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Coding-based instruction for developing computational thinking in primary education: a systematic review

Rohmadi Purwono^{1*}, Murbangun Nuswowati², Bambang Subali³, Ellianawati⁴

¹Elementary Education Study Program, Universitas Negeri Semarang, Semarang, Indonesia

²Chemistry Education Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Semarang, Indonesia

^{3,4}Physics Education Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Semarang, Indonesia

*Corresponding author's e-mail: rohm@students.unnes.ac.id

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Keywords:	Abstract
coding; computational thinking; primary school	<i>The integration of computational thinking (CT) into elementary education is increasingly viewed as essential for developing students' problem-solving and digital literacy skills. However, effective implementation of CT-based instruction through coding remains varied in practice. This study aims to synthesise empirical evidence on how coding supports CT development in primary school students. A systematic literature review was conducted following PRISMA guidelines, with an initial identification of 1145 records from Scopus and Google Scholar. After removing 104 duplicates, 1041 titles and abstracts were screened, and 113 full-text articles were assessed for eligibility. Based on the inclusion criteria, five empirical studies published between 2021 and 2025 were selected. Thematic analysis revealed that instructional approaches such as unplugged activities, educational robotics, and pair programming effectively enhanced core CT skills—abstraction, decomposition, and algorithmic thinking—while also promoting student engagement and collaboration. However, persistent barriers include limited teacher readiness, inadequate assessment tools, and unequal access to technology. The study concludes that early exposure to structured coding interventions positively influences CT development. To ensure sustainability and equity, future efforts must focus on teacher training, culturally responsive pedagogy, and integration of CT into the broader curriculum. This review provides a focused synthesis that can guide educational stakeholders in designing and supporting effective CT instruction at the primary level.</i>

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INTRODUCTION

Background of the Study

Computational thinking (CT) is increasingly recognised as a vital skill that young learners must acquire to effectively navigate the demands of the 21st century. In elementary education, the integration of CT principles enhances problem-solving capacities and prepares students for subsequent educational challenges in areas such as science, technology, engineering, and mathematics (STEM). CT's foundational elements, such as problem decomposition, pattern recognition, abstraction, algorithmic thinking, and iterative testing, enable learners to approach problems methodically (Ching & Hsu, [2023](#)).

As educational policies worldwide move toward embedding CT into primary curricula, early exposure to these skills becomes increasingly relevant. Robotics, for instance, has emerged as a powerful tool for cultivating CT skills in young learners through interactive and developmentally appropriate programming tools that support creativity and hands-on learning. These tools not only engage children but also encourage them to collaborate and solve problems in structured ways, enhancing their algorithmic thinking (Chaldi & Mantzanidou, [2021](#)). Recent studies in elementary settings emphasise that effective learning must integrate material with the context of critical thinking and local wisdom to be truly impactful. However, analyses of teaching materials indicate that the distribution of intelligence stimulation in textbooks is often uneven, with a heavy dominance of linguistic and spatial intelligences at the expense of others, such as musical or existential intelligences (Adam et al., [2025](#)).

The literature further emphasises the role of CT in promoting equity and inclusion in digital learning environments. Gender and socio-cultural biases that may hinder participation in STEM are areas of concern, with early interventions being vital to ensure equal access to CT skill development (Angeli & Georgiou, [2023](#)). These findings underscore the relevance of introducing CT in elementary education, not just as a technological skill but as a foundational cognitive tool that enables diverse learners to thrive across disciplines. Furthermore, curriculum analysis indicates that for materials to be effective, they must be strictly aligned with the thematic integration required by current curricula, ensuring that competencies are not taught in isolation.

The Problem of The Study

Despite the growing emphasis on integrating computational thinking (CT) into elementary education, practical implementation continues to face considerable challenges. A major concern lies in the inconsistencies between educational policy directives and classroom-level practice. Although several national education systems have incorporated coding and CT into their curricula, many teachers lack the training and confidence needed to deliver these concepts effectively (Hudin, [2023](#)). This issue is exacerbated by the fact that professional development models for teachers are often sporadic and lack the continuous, integrative support needed to improve basic education quality.

