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Integration And Evaluation of Computational Thinking in Mathematics Education: A Systematic Review of Research 2016-2025

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Abstrak

Penelitian ini bertujuan memetakan bagaimana computational thinking (CT) diintegrasikan dalam pendidikan matematika serta bagaimana CT dan hasil belajar matematika dievaluasi dalam studi empiris terindeks Scopus periode 2016–2025. Tinjauan disusun mengikuti pedoman PRISMA 2020 melalui penelusuran Scopus; penelusuran awal menghasilkan 149 artikel dan 54 artikel memenuhi kriteria inklusi untuk dianalisis. Data diekstraksi lalu dianalisis menggunakan analisis deskriptif dan tematik untuk mengidentifikasi pola integrasi CT–matematika dan pendekatan evaluasinya. Hasil menunjukkan tren publikasi meningkat dengan puncak produktivitas sekitar 2022–2023. Sebaran penelitian didominasi konteks Global North, sehingga transfer model integrasi ke konteks berdaya dukung terbatas perlu dikaji lebih hati-hati. Integrasi CT paling sering berorientasi alat. Dari sisi evaluasi, studi menggunakan beragam asesmen, namun ditemukan ketidakkonsistenan indikator CT dan capaian matematika, penggunaan instrumen yang berdiri terpisah, serta keterbatasan validasi lintas konteks dan jenjang pendidikan, sehingga asesmen autentik yang secara eksplisit mengukur keterkaitan CT dan capaian matematika dalam satu kerangka tugas masih terbatas. Temuan ini menegaskan perlunya pergeseran dari integrasi yang tool-driven menuju concept-driven serta pengembangan asesmen CT–matematika yang lebih autentik dan adaptif, termasuk untuk konteks Indonesia.
Kata Kunci: *Pendidikan Matematika; Computational Thinking; Assessment.*

Abstract

This study mapped how computational thinking (CT) has been integrated into mathematics education and how CT and mathematics learning outcomes have been evaluated in empirical Scopus-indexed research from 2016 to 2025. A systematic review was conducted following PRISMA 2020 guidelines. The initial search retrieved 149 records, and 54 studies met the inclusion criteria for analysis. Data were extracted and analyzed using descriptive and thematic approaches. Findings show a rising publication trend with peak productivity around 2022–2023. Studies were dominated by Global North contexts, raising concerns about transferability to resource-limited settings. CT integration was most often tool-oriented, while unplugged and concrete-manipulative approaches emerged as feasible alternatives. From an assessment perspective, studies employed diverse approaches; however, inconsistencies in CT and mathematics indicators, fragmented measurement of the two domains, and limited cross-context and cross-level validation were evident, indicating that authentic assessments jointly capturing CT and mathematics achievement within a single task framework remain scarce.
Keywords: Mathematics Education; Computational Thinking; Assessment.

I. INTRODUCTION

Computational thinking (CT) is increasingly recognized as a key cognitive competency in the digital society because it provides a systematic framework for formulating problems, designing solutions, and representing data in a structured manner (Wing, 2006). The integration of CT into the science, technology, engineering, and mathematics curriculum makes the position of CT shift from the typical competencies of computer science to the cross-disciplinary literacy required of all learners (Ersozlu et al., 2023; Weintrop, 2016; Zhao & Shute, 2019). Various systematic studies map the increase in interest in CT research in the context of formal and non-formal education so that the expansion of the theme from concept definition to curriculum design, assessment, and learning practice can be seen (Ye et al., 2023). The situation demands a remapping that is more focused on how CT is truly integrated in mathematics learning as well as how its impact on student learning is empirically evaluated.

Mathematics is often seen as aligned with CT because both emphasize abstraction, generalization, symbolic modeling, and systematic algorithmic reasoning (Abidi et al., 2023; Acevedo-Borrega, 2022; Wing, 2006). A number of studies have shown that CT can bridge mathematical concepts and real-world situations through the steps of decomposition of problems, systematic procedure design, and iterative testing of solutions. The results of the study also indicate a reciprocal relationship between mathematics literacy, mathematics learning beliefs, and CT competence so that the strengthening of one aspect has the potential to have an impact on other aspects (Kong et al., 2023; Lee, 2024). This kind of conceptual linkage emphasizes the need for a literature synthesis that examines how CT is manifested in mathematics curriculum, assignments, and pedagogy in more detail.

