving capabilities and promotes a deeper comprehension of abstract mathematical ideas. By using algorithmic representations, learners can break down complex mathematical problems into simpler parts, facilitating a systematic problem-solving process [3]. This technique not only supports the grasp of mathematical theories but also enables learners to relate abstract concepts to practical implementations, thus enriching their overall mathematics learning experience. Moreover, engagement with computational thinking facilitates the development of critical skills, including logical reasoning and pattern recognition [4]. Additionally, embedding computational thinking into mathematics fosters creative ideation and encourages collaboration among students. A study observed that participation in computational thinking tasks cultivates cooperative solution design, nurturing a collaborative educational environment essential for success in today's globally connected society [4]. Ultimately, the integration of computational thinking within mathematics education establishes a robust framework for comprehension while preparing students to confront real-world challenges with assurance and inventiveness.

Mathematics is also indirectly connected to CT through fundamental elements such as algorithms, problem solving, abstraction, and decomposition. The integration of CT into mathematics instruction is vital for enhancing students' problem-solving capacities, reasoning abilities, and overall mathematical literacy. The systematic methodology fostered by CT not only assists in resolving complex mathematical issues but also equips students with essential skills to thrive in a technology-oriented society [3]. By embedding CT in mathematics education, educators can more effectively prepare learners to approach authentic problems with confidence and creativity [4]. Despite the expanding corpus of research on CT in education, notable gaps and challenges persist, especially within the domain of mathematics education. A primary concern involves the definition and metrics of CT, which may result in inconsistent application and comprehension across studies. Furthermore, scant research exists regarding optimal pedagogical approaches for incorporating CT into the mathematics curriculum, leaving educators without a definitive implementation framework. Moreover, existing studies often concentrate on specific topics, such as algebra or geometry, and are frequently confined to particular educational stages, like middle school, thereby limiting the generalizability of outcomes [1]. This limited scope underscores the necessity for a comprehensive synthesis of CT research trajectories and tendencies in mathematics education, as such a review can illuminate potential directions for future investigation and guide best practices for practitioners.

Many earlier studies have conducted literature reviews on computational thinking. The existing research includes explorations focused on the integration of mathematics and computational thinking within K-12 education [5], the use of computer technology to enhance computational thinking skills in math teaching [6], the definition and description of computational thinking in mathematics education [7], and studies on research trends related to abstraction in math education [8]. However, there is a lack of reviews addressing theoretical frameworks and teaching methods for combining mathematics and computational thinking beyond empirical studies and K-12 settings [5]. Furthermore, evaluations of non-computer-based interventions aimed at improving computational thinking skills in mathematics, along with the application of computational thinking and computer technology in other fields like science, remain limited [6]. In addition, a systematic review comparing expert opinions with empirical data on computational thinking in math education is needed [7]. Therefore, through an in-depth review of the gathered literature, this article aims to explore current trends, key themes, theoretical frameworks, and teaching approaches for integrating mathematics and computational thinking in both plugged and unplugged settings.

2. Methodology

This study employed a Systematic Literature Review (SLR) design, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [9]. This design was chosen because it provides a comprehensive synthesis of empirical evidence regarding the application of computational thinking (CT) in mathematics learning in Indonesia.

Research data was obtained from one source, namely Scopus, a reputable international database. The reason for choosing Scopus as the primary database is the credibility and quality of sources. Scopus only includes journals that have gone through a rigorous selection process, ensuring that the articles obtained have high scientific validity. The article search was limited to the period 2016–2025. The query used was: (TITLE-ABS-KEY ("computational thinking" OR "CT" OR "computational skills" OR "computational literacy" OR "computational approach" OR "computational competence" OR "algorithmic thinking")) AND TITLE-ABS-KEY ("mathematics" OR "mathematics education" OR "mathematics learning" OR "mathematical literacy" OR "mathematical competence" OR "numeracy" OR "PISA

mathematics")) AND PUBYEAR > 2018 AND PUBYEAR < 2026 AND PUBYEAR > 2018 AND PUBYEAR < 2026 AND (LIMIT-TO (OA,"all")) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (AFFILCOUNTRY,"Indonesia")). The search yielded 1,418 articles. They were then filtered for all open access articles, English-language articles, journal-only publications, and restrictions on Indonesia, resulting in 39 articles. Further in-depth identification of articles was conducted to exclude those not related to empirical research and those not related to mathematics learning. The final result was a synthesis of 22 articles.