This disconnect creates an implementation gap where CT is either underutilised or introduced superficially. Moreover, the limited availability of resources, particularly in underfunded schools or rural areas, exacerbates these issues. Educators also encounter difficulties in designing lesson plans that align CT objectives with subject content (Saidin et al., [2021](#)). These issues are compounded by the lack of standardised assessment tools, making it difficult to evaluate CT skill acquisition among young learners. Recent research highlights that assessment plays a crucial role in the educational process, allowing teachers to evaluate understanding and provide feedback, yet this remains a weak point in many technological implementations (See et al., [2022](#)).

Addressing this problem requires not only the development of teacher competencies but also a systematic review of current practices. It is within this context that this study aims to critically examine how CT is being implemented through coding and unplugged activities at the elementary level.

Research's State of the Art

The integration of computational thinking (CT) into primary education has attracted substantial scholarly interest over the past decade, driven by global shifts toward digital literacy and problem-solving-based learning. CT, defined by its core competencies such as abstraction, decomposition, algorithmic thinking, and debugging, is increasingly recognised as a necessary cognitive framework for students in early education (Ching & Hsu, [2023](#)). Initial efforts to introduce CT in elementary schools often relied on visual programming platforms such as Scratch, with subsequent studies expanding to include educational robotics, game-based learning, and unplugged activities (Chaldi & Mantzanidou, [2021](#)). This diversification of pedagogical approaches reflects a growing consensus that CT is not exclusive to

computer science, but is a transdisciplinary competence relevant across STEM fields and beyond. Countries like the UK and Estonia have institutionalised CT instruction in early education, influencing research trends that emphasise both curricular integration and instructional design (Ye et al., [2023](#)).

Recent literature has shifted toward examining the impact of coding-based interventions on students' cognitive development and engagement. Studies demonstrate that even young learners can grasp complex CT principles when instruction is scaffolded and contextualised within age-appropriate activities (Angeli & Georgiou, [2023](#); Ibrohim et al., [2023](#)). This includes unplugged coding methods, which emphasise tactile, collaborative learning without the use of digital devices, allowing for equitable access to CT regardless of socioeconomic background (Threekunprapa & Yasri, 2020). Further supports the view that CT can be meaningfully developed through robotics and maker-based education, where students actively design, build, and iterate on problem-solving tasks. The success of such interventions is often linked to the presence of teacher training, curriculum support, and structured learning environments that promote inquiry and experimentation (Barbosa & Vale, [2025](#)).

Despite growing empirical evidence supporting CT's integration in primary education, existing research still presents critical gaps and inconsistencies. Many studies focus on short-term interventions without longitudinal insight into how CT competencies evolve (Hudin, [2023](#)). Additionally, there is limited agreement on how CT should be assessed, particularly in informal or unplugged learning contexts (Sungkaew et al., [2022](#); Battal et al., [2021](#)). Research by Washbrooke ([2023](#)) also highlights ongoing challenges in teacher preparedness and policy alignment, indicating a need for scalable models that can bridge theory and classroom practice. While the body of evidence suggests that CT instruction is beneficial and feasible at the primary level, the field requires more systematic exploration of curriculum integration models, assessment frameworks, and the socio-cultural factors influencing CT acquisition. The present study seeks to address these gaps by synthesising recent literature from 2021 to 2025 to establish a comprehensive understanding of how CT is being taught, learned, and evaluated within the scope of elementary education.

For example, unplugged activities have been shown to support early abstraction and logical reasoning, especially when digital tools are not accessible (Threekunprapa & Yasri, 2020). These methods are increasingly adopted in resource-

constrained schools as viable strategies for CT development (Harper et al., [2024](#); Zhan et al., [2022](#)).

Novelty, Research Gap, & Objective

The novelty of this study lies in its focused examination of how coding-based instructional interventions between 2021 and 2025 have been used to develop computational thinking (CT) skills in primary school settings. While earlier systematic reviews have addressed CT in broader or secondary education contexts, few have exclusively investigated elementary education by using recent empirical data filtered through rigorous inclusion criteria. This study uniquely synthesises various instructional models—such as unplugged coding, robotics-based learning, and interdisciplinary integration—offering an up-to-date panorama of pedagogical innovation in CT instruction. Furthermore, this review incorporates a detailed mapping of how cultural responsiveness, equity, and technology access intersect with the development of CT, presenting a nuanced perspective that moves beyond traditional STEM-centred discussions. Through this lens, the study contributes a holistic and practical framework that can inform educators, policymakers, and curriculum designers alike.