Indonesia's context faces a similar dynamic because curriculum policies emphasize high-level thinking skills, problem-solving, and digital literacy in mathematics lessons. Classroom practice does not fully reflect this orientation because activities that have the potential to develop CT often appear as additional activities that are separate from the main learning flow. Teachers face limited time, infrastructure, and pedagogical examples when designing explicit mathematics assignments to foster CT at various levels of education. This reinforces the urgency of providing evidence-based references to CT–mathematics integration models that are relevant to contexts with limited carrying capacity such as many schools in Indonesia.

A number of systematic studies have examined CT in general education and in mathematics specifically, but the focus is often fragmented on aspects of curriculum, assignment design, or learning outcomes separately (Lu et al., 2022; Zhong et al., 2016). Reports highlighting the integration of CT in K–12 mathematics place a lot of emphasis on the potential of programming environments and STEM projects, while the mechanisms by which CT supports understanding of mathematical concepts are not always explicitly explained (Bedar,

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2020; H. Ye et al., 2023; Yeni, 2024). Scientific mapping studies that examine CT through mathematics show rapid publication growth, but the relationship between the form of integration and CT–mathematical evaluation strategies has not been systematically mapped (Clark, 2020; Ezeamuzie, 2022; Gadanidis, 2018). These limitations open up space for studies that combine the perspective of integration and evaluation of CT in a single coherent analytical framework. Building on these gaps, the review period needs to be stated explicitly so that the mapping of CT–mathematics integration and its evaluation reflects the field's point of emergence. We therefore set 2016 as the start year because our preliminary Scopus scoping (supported by WATASE) indicated that Scopus-indexed empirical studies explicitly positioning computational thinking within mathematics education begin from that year. Accordingly, the 2016–2025 window is intended to capture both the early stage and subsequent development of CT–mathematics research, while complementing prior SLRs that predominantly address CT in general education or review curriculum, task design, and learning outcomes in a fragmented manner.

This study was prepared as a systematic literature review that aims to map how CT is integrated in mathematics education as well as how CT and mathematics learning outcomes are evaluated in Scopus indexed empirical research in the period 2016–2025. The goal is described into two main research questions, namely how researchers conceptualize and realize the integration of CT in mathematics curriculum, assignments, and pedagogy at various levels. The next question focuses on what approaches, instruments, and indicators are used to evaluate the influence of CT integration on CT competence, math learning outcomes, and student engagement. The results of the answers to these two questions are expected to produce a structured synthesis that can be the basis for curriculum design, learning design, and advanced research agendas in national and international contexts.

II. METHOD

This study uses a systematic review approach to analyze the integration and evaluation of computational thinking (CT) in mathematics education during the period 2016–2025. The preparation and implementation of the review follows the guidelines of PRISMA 2020 (Page et al., 2021), which provides a framework for the process of transparently identifying, screening, and reporting studies. This approach is relevant because systematic review allows researchers to summarize diverse empirical findings, identify thematic patterns, and uncover research gaps as a whole (Cooper, 2015; Petticrew & Roberts, 2008). The literature search was conducted through the Scopus database, which was chosen because it has extensive coverage of reputable international journals and is consistently used in the study of education and learning technology. The search strategy was developed by combining key terms such as computational thinking, mathematics education, mathematics learning, and assessment using Boolean operators. The complete Scopus query syntax was: TITLE-ABS-KEY (("computational thinking in mathematics learning") OR ("computational thinking" AND ("mathematics education" OR mathematics)) OR ("computational thinking" AND assessment)). This approach is in line with the recommendations Gough et al. (2017) which emphasizes the importance of building a comprehensive but focused search strategy. Search limits are set for English-language articles, are empirical and are published between 2016 and 2025. The initial search process resulted in 149 articles. Based on the PRISMA flow generated using WATASE, no records were removed due to duplication (n = 0) and no records were marked ineligible by automation tools (n = 0). Before screening, 19 records were removed for other reasons (Tier 01–04) and one record without an abstract was removed (n = 1), resulting in 129 records screened.

