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Computational Thinking in Technology-Supported Primary Mathematics: A Systematic Review

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Abstract. This systematic review synthesizes research on how technology-supported approaches to computational thinking (CT) are integrated into primary mathematics learning environments. Following a PRISMA-guided search, 18 studies published between 2016 and 2025 were analyzed to examine how digital tools support CT-related mathematical learning processes in primary school settings. The review identifies recurring patterns linking mathematical domains, CT constructs, and technological environments, illustrating how programming platforms, robotics, game-based tools, and analytics-supported systems are used to structure mathematical problem-solving activities. Across the intervention studies, several reported improvements in students' mathematical problem-solving and reasoning skills. However, the strength of the evidence varies across studies due to differences in study design, sample size, and assessment methods. The analysis further highlights how technology can support CT-informed instructional design by enabling programmable tasks, iterative testing of solutions, and, in some cases, analytics-supported feedback for teachers and students. At the same time, the review points out ongoing gaps in methodological rigor, assessment of the CT construct, and the scalability of interventions. These findings underscore the need for more rigorous, long-term, classroom-based research to strengthen the evidence for CT-integrated primary mathematics education.

Keywords: computational thinking (CT), primary mathematics education, technology-enhanced learning, mathematical problem solving, systematic review, learning analytics

1. Introduction

Digital technologies are transforming how children learn, communicate, and engage with information from the earliest school years. In primary education, these tools play a vital role in shaping students' developing relationship with technology, not just as users but increasingly as creators and problem solvers. Recent advances in digital technologies, including adaptive learning systems, automated feedback tools, and data-driven learning platforms, provide new opportunities for personalized, responsive learning experiences in primary schools. Some of these environments feature artificial intelligence (AI) or learning analytics systems that support structured problem-solving and computational thinking (CT) activities (Hirashima, 2017; Nordby et al., 2022; Supianto et al., 2016; Zhu et al., 2023). For young learners, such tools can help with differentiated instruction, scaffold difficult tasks, and open new paths for exploration, as shown in studies where adaptive feedback, structured task progression, and teacher-guided digital environments assisted students in engaging with complex math and CT-related activities (Arroyo et al., 2017; Alrefaei, 2025; Baccaglini-Frank et al., 2020; Passey, 2024).

However, the rapid spread of AI in education also raises urgent questions about equity, accessibility, transparency, data use, and pedagogical appropriateness. These are key considerations. The elementary school environment presents unique challenges, including students' cognitive development, learning identities, and the mediating role of teachers, which strongly influence how technology- and AI-supported tools are used and experienced in practice. Research on CT integration in elementary mathematics shows that teacher coordination, task design, and classroom context are crucial factors in technology-based learning (Baccaglini-Frank et al., 2020; Nordby et al., 2022; Passey, 2024). Despite rapid technological advances, research on how advanced digital learning environments impact teaching and learning in primary education remains scattered. Most studies focus on specific tools or learning outcomes, with limited attention to broader pedagogical, developmental, and ethical issues, as highlighted by reviews and qualitative analyses that point out fragmented CT definitions, tool-centered reporting, and insufficient discussion of classroom mediation and learner development (Anugrahaeni and Haryanto, 2023; Nordby et al., 2022; Passey, 2024). Consequently, educators and policymakers lack a solid evidence base to confidently and responsibly incorporate digital technologies and CT-based learning environments into primary education.

Within the broader context of digital and data-supported learning environments, this review specifically focuses on integrating CT into technology-supported primary mathematics education. Instead of viewing artificial intelligence or analytics systems as separate innovations, the review examines how these digital environments can facilitate CT-related practices, including abstraction, decomposition, sequencing, and variable reasoning, during mathematical problem-solving activities. By synthesizing studies conducted in primary school settings, the review aims to clarify how CT practices are integrated into digital mathematics tasks, how they interact with instructional design and teacher guidance, and how technological tools enhance students' mathematical reasoning processes.

Building on the broader discussion of AI and digital technologies in early education, this review examines the rapidly growing field of technology-supported CT in elementary mathematics. International curricula increasingly recognize CT as an essential skill, emphasizing its potential to improve mathematical reasoning, strategic problem-solving, and student engagement with complex multi-step tasks (Grover & Pea, 2013; Shute et al., 2017; Nordby et al., 2022). In primary grades, especially Grades 3–5, as students develop more abstract mathematical thinking, integrating CT through digital tools, programming activities, robotics, or adaptive learning platforms can create new opportunities to enhance their understanding of mathematics.