Inclusion criteria include: (1) articles published in journals, (2) research on CT in mathematics learning, and (3) articles resulting from empirical studies. While exclusion criteria include: (1) conference proceedings, (2) not relevant to CT in mathematics learning, such as in the fields of science, technology, informatics, and other fields, and (3) studies in the form of a literature review, including scoping reviews, meta-analysis, bibliometrics, and the like.

The selection process was carried out in three stages. First, the identification stage yielded 1418 articles from the initial search results. Second, the screening stage was conducted by reviewing titles and abstracts to exclude non-empirical articles. Third, the eligibility stage reviewed the full text based on the inclusion and exclusion criteria. From this process, 22 empirical articles were selected for analysis. The entire selection process is illustrated using a PRISMA diagram presented in Figure 1.

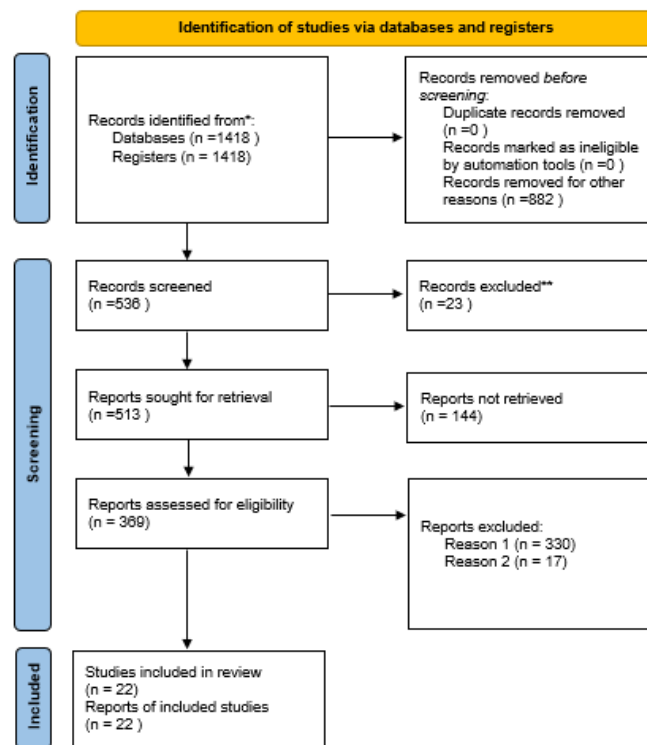


Figure 1. PRISMA Diagram

Next, data from the selected articles were extracted into a table that included the title, author, year of publication, publication, methodology, main findings, intervention, limitation, and future recommendation. Then, 22 articles were synthesized according to the research questions. There are three research questions in this article:

RQ1. How computational thinking (CT) is conceptualized and integrated into mathematics learning in Indonesia?

RQ2. How are plugged and unplugged activities applied in CT research?

RQ3. What are the research trends on computational thinking in Indonesia?

3. Results and Discussion

3.1 Computational Thinking (CT) Concept in Learning

This first research question examines how computational thinking (CT) is conceptualized and integrated into mathematics learning in Indonesia, encompassing both theoretical foundations and pedagogical implementation. The discussion of this research question aims to analyze the framework, including definitions and components used in the integration of mathematics learning.

Various experts present varying perspectives on the definition of computational thinking. CT introduce as a thinking process for solving problems, designing systems, and understanding human behavior based on fundamental concepts of computer science [3]. CT also conceptualized as a set of skills encompassing decomposition, pattern recognition,

abstraction, and algorithmic thinking, all of which help students solve problems systematically [10]. Moreover, CT described as a thinking process for formulating problems so that their solutions can be represented as computational and algorithmic steps [11].

Most studies in Indonesia consider CT to be an essential set of skills consist of encompasses decomposition, abstraction, algorithm construction, debugging, and pattern recognition, as illustrated in Table 3.1. Of the 22 articles reviewed, eight explicitly identified one or more of these core skills as learning targets or evaluative indicators. One study highlighted algorithmic thinking as the primary focus, which is commonly used as a metric for intervention effectiveness. Approaches correlating CT with problem-solving methods based on Polya's framework were relatively numerous, appearing in eleven studies. Research framing CT as a origin with mathematical thinking and reasoning was very limited, with only two studies. These results suggest that in Indonesia, CT is largely operationalized as a directly measurable skill.