The inclusion criteria were formulated based on the suitability between the study objectives and the content of the article, namely studies that reported the integration of CT in mathematics learning, the use of CT in the context of mathematical activities, or CT evaluations related to mathematics learning outcomes. Theoretical articles, studies that are not relevant to mathematics, articles without abstracts, or articles that are not available in full-text form are excluded from consideration. The approach to determining this criterion is consistent with the principle of a priori selection in systematic review (Gough et al., 2017). The study selection process is carried out in stages following the PRISMA flow. The first stage involved an initial duplication and relevance check, which excluded 19 articles because they were out of the time span or not directly related to the focus of the research, as well as one article without an abstract. Title and abstract screening was conducted on 129 articles and resulted in 43 articles being removed for not meeting the criteria. A total of 86 articles were then attempted to access the full text, but 31 articles were not successfully obtained. After that, 55 articles were assessed for eligibility through a thorough reading, and one article was eliminated at this stage. Thus, 54 articles met all the criteria and were included in the analysis. The PRISMA diagram illustrating the selection process is presented in Figure 1.

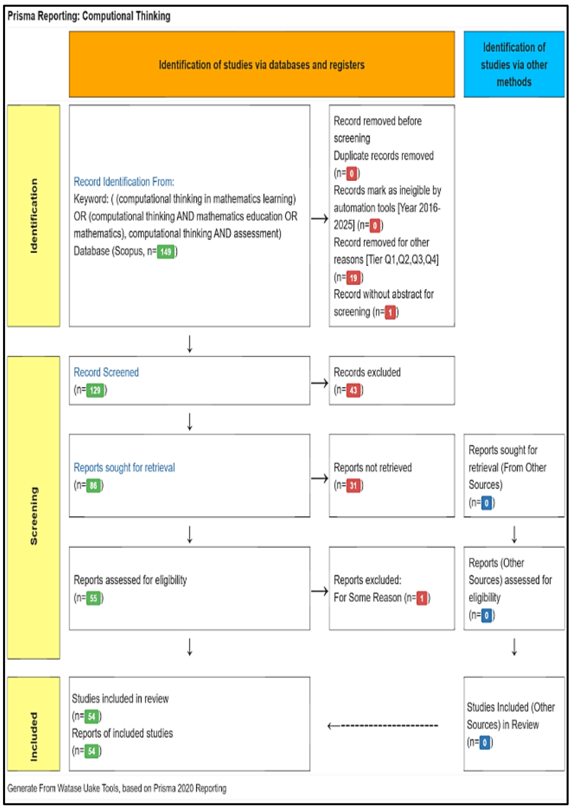

Figure 1. Diagram PRISMA.

Data extraction was carried out using a systematic summary sheet format developed based on analysis guidelines in systematic education review (Cooper, 2015; Gough et al., 2017). Data extraction was carried out using a systematic summary sheet format developed based on analysis guidelines in systematic education review. Thematic analysis was then applied to identify CT integration patterns, mechanisms of CT–mathematics relationships, and evaluation approaches reported in the studies. A narrative synthesis approach was chosen to group and interpret findings, as recommended in a systematic review of diverse educational fields (Petticrew & Roberts, 2008). Through this procedure, the research produces a comprehensive picture of the trends in CT–mathematics integration and reinforcement spaces that are still open to research and educational practice. This review relied on Scopus as a single database; therefore, relevant studies indexed exclusively in Web of Science (WoS) may not have been captured, which may limit the completeness of the evidence base.

III. Result and Discussion

A. Result

1. Publication Trends

Analysis of 54 articles shows a consistent trend of increasing publications in the 2016–2025 period with a peak of productivity around 2022–2023. The initial phase of 2016–2018 was marked by a limited number of publications and the dominance of exploratory studies on the definition of CT as well as pioneering examples of CT integration in mathematics classrooms. The 2019–2021 period saw a shift towards more systematic scientific intervention and mapping studies, including the use of visual programming-based quasi-experimental designs such as Scratch in mathematics learning (Álvaro Molina-Ayuso et al., 2022; Chou, 2020). The 2022–2025 period shows a diversification of research themes that include the relationship between CT and mathematical literacy, learning beliefs, affective variables, and the integration of CT in vocational education and early childhood education. The fluctuations of the study are presented in Figure 2.