However, the current research landscape remains fragmented. Studies vary greatly in how they define CT, apply it to mathematical tasks, use technological environments, and evaluate learning outcomes. Evidence on how CT-enhanced technologies are employed in primary mathematics learning and how they relate to students' problem-solving processes remains inconsistent. Additionally, the roles of teachers, scaffolding strategies, and learning analytics in supporting CT-informed mathematical learning are often under-examined. These gaps make it difficult to establish clear design principles for classroom-ready, developmentally appropriate interventions.

To address these challenges, this systematic review synthesizes studies examining how digital technologies that incorporate CT are used in elementary mathematics learning environments. The review highlights how CT practices, such as decomposition, sequencing, abstraction, and debugging, are integrated into learning activities and how these practices relate to mathematical reasoning processes. Special emphasis is placed on instructional design, teacher mediation, and the technological features that support CT in mathematics education.

2. Research framework

Mathematical problem-solving is widely considered a key goal of primary math education, especially in areas like word problems, arithmetic structures, and early algebraic thinking (Grover and Pea, 2013; Nordby et al., 2022; Shute et al., 2017). These tasks often require students to analyze relationships between quantities, organize multi-step procedures, and adapt strategies when errors occur. Research on CT shows that practices such as decomposition, abstraction, sequencing, and debugging closely align with the thinking processes involved in solving math problems (Brennan & Resnick, 2012; Grover and Pea, 2013; Shute et al., 2017). At the same time, technology-enhanced learning (TEL) tools can make these processes more visible and engaging by supporting programmable tasks, providing immediate feedback, and offering different ways to represent mathematical relationships (Hirashima, 2017; Passey, 2024; Nordby et al., 2022). Despite growing interest in these connections, current research remains fragmented, and few studies have explored how CT practices, math problem-solving strategies, and technology features interact within primary math learning environments.

This review explores how TEL environments can support primary students' mathematical problem-solving by using digital tools that activate or incorporate CT constructs. Current research increasingly views CT not just as a programming skill but as a set of flexible practices, such as decomposition, sequencing, abstraction, conditionals, and debugging, which match the cognitive demands of multi-step problem solving (Grover and Pea, 2013; Shute et al., 2017; Wing, 2006; Wing, 2011). For example, working on word problems involves breaking down the story (decomposition), identifying key quantities (abstraction), organizing steps (sequencing), and modifying strategies when mistakes occur (debugging). TEL environments can support these processes by making them more visible, organized, and adaptable through personalized tasks, immediate feedback, and data-driven insights.

Aligned with identified gaps in the literature, the review focuses on grades 3–5 (ages 9–10), a developmental stage when students shift from basic calculation to more abstract mathematical reasoning. The review examines a wide range of digital interventions, including robotic systems, block-based programming platforms, game-based learning environments, mobile math applications, and learning analytics or intelligent tutoring systems. In each case, the analysis considers how these technologies are designed, implemented in classroom settings, and what mathematical learning outcomes are reported.

A key contribution of this review is the synthesis of instructional design principles and technological tools discussed in studies of CT-integrated mathematics learning in elementary education. This involves examining how existing research incorporates CT into math tasks, how teachers facilitate CT-based learning activities, and how digital analytics are used to monitor learning progress.

The review has two main objectives:

1. To examine empirical data on the outcomes of mathematics problem-solving in technology-based interventions that incorporate CT into teaching word problems, arithmetic, and introductory algebra for elementary school students (grades 3–5).
2. To analyze how CT is implemented in technology-based mathematics instruction in elementary education by reviewing task design, opportunities provided by technology, teacher support, and assessment practices, and to synthesize these models into insights relevant to design.

Unlike previous reviews that mainly focus on CT development across STEM (science, technology, engineering, and mathematics) subjects or programming education, this review specifically emphasizes the integration of CT practices within technology-supported contexts for primary mathematics problem-solving.

2.1. Computational thinking in K–12 research

An increasing number of systematic reviews have explored the role of CT in K–12 education. CT is often defined as the process of formulating problems and expressing solutions in ways that humans or computational agents can perform (Wing, 2006; Wing, 2011). In educational research, CT is often viewed as a set of cognitive practices that support systematic problem solving, including decomposition, abstraction, algorithmic thinking, and debugging (Grover and Pea, 2013; Shute et al., 2017). These practices are increasingly acknowledged as vital components of modern STEM and mathematics education. Early reviews emphasized the emergence of CT within school curricula and its connections to analytical reasoning and problem solving (Grover and Pea, 2013).

Later systematic reviews analyzed instructional methods to promote CT development, including programming environments, robotics platforms, and game-based learning contexts (Hsu et al., 2018). Other reviews have concentrated on evaluating CT skills and aligning CT concepts with learning tasks (Shute et al., 2017).

Despite the growing body of research, few reviews specifically examine how CT is integrated into primary math learning environments supported by digital technologies. Notably, the connections between CT practices, mathematical problem-solving, and the technological features of digital learning settings remain inadequately summarized in current literature.