Despite the growing body of research on computational thinking, notable gaps remain, particularly in terms of longitudinal evidence, cross-contextual analysis, and evaluation methods. Much of the current literature relies on isolated case studies or short-term interventions, limiting generalizability and policy translation. Additionally, few studies provide robust comparisons between plugged and unplugged CT approaches in early education or explore how teacher preparedness and curriculum design influence implementation success. The absence of standardised CT assessment tools further complicates efforts to measure student progress and instructional impact accurately. Another significant gap involves the limited exploration of how CT can be effectively embedded into non-STEM subjects, such as language arts or social studies. These limitations suggest a need for comprehensive, integrative studies that draw from diverse methodologies and contexts to establish scalable models of CT education at the primary level (Mertens & Colunga, [2025](#)).

Despite existing research, there remains limited synthesis on the effective modalities—such as unplugged approaches or robotics—used to cultivate CT in diverse elementary classroom contexts (Chaldi & Mantzanidou, [2021](#)). This study

bridges this gap by systematically identifying pedagogical patterns and outcomes from recent empirical works.

In response to these gaps, the primary objective of this study is to conduct a systematic literature review of peer-reviewed articles published from 2021 to 2025 that investigate the integration of coding in elementary education and its effect on students' computational thinking development. The study aims to (1) identify common instructional strategies and pedagogical models used to foster CT in primary classrooms; (2) evaluate the cognitive, social, and academic outcomes reported in empirical studies; (3) map emerging trends and innovations in CT instruction; and (4) highlight contextual factors—such as teacher readiness, access to technology, and cultural responsiveness—that influence implementation success. By consolidating these findings into a coherent framework, the study intends to guide educators, researchers, and curriculum developers in designing more effective and equitable CT learning environments for young learners. Ultimately, the review seeks to contribute both theoretically and practically to the discourse on 21st-century skills in early education (Muñoz et al., [2023](#)).

METHOD

Type and Design

This study employs a Systematic Literature Review (SLR) approach to examine the integration of computational thinking (CT) in elementary education through coding-related instructional strategies. The SLR method was selected due to its structured and replicable procedures for identifying, analysing, and synthesising existing research findings (Mukasheva & Omirzakova, [2021](#)). By adopting this approach, the study aims to provide an evidence-based overview of effective pedagogical interventions that support CT development in young learners. The systematic nature of the SLR ensures that all included studies meet clearly defined criteria, reducing the risk of bias and enhancing the reliability of findings. This method allows the study to move beyond anecdotal or fragmented reports by drawing on a curated body of empirical evidence that reflects global trends, challenges, and innovations in the field.

The design of this systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The PRISMA protocol provides a step-by-step guideline for conducting systematic reviews, encompassing identification, screening, eligibility, and inclusion stages. This model

ensures transparency in the selection process and helps to delineate the scope of the review accurately. By adhering to PRISMA, this study maintains a high level of methodological rigour, documenting each stage of article selection and providing justification for inclusion or exclusion. This structured approach facilitates replication and comparison with future studies, further contributing to the body of knowledge in computational thinking education.

The review focuses on empirical and peer-reviewed studies published between 2021 and 2025, aligning with the recent surge of interest in CT integration at the elementary level. Studies were selected based on their explicit focus on CT skills and their application in primary school settings, through either unplugged or technology-based coding activities. The review excluded theoretical discussions, editorials, or studies focused on higher education or adult learners to maintain clarity and relevance. The combination of this narrow time window and targeted scope enables the study to generate a contemporary snapshot of how educators are currently implementing CT in early schooling environments.

Overall, the design rationale rests on the need to consolidate fragmented findings across diverse instructional practices into a coherent synthesis. Through methodical screening and critical evaluation of selected studies, this review aims to uncover patterns related to the types of CT skills most frequently developed, the teaching methods employed, and the contextual factors influencing implementation success. The emphasis on coding and CT within elementary education distinguishes this review from previous studies that addressed broader age groups or focused solely on digital tools. This specificity enables actionable insights for curriculum developers and educators seeking to optimise CT instruction for younger learners.