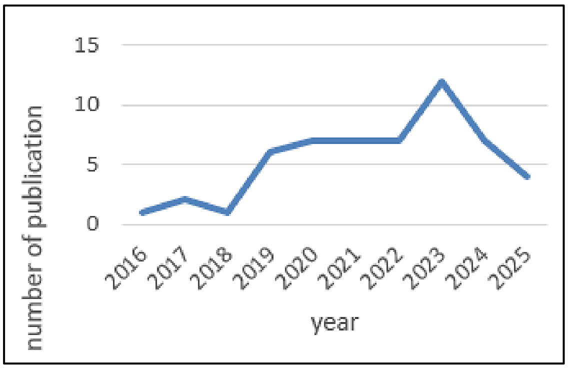

Figure 2. Publication Trend.

This trend indicates that the field of CT–mathematics has entered a maturation phase as research is no longer limited to introducing CT as a new topic, but rather exploring the integration of CT in complex learning ecosystems. This reinforcement can be seen in increasing efforts to link CT with mathematics learning outcomes empirically, both through correlational studies and long-term interventions (Agbo et al., 2023). This situation opens up opportunities to further examine how the quality of assignment design and CT–mathematics assessment develops as researchers pay increasing attention to the evaluation aspect. The results of the chronological mapping also provide a basis for recommendations for a more targeted research agenda for the period after 2025.

The results of the mapping on the Heatmap Matrix emphasized the inequality in existing integration practices. The dominance of algorithm components in almost all mathematical domains confirms that today's integration is still very tool-driven, where learning activities tend to follow the logic of tools such as coding or robotics rather than the conceptual needs of mathematics itself. The Heatmap matrix is shown in Figure 3.

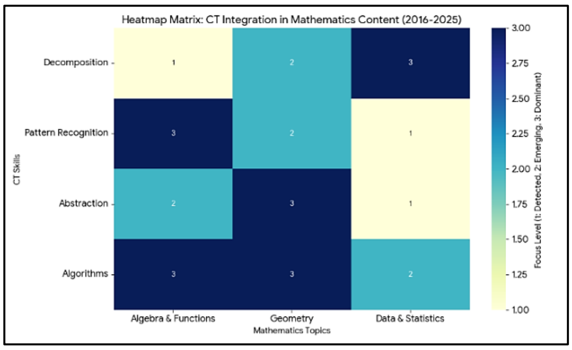

Figure 3. Heatmap Matrix.

This gap can be seen from the low exploration of decomposition components in geometry or abstraction in statistics outside of the digital context. These findings support the need for a shift towards a concept-driven approach, where the selection of CT components is based on the characteristics of the mathematical content being studied, so that CT becomes not only an additional technical skill but becomes an authentically integrated way of thinking in mathematical problem solving.

2. Distribution of Countries and Regions

Sebaran geografis publikasi shows the dominance of the Global North context, especially North America, Europe, and East Asia as the main location of CT research in mathematics education (Acevedo-Borrega, 2022). This dominance is in line with the general pattern of educational research that places a strong infrastructure education system as the main source of empirical data, including in the study of CT integration in mathematics classrooms. Many interventions in the corpus of studies utilize computer labs, specialized programming environments, educational robotics, or licensed digital platforms that require adequate technology support (Rich, 2020; Zapata et al., 2021). This raises critical questions about the extent to which the reported integration model can be transferred in its entirety to a system-limited education system such as many schools in developing countries.

Figure 4. Country Distribution.