2.2. Conceptual framework

This review uses a conceptual framework that connects three main analytical areas often discussed in research on CT in education: CT practices, mathematical problem-solving domains, and the technological tools found in digital learning environments. Previous research indicates that CT processes such as decomposition, abstraction, and algorithmic reasoning (Brennan and Resnick, 2012; Grover and Pea, 2013) are closely linked to structured problem-solving methods commonly used in mathematics education (Grover and Pea, 2013; Shute et al., 2017).

Meanwhile, research on technology-enhanced learning highlights how digital environments can support exploratory learning, interactive feedback, and scaffolded reasoning in mathematics education (Hirashima, 2017; Passey, 2024). Building on these concepts, this review examines how CT practices are implemented in technology-supported primary mathematics learning settings and how these interactions assist mathematical problem-solving.

2.3. Research questions

This review uses research questions to systematically analyze existing studies on integrating CT into primary mathematics education. The analysis examines both empirical evidence about mathematical problem-solving outcomes and how CT constructs are incorporated into tasks, technological settings, and classroom practices. These perspectives together offer a comprehensive understanding of current strategies and provide a basis for designing CT-integrated digital mathematics interventions.

RQ1. What empirical evidence exists regarding the outcomes of mathematical problem-solving in technology-based mathematics interventions that incorporate CT in grades 3–5?

To answer this question, each experimental or pilot study is examined based on its design type, participant characteristics, intervention duration, teacher involvement, and measures of mathematical problem-solving performance. The results presented, and, where possible, the effect sizes, are described and evaluated in light of the quality of the evidence base.

RQ2. How are CT constructs incorporated into primary mathematics tasks and technologies? What types of teacher support are identified in their implementation, and how are CT and problem-solving skills evaluated?

To answer this question, studies are systematically coded to determine how CT skills are defined and implemented, what technological environments and task structures are used, and how learning outcomes and assessment practices are interconnected. These findings are integrated to identify relationships between mathematical topics, CT constructs, and technological opportunities, and to develop a conceptual model that can inform the design of CT-integrated digital mathematics interventions in elementary education.

2.4. Method

The review was conducted following the PRISMA 2020 guidelines for systematic reviews (Page et al., 2021a), ensuring transparency, reproducibility, and rigor in the methodology. It employs a PRISMA-guided systematic review approach with interpretive synthesis, integrating empirical, qualitative, and conceptual studies to analyze how CT is implemented in technology-supported primary mathematics learning environments. A clearly defined protocol and eligibility criteria guided each stage of the review process.

Records were identified through database searches and broad search-engine retrieval procedures, and all search procedures were systematically documented, including search terms, databases, retrieval dates, and duplicate removal, in accordance with the PRISMA-S extension for reporting search strategies (Rethlefsen et al., 2021).

Titles and abstracts were initially screened against the inclusion criteria. Afterward, full texts were reviewed to determine eligibility, with reasons for exclusion clearly documented for each excluded item (Page et al., 2021b). All included studies underwent data extraction and risk-of-bias assessment, followed by both quantitative and qualitative analysis. The heterogeneity of the studies and the strength of the evidence were systematically evaluated, and each step was illustrated in a PRISMA 2020 flow diagram (Page et al., 2021a).

To ensure methodological transparency, the following subsections outline the inclusion criteria, identification and screening procedures, and the final study selection. Since effect sizes were reported inconsistently across studies and intervention designs varied, the quantitative findings are interpreted descriptively rather than as a formal meta-analysis.

The risk of bias for empirical intervention studies was assessed descriptively using simplified criteria adapted from standard educational intervention review practices, focusing on randomization, group comparability, attrition, and reporting transparency.

2.4.1. Inclusion criteria

To ensure a focused, methodologically consistent selection of studies, this review used clearly defined inclusion criteria. These criteria covered the target population, instructional setting, mathematical content, the presence of CT constructs, and the type and quality of publications. In addition to empirical studies, theoretical and review-based contributions were included to support a comprehensive understanding of how CT can be integrated into technology-supported primary mathematics learning. Accordingly, the review adopts an interpretive systematic approach, aiming to synthesize both empirical evidence and conceptual insights across studies.