Data and Data Sources

The data used in this systematic review consisted of peer-reviewed journal articles and conference proceedings obtained from two major academic databases: Scopus and Google Scholar. These platforms were chosen for their comprehensive coverage of educational research, particularly in the areas of computational thinking (CT), programming education, and pedagogy in primary school settings. Scopus, known for its rigorous indexing and quality control, ensured that selected studies met high academic standards, while Google Scholar offered broader access to emerging literature, including open-access and interdisciplinary publications that may not yet be fully indexed in commercial databases. The use of both platforms enabled a diverse

yet high-quality pool of research studies, ensuring both depth and breadth in the literature selection.

The initial search strategy involved combining specific keyword terms aligned with the focus of this review. Keywords included “computational thinking,” “coding,” “programming,” “primary school,” “elementary education,” and “unplugged activities.” Boolean operators such as AND and OR were used to refine and expand the search, ensuring relevance while minimising the exclusion of potentially important studies. For example, search strings like “computational thinking AND primary school” or “coding OR programming AND elementary education” helped identify studies where CT was a central pedagogical objective. The time filter was set between January 2021 and April 2025, reflecting the study’s emphasis on recent trends and innovations in instructional practices for early learners.

Each article retrieved was screened manually to assess its relevance and alignment with the inclusion criteria of this study. Articles were considered if they explicitly discussed CT skills and were implemented within an elementary or primary school context. Studies targeting early childhood (e.g., preschool) were included only if they addressed students aged five or older and connected the intervention to structured learning outcomes. Articles that primarily targeted middle school, secondary, or higher education populations were excluded. The screening also ensured that included studies were empirical in nature, involving quantitative, qualitative, or mixed-methods approaches, and reported on measurable outcomes or teaching strategies relevant to CT development.

In total, the initial search yielded 1,145 articles, of which 87 were deemed potentially relevant based on title and abstract screening. Following full-text review and alignment with inclusion criteria, only 15 articles met the eligibility standards for detailed analysis. Among these, five articles were selected as the final corpus for data extraction due to their methodological clarity, focus on elementary education, and explicit discussion of CT skill outcomes. These articles form the empirical basis of this review and offer insight into various pedagogical practices for fostering computational thinking through coding and unplugged activities in primary school settings.

Data Collection Technique

The data collection technique in this systematic literature review followed a multi-phase filtering process based on the PRISMA framework, ensuring rigor, transparency, and replicability. The process began with an initial identification of

studies through the keyword-based search strategy described earlier. All articles retrieved were compiled into a spreadsheet where relevant metadata such as author names, publication year, title, abstract, and source URL were recorded. This initial compilation enabled efficient categorisation and initial screening based on relevance, duplication, and scope. Duplicate articles, non-academic sources, and those lacking abstracts were eliminated, resulting in a refined list of potentially eligible studies.

In the screening phase, titles and abstracts were reviewed to determine alignment with the predefined inclusion criteria. Specific attention was given to whether the studies: (1) were conducted within elementary or primary education settings, (2) addressed computational thinking (CT) explicitly, and (3) involved the use of coding or programming-based instructional strategies, including unplugged methods. Articles that only mentioned CT tangentially or without empirical grounding were excluded. During this phase, multiple rounds of discussion and verification were employed to resolve ambiguities and ensure that no relevant studies were overlooked due to a narrow interpretation of abstracts.

The eligibility phase involved a full-text review of the shortlisted studies to assess methodological soundness and the presence of clearly articulated findings related to CT development. Only studies that included empirical data—quantitative, qualitative, or mixed-methods—were retained. Descriptive conceptual papers, editorials, or policy discussions without direct classroom interventions or outcome measurements were excluded. Additionally, studies were excluded if they did not detail specific CT skills developed, such as algorithmic thinking, abstraction, decomposition, pattern recognition, or debugging.

The final inclusion phase yielded five core studies, which formed the primary data set for in-depth extraction and analysis. Each article was examined for details on research objectives, sample characteristics, instructional strategies, CT skills assessed, and key findings. Data extraction was conducted using a structured matrix that allowed for consistent comparison across studies. This process facilitated the identification of emerging themes, patterns of instructional practice, and the range of CT competencies addressed. The meticulous data collection technique adopted in this review ensured the credibility, traceability, and validity of the synthesised findings, as shown in Table 1.

Table 1. Summary of the five empirical studies included in this review, detailing their origin, methodology, educational level, and computational thinking focus.