A number of studies from limited carrying capacity contexts highlight the use of unplugged activities, concrete manipulatives, and low-cost tools as realistic strategies for growing CT (Sung, 2020; Wang, 2022; Weintrop et al., 2022) (see Figure 4). This alternative approach suggests that CT can be facilitated through tasks that emphasize step structures, patterns, and algorithms without absolute dependence on advanced technology. The findings are relevant to the Indonesian context as many schools face limitations in computer devices and connectivity, while the demands for CT development continue to strengthen. The practical implication is the need to develop a CT–mathematics integration model that is adaptive to the variety of resources and school cultures in various regions.

3. Theoretical Framework

The mapping of theoretical frameworks reveals two main dominant groups, namely constructivist and constructionist learning theories and specific CT frameworks that contain concepts and practices such as decomposition, pattern recognition, abstraction, and algorithmics (Brennan & Resnick, 2012; Wing, 2008). The first group places learners as knowledge builders through problem-solving activities, digital artifact-making projects, and iterative exploration of the program. This emphasis on learning by making is in line with the long tradition of programming as a vehicle for the development of mathematical reasoning in mathematics education (Clarke-Midura et al., 2023; Shute et al., 2017), Specific CT frameworks are generally used to define indicators in assignment design and assessment rubrics so that students' CT practices can be identified more explicitly (Lavigne et al., 2020).

In addition to these two main groups, a number of studies have used cognitive theory to link CT to the development of problem-solving skills, executive function, and high-level thinking skills that are the foundation of learning mathematics (Yang, 2022). Sociocultural perspectives emerged in research that emphasized the collaborative dimensions, social justice, and community context in project-based CT–mathematics activities. The TPACK framework is widely used in teacher education studies because of its focus on the integration of content knowledge, pedagogy, and technology when prospective teachers design CT activities in math lessons. Some articles do not explicitly state the theoretical framework, so the systematic relationship between theory, task design, and CT–mathematical indicators is still weak and opens up space for the development of a more complete conceptual model.

4. Education Level and Learning Context

The distribution of articles by level of education shows the dominance of studies at the primary and K–12 levels, partly secondary, higher education, early childhood education, teacher education, and vocational education. At the primary and K–12 levels, CT integration is generally realized through math problem-solving tasks, data analysis projects, dynamic geometry activities, and block-based visual programming to support the understanding of concepts and procedures (Gadanidis et al., 2016; Humble & Mozelius, 2023; H. Ye et al., 2023). Studies in early childhood education highlight playful activities, concrete manipulatives, and unplugged activities that emphasize the sequencing of steps, patterns, and simple algorithmic thinking (Hadad et al., 2020; W. Kong et al., 2023). Studies at the secondary and higher education levels position CT more in the context of modeling, data analysis, and interdisciplinary courses that combine mathematics and computer science. The distribution can be seen from Figure 5.

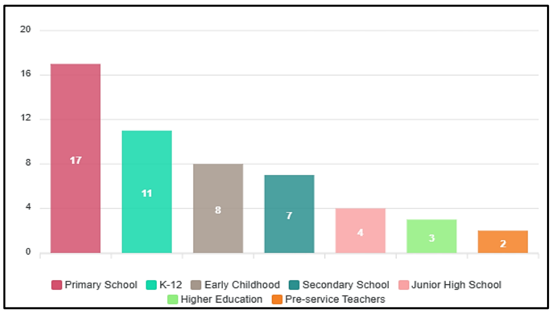

Figure 5. Level Distribution.

The research on prospective teachers and in-office teachers focuses on their understanding of CT, how to interpret the CT–mathematics relationship, and the ability to design and implement learning activities that integrate the two (Humble & Mozelius, 2023). These professional development programs often utilize visual programming environments, assignment design projects, and practical reflection as a means of improving teacher readiness. Studies in vocational education are still relatively limited, but they provide an interesting illustration of the use of CT and mathematics in real-world work contexts such as production planning and data-driven decision-making. The combination of results from different levels suggests the need for a sustainable CT–mathematics development trajectory from early childhood education to higher and vocational education.