Table 1. Computational Views on Indonesia's Studies

CT Concept	Number of studies	Studies
Core-CT (decomposition/ abstraction/ algorithms/ debugging)	8	[12]–[19]
Algorithmic thinking emphasis	1	[20]
Problem-solving approach	11	[21]–[31]
Integration with mathematical thinking/reasoning	2	[32], [33]

Research on computational thinking (CT) in Indonesian mathematics education reveals diverse conceptual frameworks, but common patterns remain. Most studies conceptualize CT directly as a collection of essential skills, such as decomposition, abstraction, algorithm design, pattern recognition, and debugging. This trend aligns with Wing's (2006) framework, which conceptualizes CT as a fundamental cognitive approach to solving methodological problems. Beyond core competencies, some studies emphasize algorithmic thinking as a crucial aspect of CT. One study used a robotics-based pedagogy to develop skills in algorithmic step composition and debugging [34]. This focus on the algorithmic dimension aligns with global research identifying algorithmic proficiency as the "core" of CT in educational contexts [35]. Furthermore, a group of researchers used a problem-solving framework to conceptualize CT. This perspective emphasizes that CT goes beyond procedural skills to encompass comprehensive mathematical problem-solving strategies. Furthermore, few studies link CT to mathematical thinking or reasoning. One study explored CT's potential to improve mathematical reasoning through a process involving algorithmic representations [18], while another focused on its relationship to students' mathematical argumentation [29]. This scarcity of studies suggests that in Indonesia, CT is viewed more as a measurable technical skill, rather than an epistemic framework integrated with mathematical thinking and modeling methodologies.

In general, conceptualizations of CT in Indonesian research still tend to be procedural-strategic, focusing on easily measurable indicators (algorithms, debugging, patterns). In contrast, more comprehensive conceptualizations, such as CT understood as a form of literacy, a 21st-century competency, or an epistemological pathway to mathematical reasoning, are rarely emphasized. This aligns with the findings of their systematic observational study, which revealed that CT in mathematics classrooms is often implemented as a measurable skill, but has not yet been fully established as a framework capable of transforming students' understanding of mathematics [36]. Thus, the contribution of CT research in Indonesia tends to be stronger in the realm of practical implementation, such as media development or technological interventions, rather than the broader meaning of the concept. Indonesian researchers' conceptions of CT fall into six concepts, namely CT as a problem-solving skill, CT as a computational concept, CT as a data analysis support skill, CT is associated with a certain course, CT as a component of digital literacy, and CT as a teaching approach practice [37].

3.2 CT Mode in Mathematics Learning

CT can be implemented using plugged and unplugged modes, as shown. Based on an analysis of 22 articles shows on Figure 2, most studies on CT in Indonesia reported the use of plugged or unplugged activities, or both. Only two articles did not demonstrate the integration of plugged or unplugged activities in CT research. Both plugged and unplugged activities dominate CT research in Indonesia, accounting for nearly 50%. However, only one study integrated both simultaneously.

Plugged activities included the use of Augmented Reality (AR) [12], Educational robotics within a Personalized Digital Learning Environment (PDLE) [13], Scratch [14], [22], Android interactive e-modules [15], [28], GeoGebra [23], [30], videos [17], and coding-based [20]. Unplugged activities included mathematical problem-solving tests [24]–[26], [29], [32], [38], and worksheets [18], [31]. Other studies used both plugged and unplugged activities simultaneously. In this study, the activities were blended strategies using interactive mobile technologies and task designs.

In general, plugged activities in this synthesis were often used as visual media or to explore concepts. Research integrating plugged activities directly into CT contexts is still rare. Plugged activities are also still very limited to problem-solving tasks and the use of worksheets.