Author (Year)	Country	Education Level	Methodology	Focus of CT	Key Findings
Ching & Hsu (2023)	USA	Primary	Systematic Review	Algorithmic Thinking	Robotics improves CT among young learners
Zhan et al. (2022)	China	Primary	Quasi- Experimental	CT & Interaction	Unplugged aids enhance CT and classroom interaction
Peel et al. (2022)	USA	Primary	Qualitative	CT Integration in Science	Unplugged strategies support algorithmic learning in science
Ibrohim et al. (2023)	Indonesia	Primary	Meta- Analysis	Scratch- based CT	Scratch significantly boosts CT performance
Battal et al. (2021)	Turkey	Primary	Systematic Review	Unplugged CT activities	Systematic review supports unplugging as an effective method

Data Analysis

The data analysis stage in this systematic review involved a qualitative synthesis and thematic categorisation of the five selected studies. Each article was examined using a structured data extraction matrix that captured variables such as study context, research design, participant demographics, instructional approaches, and the specific computational thinking (CT) skills targeted. The CT skills considered included decomposition, pattern recognition, abstraction, algorithmic thinking, and debugging, in accordance with widely accepted CT frameworks (Ching & Hsu, 2023).

This structured approach allowed for cross-case comparison and ensured that key educational elements were consistently captured across the diverse studies.

A central focus of the analysis was identifying instructional strategies used to develop CT skills in elementary learners. These strategies were coded into categories such as visual programming environments, educational robotics, unplugged activities, pair programming, and project-based learning. The frequency and context of each strategy's use were noted, providing insight into both popularity and pedagogical suitability. For instance, visual tools like Scratch were noted for their high frequency and accessibility, while robotics and unplugged methods were linked to deeper conceptual engagement in specific contexts. This coding enabled the development of a taxonomy of instructional methods mapped to the CT competencies they most effectively fostered.

Descriptive statistics were used to identify and present publication patterns across the included studies. As illustrated in Figure 1, the number of publications focusing on computational thinking in elementary education demonstrated a steady increase between 2021 and 2025, peaking in 2023. This upward trend reflects a growing scholarly interest in the integration of coding and computational thinking within primary education settings. The publication data provide foundational context for understanding the scope and focus of empirical work conducted during the selected period.

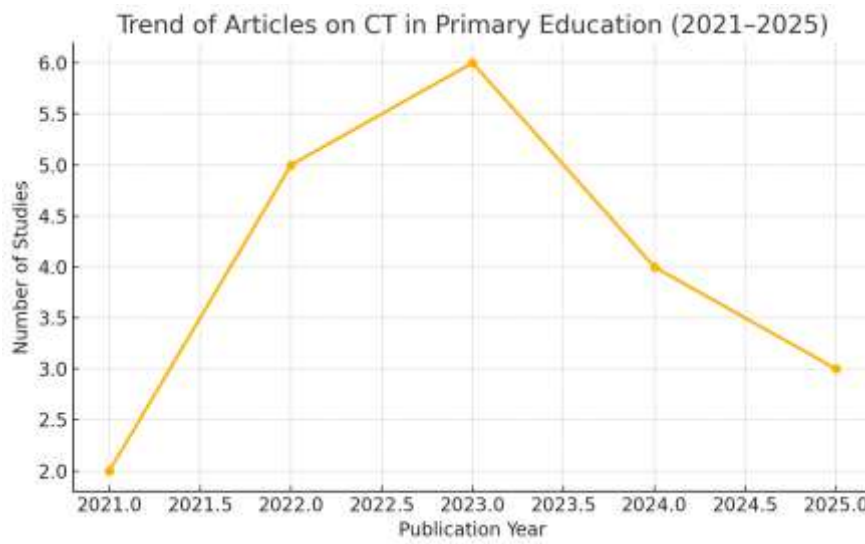


Figure 1. Publication Trends on Computational Thinking in Elementary Education (2021–2025)

The study selection process was systematically conducted following PRISMA guidelines. As shown in Figure 2, the initial search across Scopus and Google Scholar yielded 1,145 articles. After removing duplicates and applying inclusion and exclusion criteria, only five empirical studies met all eligibility requirements and were included in the final synthesis. The flow diagram visually outlines each phase of the selection process, thereby enhancing transparency and replicability. This visual aid complements the narrative synthesis by clearly mapping the filtering steps used to curate relevant literature.