The learning context that is the vehicle for CT–mathematics integration is not only formal mathematics lessons, but also other learning environments such as integrated STEM or STEAM classes, robotics clubs, makerspaces, and teacher professional development programs. Routine math lessons typically utilize CT to strengthen understanding of topics such as numbers, geometry, measurements, data, and opportunities through assignments that highlight decomposition, generalization, and diverse representations. The STEM or STEAM context positions mathematics as a quantitative language for science and technology, while CT serves as a cross-disciplinary problem-solving practice in robotics projects, product design, or data investigation (Adnan et al., 2023). The teacher education context serves as a pedagogical laboratory where prospective teachers and in-office teachers experiment with CT–math assignment designs before they are implemented in the regular classroom.

5. CT Tools and Activities

The tools used in CT–mathematics integration can be grouped into unplugged activities, concrete manipulatives, block-based visual programming, educational robotics, as well as mathematics software and data applications. Unplugged and concrete manipulative activities are widely used in the early stages to cultivate the ability to recognize patterns, sequence steps, and understand algorithmic ideas without a computer (Relkin, 2023). Visual programming environments such as Scratch are often leveraged to connect CT with real-world geometry concepts, functions, and situations so that students can model mathematical problems while building programs (Ye et al., 2022). Educational robotics and other physical devices are often used in collaborative projects that combine mathematics, science, and engineering, while GeoGebra, spreadsheets, and data visualization applications support computational modeling and analysis of data (Chen, 2017).

The diversity of tools shows that CT is often present in mathematics classes

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through certain technologies so that the meaning of CT among practitioners has the potential to be very tool-oriented. Too much focus on a particular platform risk obscuring CT as a way of thinking that can be expressed through different types of representations and types of math tasks, including non-digital tasks (Sung, 2017). These findings confirm the need for a more concept-driven integration approach, namely making CT practice the starting point for task design, while the selection of tools is placed as a flexible pedagogical decision. This kind of approach is important for schools with limited infrastructure because CT development can still be done through carefully designed math tasks without a strong reliance on specific devices.

6. CT Evaluation in Mathematics Learning

Some articles in the corpus of studies develop or utilize specific instruments to assess CT competence in a mathematical context, while others only include CT assessments on a limited basis. Types of assessment that have emerged include performance-based assessments that are integrated into the curriculum, unplugged assessments based on observation or interviews, computer-based CT tests, multiple-choice instruments and self-report questionnaires, and mixed assessments that combine CT indicators and mathematical achievement (Cutumisu et al., 2019; Guggemos et al., 2023). An example of performance assessment is seen in authentic tasks designed using evidence-centered design principles so that CT practice and understanding of mathematical content can be assessed simultaneously (Clarke-Midura, 2021; Clarke-Midura et al., 2023). Unplugged instruments such as TechCheck and early CT formative assessments utilize non-digital challenges to assess early childhood CT ability psychometrically as well as qualitatively (Relkin, 2023).

Computer-based CT tests are widely used in longitudinal studies that monitor the development of students' CT practices, while psychometric instruments such as CTt and CTS assess the performance of CT as well as the disposition of adolescent CT (Brennan & Resnick, 2012; Guggemos et al., 2023). A number of studies have combined CT measurements with mathematical literacy, math learning beliefs, and affective indicators so that the relationship between mathematics and CT can be analyzed through structural statistical models (Kong & Wang, 2023). The assessment landscape appears to be diverse, but the number of instruments designed to capture the interconnectedness of CT and math learning outcomes in a single authentic framework is still limited. Cross-contextual and cross-level validation of such instruments is also not optimal, so claims about the impact of CT integration on mathematical achievement need to be interpreted with caution.

7. Synthesis of Main Patterns

The synthesis of findings shows three main patterns, namely the tendency of tool-oriented CT integration, the inequality between the intensity of integration and the quality of CT–mathematics assessments, and the diversity of theoretical frameworks that are not fully connected to task design and evaluation. The first pattern appears in the dominance of studies that place programming, robotics, or certain software as the main entry points of CT in math lessons, while non-digital CT practices are relatively underexplored. The second pattern can be seen in the many learning designs that integrate CT without being followed by CT measurements and mathematics learning outcomes through instruments that are explicitly designed based on theory. The third pattern is characterized by the use of various conceptual frameworks without always following a clear mapping between theory, CT practice, mathematical content, and assessment indicators, so that an integrative model is still needed that is able to bridge these four aspects.