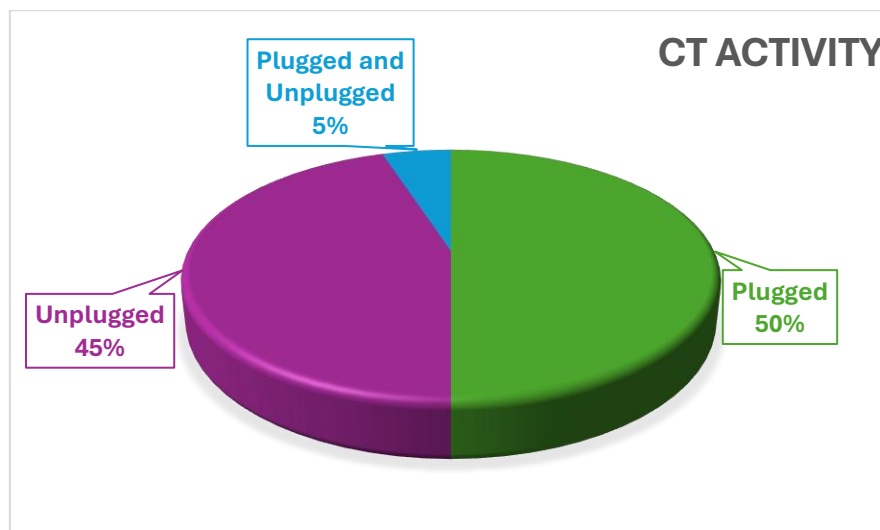


Figure 2. Plugged and Unplugged CT Activity Percentage

Research on computational thinking (CT) in mathematics learning in Indonesia balances the integration of digital technology (plugged-in) and physical or hands-on activities (unplugged). Plugged activities are conducted through various technology-based media integrations. Meanwhile, unplugged activities focus solely on math problem-solving tests and worksheets. Nevertheless, international studies show that the unplugged approach is highly effective during the initial phase of CT learning because it reduces technological complexity, facilitates understanding of step-by-step representations, and acts as a bridge to plugged activities [39]. A meta-analysis study confirmed that unplugged activities such as board games and paper-based exercises significantly enhance CT, particularly in representation, decomposition, and explaining thinking steps [40].

In addition to media, several interventions in the form of learning models can influence students' computational thinking skills. In this case, CT is viewed as a cognitive ability. Personalized digital learning environments (PDLEs) significantly improve students' computational thinking skills, particularly in problem-solving and algorithmic thinking [13]. Furthermore, Kolb's learning style model significantly influences students' understanding of mathematical semiotics and computational thinking related to number patterns [17]. Furthermore, game-based learning (GBL) positively influences computational thinking (CT) skills among elementary school students [28]. Another study examined pre-service mathematics teachers who successfully solved mathematical modeling problems involving epidemics effectively using CT [31].

When CT is viewed as an approach that can be incorporated into learning, several studies support the positive impact of CT integration. One study showed that STEM attitudes have a positive and significant effect on computational thinking skills; while improving STEM attitudes and computational thinking can improve students' 21st-century skills [21]. Computational Thinking (CT)-based teaching practice models can enhance teaching creativity [22]. Integrating computational thinking (CT) components significantly improves prospective teachers' ability to construct algebraic proofs [18]. Other studies also show that integrating CT with media, such as GeoGebra-based Math+CT tasks, effectively encourages a variety of problem-solving strategies [30].

Regarding learning approaches, research conducted in Indonesia indicates that CT integration is most commonly implemented through the STEM/STEAM framework and Problem-Based Learning (PBL). The STEM/STEAM model frames CT as a multidisciplinary skill that connects mathematics with science and technology [24]. Furthermore, the PBL model helps organize the problem space, encompassing problem analysis, algorithmic solution design, and evaluation and debugging. A recent literature synthesis verified that CT integration in PBL is effective when tasks are authentic, data-rich, and include clear iteration cycles [41]. Therefore, pedagogical models such as STEM and PBL can enhance plugged-in and unplugged activities by presenting CT not only as a technical skill but also as a broader mathematical problem-solving strategy. This presentation shows that CT research in Indonesia is still dominated by technology (based on digital media), while pedagogically based approaches (based on learning strategies such as PBL or inquiry) have not received significant attention.

3.3 Research Trend of CT Studies

The third research question in this study is formulated as follows: What are the research trends on computational thinking in Indonesia? This research question aims to examine the patterns and research conducted on computational thinking in mathematics learning in Indonesia. Several factors analyzed in this section are (a) trends in the number of articles published in Scopus journals, (b) the focus of research on computational thinking, (c) the distribution of research methods used, and (d) limitations of the research.