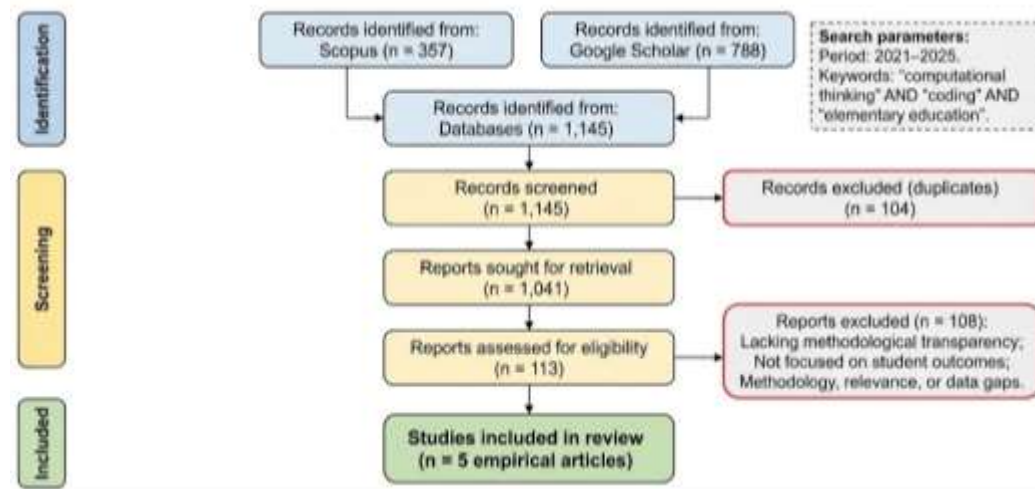


Figure 2. PRISMA Flowchart

Lastly, findings were triangulated by comparing reported outcomes with theoretical expectations from existing literature. This validation step reinforced the credibility of conclusions drawn from the reviewed data and allowed for the identification of gaps in current research, particularly regarding underrepresented skills such as debugging or cultural dimensions of CT instruction. The outcome of this analytical process formed the foundation for the discussion section, which interprets these findings in light of existing pedagogical theory and practice.

RESULTS

1. Research Methods Used in the Selected Studies

The selected articles in this systematic review employed a variety of research methodologies, reflecting the diverse approaches used to investigate computational thinking (CT) development in elementary education. Three out of five studies utilized experimental or quasi-experimental designs to assess the causal relationship

between specific interventions and CT outcomes. For example, Angeli (2023) used a controlled experiment to test scaffolded programming scripts. These methods allowed for precise measurement of instructional impact. In contrast, two studies—Nordby et al. (2022) employed case study and qualitative designs, offering in-depth descriptions of learning contexts and instructional implementation. The combination of quantitative and qualitative approaches provides a comprehensive perspective on the current landscape of CT instruction in primary schools.

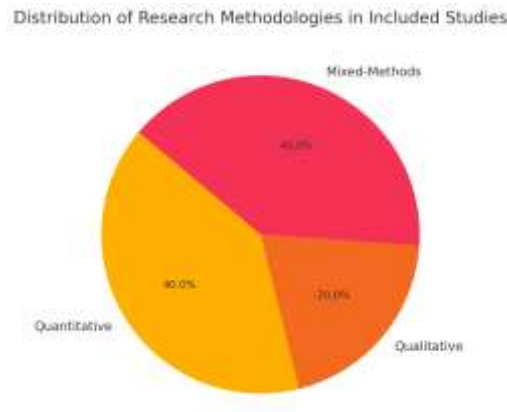


Figure 3. The distribution of research methodologies across the included studies indicates a balance between qualitative and quantitative approaches

2. CT Skills Targeted in the Reviewed Studies

Numerous studies have identified decomposition, abstraction, and algorithmic thinking as the most prominently developed CT components in elementary students (Ching & Hsu, 2023; Pugnali et al., 2017). Each reviewed study explicitly identified computational thinking skills as either primary outcomes or core components of the intervention. The most frequently targeted skills included algorithmic thinking, abstraction, and decomposition, all of which are widely recognised as foundational in CT frameworks. For instance, Angeli (2022) demonstrated that scaffolded programming scripts supported both debugging and abstraction. Nordby et al. (2022) focused on logical reasoning and abstraction using visual programming tools, suggesting that CT can be nurtured through visual and symbolic manipulation. This variety illustrates how CT is a multi-dimensional construct, adaptable across different instructional modalities and learning objectives. As shown in Figure 4, algorithmic thinking was the most frequently targeted CT skill, followed by problem-solving and pattern recognition.