B. Discussion

The results confirm that the integration of CT in mathematics education has evolved into an increasingly rich and complex area of study, in line with the recognition of CT as an essential 21st century skill (Maharani, 2019; Wing, 2006). The literature map also shows fundamental issues that are important to be criticized, especially related to the orientation of the tools, the quality of the assessment, the consistency of the theoretical framework, and the relevance of the context. The orientation of the tool is seen when CT is practiced mainly through the use of certain programming environments or robotics until CT is often matched with the activity of coding or moving the device. This situation has the potential to reduce CT to a purely technical skill and mask its nature as a way of thinking that can be realized in various forms of mathematical tasks, including paper-pencil-based and concrete manipulative tasks.

In the evaluation area, the review showed a gap between the intensity of CT integration discourse and the availability of high-quality CT–mathematics assessments. In addition, this review highlights a practical paradox. Although CT–mathematics instruction is frequently designed in innovative ways (e.g., project-based and constructionist approaches supported by programming tools, robotics, or software), the reported assessments often remain conventional or are administered as stand-alone measures that are not tightly aligned with the learning tasks. This misalignment may reflect classroom constraints and research design trade-offs. Paper–pencil tests tend to be familiar, time-efficient, and easier to score within existing school routines, which may explain why they persist even when learning activities are tool-rich and exploratory. At the same time, the diversity of CT tools and contexts can make it difficult to keep indicators stable. This is consistent with our finding that authentic assessments jointly capturing CT and mathematics achievement within a single task framework are still limited and that cross-context validation is not yet optimal.

The consequence is not merely methodological. When assessment formats do not preserve the CT practices enacted during learning, students may receive limited feedback on decomposition, pattern recognition, and algorithmic reasoning as part of mathematical problem solving. Moreover, evidence building becomes harder. Weak alignment between pedagogy and assessment can lead to underestimation of CT-related learning gains and reduce comparability across studies.

Several feasible solutions emerge from the synthesis. First, future interventions can embed integrated performance tasks in which students must demonstrate CT practices and mathematical understanding simultaneously, supported by analytic rubrics. Second, adopting an evidence-centered design logic can help make the assessment claims explicit and align tasks, evidence, and scoring. Third, when digital testing is not feasible, unplugged or low-cost assessment formats (e.g., structured non-digital challenges plus observation-based scoring) can still elicit CT practices within mathematics tasks.

Finally, to reduce fragmentation, future studies should report how CT indicators are mapped to the theoretical framework and task design, and prioritize cross-context and cross-level validation. Many studies report the positive impact of CT integration on motivation, concept understanding, or mathematical problem-solving ability without using instruments that explicitly combine CT indicators and mathematical indicators. The existence of instruments such as TechCheck, early CT formative assessment frameworks, and computer-based CT tests demonstrate important advances, but direct integration of such instruments into mathematical task design is still rare (Clarke-Midura et al., 2023; Relkin, 2020). This suggests that the impact of CT integration on mathematics learning needs to be examined more systematically through the development of authentic assessments that are grounded in theory and validated across contexts (Guggemos et al., 2023).

The diversity of theoretical frameworks used in CT–mathematics studies has the potential to enrich the understanding of how CT and mathematics interact, but that potential has not been fully optimized. Many articles simply briefly mention the theoretical framework as the background without explicitly attributing it to variable constructs, CT practice indicators, or the design of the mathematical task being analyzed. This condition makes it difficult to build a cross-study conceptual model on how CT integration affects students' mathematics learning processes and outcomes. This study contributes by organizing the literature based on a combination of levels, learning contexts, and theoretical lenses so that relatively dense and rarely touched areas can be identified more sharply.