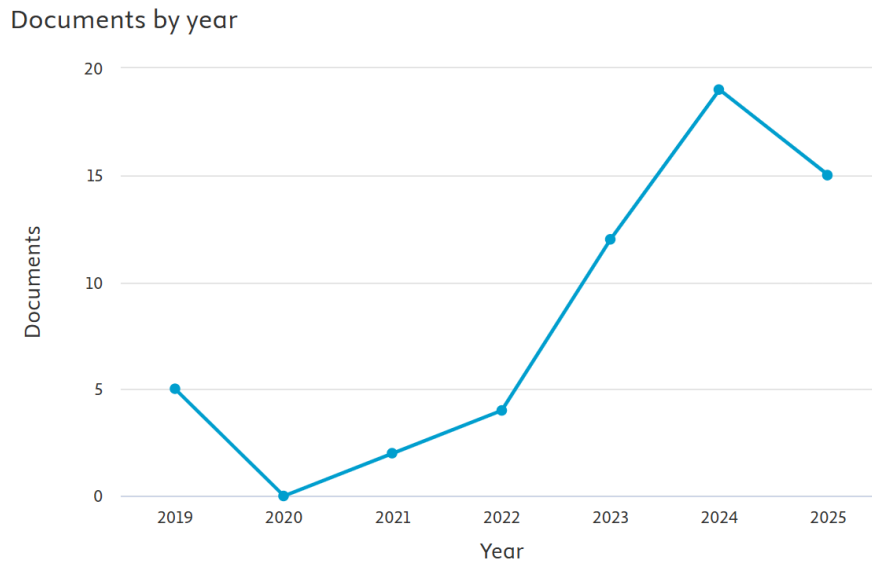


Figure 3. Distribution of articles indexed by Scopus

Computational thinking has become a new variable in mathematics learning research in recent times. Not many articles on computational thinking have been published in Scopus journals. Based on search results from 2016-2025, there were 39 published articles on computational thinking in Indonesia. Figure 3 shows that the first article on computational thinking was indexed by Scopus in 2019. The trend then began to increase from 2022 to the present. This indicates that computational thinking is a truly new topic in mathematics learning in Indonesia.

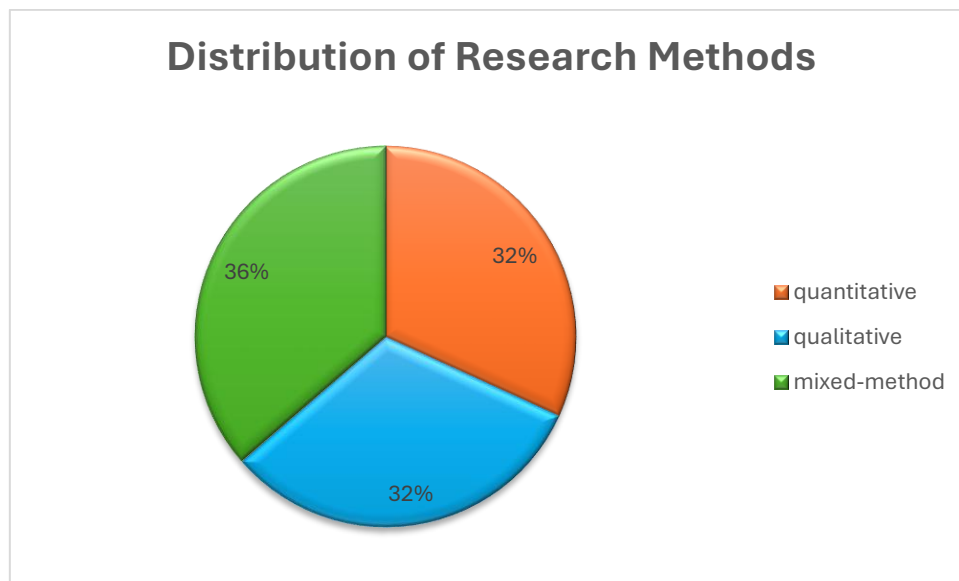


Figure 4. Distribution of Research Methods

Based on the analysis, the research methods used in empirical research on CT in Indonesia are evenly distributed. Quantitative and qualitative methods account for 32%, while mixed methods account for 36%. Many quantitative studies tested interventions for CT skills, such as the use of AR to improve CT skills [12] and the strong relationship between game-based learning and CT [28]. Furthermore, numerous studies explored the relationship between CT and other aspects, such as the positive impact of STEM attitudes on CT [21], the relationship between problem solving and computational thinking [42], and the relationship and influence of CT attitudes on CT skills [24]. Furthermore, studies examined the correlation between CT and Critical Thinking on mathematical modeling [33]. Furthermore, studies examined the effect of learning with computational thinking (CT) concepts using the Scratch program on improving students' mathematical problem-solving skills [14].