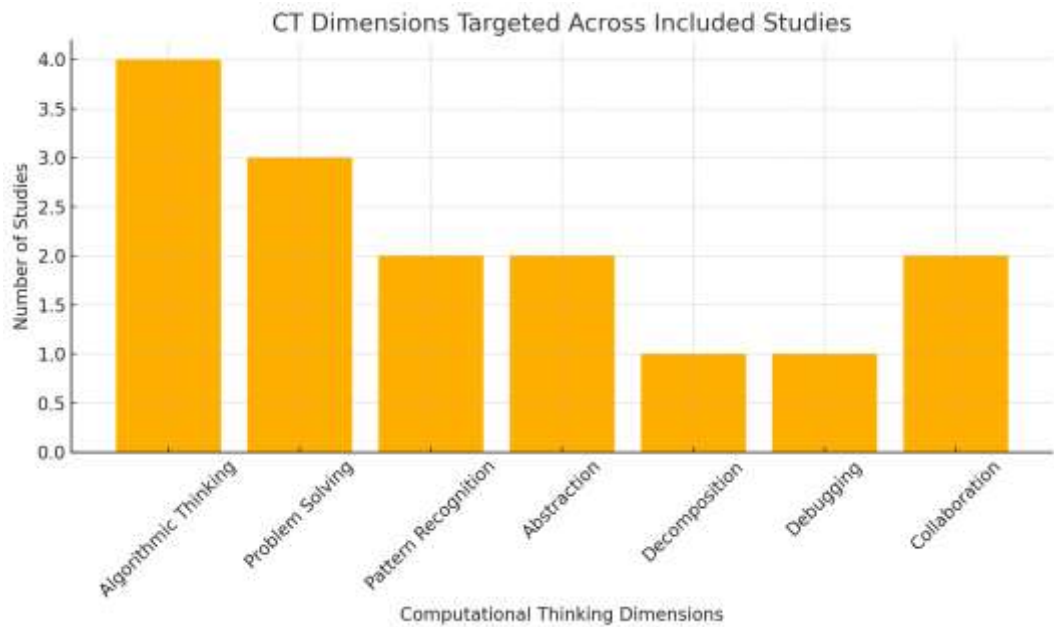


Figure 4. CT Dimensions Targeted Across Included Studies

3. Instructional Strategies Applied

Instructional strategies across the five studies ranged from digital programming environments to unplugged and interdisciplinary learning models. Three dominant approaches emerged: technology-integrated strategies (e.g., Scratch, robotics), pedagogical scaffolding (e.g., step-based programming support), and curricular integration (e.g., embedding CT into math). Nordby et al. (2022) implemented visual programming tools, which were shown to engage learners in abstraction through creative design tasks. Angeli (2022) emphasised structured learning progression using scaffolds to help students internalise CT logic. These varied methods demonstrate the pedagogical versatility of CT instruction and its potential for customisation based on content, learner needs, and resource availability.

4. Key Learning Outcomes Identified

All studies reported positive learning outcomes, both cognitive and affective, because of CT-oriented instructional interventions. On the cognitive side, improvements in CT skills acquisition, problem-solving capacity, and logical reasoning were consistent across interventions. Pair programming facilitated a structured thought process, while Angeli (2022) showed that scaffolded programming scripts enabled students to debug and abstract more effectively. Increased engagement and perseverance through robotics activities. On the affective side, students exhibited heightened motivation, participation, and confidence in managing programming tasks. Additionally, several studies emphasised social

learning gains, especially those using collaborative strategies such as pair or group programming. These outcomes confirm that well-structured CT activities not only promote technical competencies but also support soft skill development essential for 21st-century learning.

Table 2. Summarises the specific contributions and outcomes of each study regarding CT skill development in primary learners.