The context aspect emerged as an important issue because the majority of CT–mathematics intervention designs were developed in education systems with high-tech access, while many countries, including Indonesia, faced limited facilities (H. Ye et al., 2023). An advanced robotics-based intervention model or a complete computer lab may not necessarily be widely applicable in schools that still rely on minimal facilities and an imbalanced ratio of devices to the number of students. Positive findings from studies using unplugged activities, concrete manipulatives, and low-cost tools provide a more realistic alternative to CT–mathematics integration pathways for contexts with limited carrying capacity (Zeng et al., 2023). This study confirms that the adaptation of learning design and CT–mathematics assessment needs to consider local conditions so that CT integration is not only a demand of the curriculum on paper, but also a sustainable pedagogical practice in the classroom.

The role of teachers and prospective teachers emerges as a determining factor for the success of CT integration because they become the main actors who interpret CT, choose tools, and design math assignments in the classroom (Humble & Mozelius, 2023). The amount of research that in-depth examines teachers' learning processes about CT–mathematics, including changes in pedagogical beliefs, mastery of CT assessments, and practical reflection, is still limited. A follow-up research agenda that involves teachers as partners in the design and evaluation of interventions, for example through long-term design-based research, has the potential to make a significant contribution to the understanding of the sustainability of CT–mathematics integration. This study proposes that future research focus on the development of more concept-driven learning designs, validated CT–mathematics assessment instruments, as well as longitudinal studies that trace the impact of CT integration over time at various levels.

IV. Conclusion

This systematic literature review concludes that the integration of CT in mathematics education is growing rapidly during the period 2016–2025 with increasing publication trends, diversification of contexts, and the use of diverse tools. CT is integrated through regular math lessons, STEM or STEAM projects, teacher professional development programs, and non-formal learning ecosystems such as robotics clubs and makerspaces. The integration practice is supported by a variety of theoretical frameworks that include constructivism, specific CT frameworks, cognitive theory, sociocultural perspectives, and TPACK models. Strong integration orientation in certain tools, limitations of CT–mathematics assessment, and inconsistency in theoretical utilization remain major problems that need to be addressed in research and educational practice. This review underscores the importance of shifting from a tool-driven approach to a concept-driven approach so that CT practice, mathematical content, and task context become the first focal point, while tool choice is supportive. The development of authentic assessments that bring together CT indicators and math learning outcomes is a priority because such assessments allow researchers and teachers to more accurately assess the effectiveness of CT integration. Cross-contextual and cross-level validation of these instruments is necessary so that conclusions about the impact of CT integration can be generalized responsibly. Strengthening the dimensions of this assessment will help bridge the gap between theoretical claims regarding the advantages of CT and the empirical evidence supporting those claims. For the Indonesian context, the results of this study show that CT-mathematics integration needs to be directed at assignment design that takes into account the limitations of infrastructure, the diversity of students' backgrounds, and the characteristics of the national curriculum. Unplugged, concrete manipulative activities, the use of simple spreadsheets, and a relatively lightweight visual programming environment can be a realistic integration strategy option in many schools. Prospective thesis researchers are encouraged to develop intervention and assessment studies that focus on the specific relationship between specific CT practices and understanding of mathematical concepts at a clear level and context. The development of design-based research, longitudinal studies, and strengthening teacher education on CT-mathematics are promising research directions to enrich empirical evidence and support the transformation of mathematics learning in Indonesia. his review has several limitations. First, it relied on a single database (Scopus), so studies indexed exclusively in other databases (e.g., Web of Science) may not have been captured. Second, the scope was limited to English-language empirical articles published between 2016 and 2025, and some potentially relevant full texts could not be retrieved during screening, which may affect coverage. Despite these constraints, this study contributes to mathematics education by offering a structured synthesis that connects CT–mathematics integration (forms, tools, and pedagogies) with evaluation strategies, thereby clarifying where evidence is strong and where assessment gaps persist. The findings imply that future CT–mathematics work should prioritize concept-driven task design and alignment between instruction and assessment, including feasible performance-based or unplugged assessment formats for resource-limited settings. Future research should (a) develop authentic CT–mathematics assessments that capture CT practices and mathematical understanding within a single task framework, accompanied by transparent analytic rubrics; (b) strengthen cross-context and cross-level validation to improve comparability; (c) employ longitudinal and design-based approaches to examine learning trajectories and the sustainability of impacts; and (d) investigate teacher assessment literacy and implementation constraints to support scalable classroom adoption.

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