Most qualitative studies analyzed problem-solving profiles based on CT components [20], [32], [38] CT abilities [27], [31], or CT thinking processes [26]. In addition, there are studies explaining the components, characteristics, and semiotic features of mathematical and computational thinking [25].

The mixed-methods research described also exhibits several patterns. There are studies aimed at improving computational thinking competencies through various interventions, such as robotics education with PDLE [13] or interactive e-modules [15], the impact of project-based learning (PBL) integrated with flipped classes on high school students' computational thinking skills [17], and the development of Pedagogy and Content Knowledge (TPACK) technology on the achievement of computational thinking skills [23]. In addition, several studies have integrated CT into learning, such as the Computational Thinking (CT)-based teaching practice model [22] and the GeoGebra-based Math+CT task to support students' problem-solving skills and creativity [30]. Other studies have examined CT interventions on other cognitive abilities, namely CT interventions that enhanced students' logical reasoning, proof-writing abilities, and overall engagement with abstract algebra concepts [18]. A study also developed a mathematical cognitive test instrument by integrating the computational thinking (CT) model [29].

Beyond methodological approaches, the duration of interventions and sample sizes were also examined at this analytical stage. Most interventions were brief, typically spanning 1–4 sessions, especially in studies involving e-module/AR implementations. Medium-term interventions, lasting between 5–10 sessions, were observed in research integrating PBL/project-based learning. Conversely, extended studies exceeding one academic semester were virtually absent. As a result, findings often reflect short-term impacts rather than longitudinal development or the sustained enhancement of students' computational thinking capabilities.

A diverse CT assessment instruments were used in the 22 articles reviewed. Disentis. CT evaluations based on core indicators (decomposition, abstraction, algorithms, debugging) represent the predominant format, frequently integrated with mathematics learning outcome tests. Moreover, some studies employ observations or artifacts, such as coding logs or robotic projects, to evaluate algorithmic processes and debugging skills. Conversely, the utilization of standardized tools, including the Brennan & Resnick framework or the Bebras adaptation, remains infrequent; many instruments are researcher-developed with limited empirical validation. Hence, the standardization and adaptation of validated CT assessment tools are essential to facilitate comparability across studies.

An analysis of 32 articles reveals notable research limitations that must be considered when interpreting findings. The most commonly identified constraint is small sample sizes, which restrict the generalizability of results. Additionally, the brief intervention periods impede the evaluation of long-term effects. The range of variables examined remains narrow, with a predominant emphasis on cognitive and learning outcomes; affective domains such as motivation, attitudes, and self-regulated learning (SRL), as well as the transferability to mathematical literacy, are seldom systematically assessed.

4. Conclusion

This systematic literature analysis offers an extensive summary of computational thinking (CT) research in mathematics education in Indonesia covering the years 2018–2025. Analysis of 22 empirical articles shows that CT is most often conceptualized as core procedural skills (decomposition, abstraction, algorithm design, debugging), while broader conceptualizations as mathematical literacy or reasoning frameworks are rarely explored.

The educational aspects examined are mainly within the cognitive domain (problem solving, abstraction, critical thinking), emphasizing mathematics learning outcomes. Affective components such as motivation, attitudes toward STEM, and self-regulated learning are addressed in only a few studies, despite their notable potential to impact CT learning success.

From a methodological perspective, CT research in Indonesia primarily employs short-term quantitative designs with small samples. Qualitative and mixed-methods approaches exist, but their focus is contextual and the CT tools used lack standardization. Frequently cited limitations include small sample sizes, brief interventions, weak instrument validity, and insufficient technological infrastructure.

In practice, plugged-in activities (AR, e-modules, coding, robotics) are widely common, whereas unplugged activities (games, manipulatives, manual problem-solving) have been less explored in research. The incorporation of computational thinking into educational models like STEM/STEAM and Problem-Based Learning (PBL) is starting to develop, but its proportion remains smaller compared to studies focused on digital media. Overall, CT research trends in Indonesia have shown a significant increase since 2020, with a concentration on junior high school students, while research on high school students and in-service teachers is still limited.

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