Study	Study Focus	Key Findings
Ching & Hsu (2023)	Robotics and CT in early education	Robotics enhances algorithmic thinking and engagement
Zhan et al. (2022)	Unplugged aids and CT skill development	Unplugged teaching aids improved CT and classroom interaction
Peel et al. (2022)	CT integration in science through an unplugged approach	Unplugged approach effectively supports algorithmic understanding in science
Ibrohim et al. (2023)	Impact of Scratch on CT skill acquisition	Scratch significantly improves students' CT across all dimensions
Battal et al. (2021)	Review of unplugged activities effectiveness	Unplugged activities consistently support CT development in primary learners

DISCUSSIONS

The results of this systematic review reveal a growing consensus around the effectiveness of structured coding activities in developing computational thinking (CT) among elementary school students. Each of the five reviewed studies applied distinct instructional strategies, yet all demonstrated measurable improvements in core CT competencies. This convergence suggests that while the implementation modalities may vary, their shared emphasis on problem-solving, abstraction, and algorithmic thinking yields consistent pedagogical benefits.

Notably, approaches such as pair programming, educational robotics, and scaffolded scripting were associated with increased student engagement and deeper conceptual understanding. This aligns with recent findings that collaborative learning models significantly aid in the social-emotional development of students alongside cognitive gains (Ismiyanti et al., 2024). One significant theme emerging from the review is the multidimensionality of CT skills. For example, while visual programming

tools foster abstraction and creativity (Nordby et al., [2022](#)), robotics tends to enhance sequencing and problem decomposition. However, reliance solely on textbooks may be insufficient for holistic skill development, as recent findings show that standard teaching materials often fail to facilitate all intelligence types equally, requiring teachers to actively supplement materials to ensure balanced cognitive growth.

Instead of a single intervention, a blended instructional model that integrates digital and unplugged methods appears most effective. Unplugged activities allow students to engage with CT without relying on technology, fostering equity and inclusivity (Harper et al., [2024](#); Zhan et al., [2022](#)). This is consistent with the need for teaching materials that are adaptable to students' needs and the availability of school resources, as effective teaching materials are crucial for bridging the gap between curriculum and student understanding.

The role of contextual integration is also noteworthy. This integration supports broader educational goals of fostering critical thinking and transferable problem-solving skills (Cahyaningsih, [2025](#)). However, the review highlights the need for sustained professional development (Washbrooke, [2023](#)). Teachers must understand how to align CT with learning objectives and assess skill progression. Contemporary research suggests that to truly elevate the quality of basic education, professional development must evolve from traditional training into continuous, integrative models that combine digital platforms, mentoring, and collaborative action research. Without this comprehensive support, coupled with valid assessment instruments designed to measure critical thinking specifically in primary contexts, the benefits of CT integration may remain limited.

CONCLUSION

This systematic review highlights the substantial role of computational thinking (CT) in transforming elementary education into a more future-oriented, problem-solving learning environment. The five reviewed studies provide compelling evidence that diverse instructional strategies—ranging from pair programming to educational robotics and scaffolded programming scripts—effectively cultivate foundational CT competencies such as algorithmic thinking, decomposition, abstraction, and debugging. These findings affirm that coding instruction, whether plugged or unplugged, is not only feasible but pedagogically beneficial for primary school students. Moreover, the consistent improvement in student engagement, logical reasoning, and collaboration across all interventions supports the claim that

CT is integral to holistic skill development in early education. The review also underscores the importance of contextual and cross-curricular integration of CT. Embedding computational practices within subjects like mathematics or science reinforces learning by creating meaningful, real-world connections. This interdisciplinary approach broadens the scope of CT from a purely technological skill to a general cognitive strategy applicable across domains. Additionally, the studies emphasise that effective CT instruction is grounded in thoughtful design, responsive pedagogy, and scaffolded learning environments tailored to the developmental needs of young learners. However, realising the full potential of CT integration requires attention to teacher training, access to resources, and equitable instructional models. Professional development must be prioritised to bridge the gap between policy and practice. Similarly, curriculum designers and policymakers must invest in inclusive strategies—such as unplugged coding and culturally responsive instruction—to ensure all learners benefit, regardless of background or technological access. Moving forward, more longitudinal and comparative studies are needed to measure long-term CT development and the sustainability of different pedagogical models. Ultimately, as digital literacy becomes increasingly essential, embedding CT into early education stands not only as an academic initiative but as a foundational step toward preparing students to navigate and shape the future. The findings of this review corroborate prior claims that CT instruction—whether delivered via robotics, games, or unplugged activities—has measurable impacts on critical thinking, engagement, and academic success.

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