1. Population: Studies involving primary students in Grades 3–5 (including Grade 4 explicitly or within the reported range); publications available in English.
2. Intervention/Context: Studies involving technology-mediated mathematics instruction, including but not limited to programming environments, tangible or robotic interfaces, game-based learning systems, mobile applications, and intelligent tutoring or learning analytics platforms.
3. Mathematics Focus: Emphasis on word problems, arithmetic (operations, factors/multiples, fractions/ratios), and introductory algebraic equations; broader mathematical problem-solving contexts were also included when these topics were thoroughly covered.
4. CT: Studies that explicitly mention CT or include implicit CT concepts, such as algorithmic thinking, decomposition, sequencing, loops, conditionals, debugging, variables/data management, or pattern recognition.
5. Study Type: Include empirical studies (experimental, quasi-experimental, pilot, or qualitative/case designs), as well as systematic or narrative reviews and theoretical/methodological papers that meaningfully inform word problems and arithmetic/algebraic expressions (WP/AE) + CT task or technology design.
6. Publication Type: Peer-reviewed journal articles or full conference papers published in reputable academic venues.

The review included peer-reviewed empirical studies as well as theoretical and review-focused publications that offer conceptual or methodological insights relevant to integrating CT within technology-supported primary mathematics learning environments. While empirical studies contributed to analyzing instructional interventions and learning outcomes, theoretical and review papers helped support the conceptual synthesis of CT practices, task design, and technological features. Since the study aimed to synthesize conceptual relationships among CT practices, mathematical problem-solving domains, and digital learning environments, it employed an interpretive systematic review approach rather than a strictly effectiveness-oriented synthesis.

2.4.2. Identification, screening, and inclusion

Google Scholar was included in the search strategy to identify interdisciplinary publications and new studies that may not yet be indexed in traditional bibliographic databases such as Scopus or Web of Science. This was especially important in the fields of CT and educational technology, where much of the literature appears in conference proceedings and interdisciplinary venues before it is added to major databases.

A total of 438 records were identified across multiple databases and search engines: Google Scholar (418), Scopus (8), ERIC (10), and Web of Science (2). Duplicate records (n=12) were removed before the screening stage in accordance with the PRISMA protocol. No year restrictions were applied during the search; the retrieved records covered the period 2012–2025. After applying the inclusion criteria during screening and eligibility stages, the final sample included studies published between 2016 and 2025, with the earliest eligible study reported by Supianto, Hayashi, and Hirashima (2016).

Google Scholar searches were conducted across full-text fields. To reduce irrelevant results, records focused solely on general STEM topics without a specific focus on mathematics were excluded during title screening. However, this approach may miss some interdisciplinary studies because Google Scholar searches are case-insensitive; uppercase variations like "CT" and "AT" were not included in the search syntax to reduce irrelevant hits. Table 1 presents the complete search strings and database-specific queries, providing a clear, reproducible record of the retrieval process.

Table 1. Search through the lines of each database

Database	Search date	Search line
Scopus	10 Aug 2025	TITLE-ABS-KEY(("word problems" OR "word problem" OR "arithmetic" OR "problem solving task" OR "problem solving tasks" OR "algebraic equations") AND ("computational thinking" OR "algorithmic thinking") AND (primary AND education)) AND NOT TITLE-ABS-KEY("teacher education" OR "pre-service" OR "in-service") AND LIMIT-TO(SUBJAREA, "SOCI") AND LIMIT-TO(LANGUAGE, "English")
ERIC	10 Aug 2025	("word problems" OR "word problem" OR "arithmetic" OR "problem solving task" OR "problem solving tasks" OR "algebraic equations") AND ("computational thinking" OR "algorithmic thinking") AND primary AND education -"teacher education" -"in-service" -"pre-service."
Web of Science	10 Aug 2025	TS = (("word problems" OR "word problem" OR "arithmetic" OR "problem solving task" OR "problem solving tasks" OR "algebraic equations") AND ("computational thinking" OR "algorithmic thinking") AND (primary AND education))
Google Scholar	29–31 Jul 2025	noting that Scholar is case-insensitive and that STEM was excluded in the title only to avoid losing relevant "STEAM/STEM" content in full text; CT and AT acronyms were not used to prevent noise: ("word problems" OR "problem solving tasks" OR "algebraic equations") AND (math OR mathematics) AND ("computational thinking" OR "algorithmic thinking") AND primary AND education AND ("technology" OR "digital") -"teacher education" -"in-service" -"pre-service" -secondary -intitle: "K-12" -intitle: "STEM"

2.4.3. Screening and eligibility

After duplicates were removed, 370 records were excluded during the title and abstract screening phase. The main reasons for exclusion were that the studies:

- targeted non-primary populations (outside grades 3–5),
- addressed different disciplinary areas (e.g., general STEM, artificial intelligence, or psychology),
- were not published in English, or
- did not examine technology-based mathematical problem solving that incorporated CT elements.

Although detailed exclusion counts were not recorded during the title and abstract screening stage, all exclusion decisions were documented during the full-text eligibility assessment (see Figure 1 for the overall screening flow).

A total of 56 articles were identified for potential retrieval. Of these, 11 could not be accessed because they were books or lacked full-text availability, leaving 45 reports for full-text eligibility assessment.

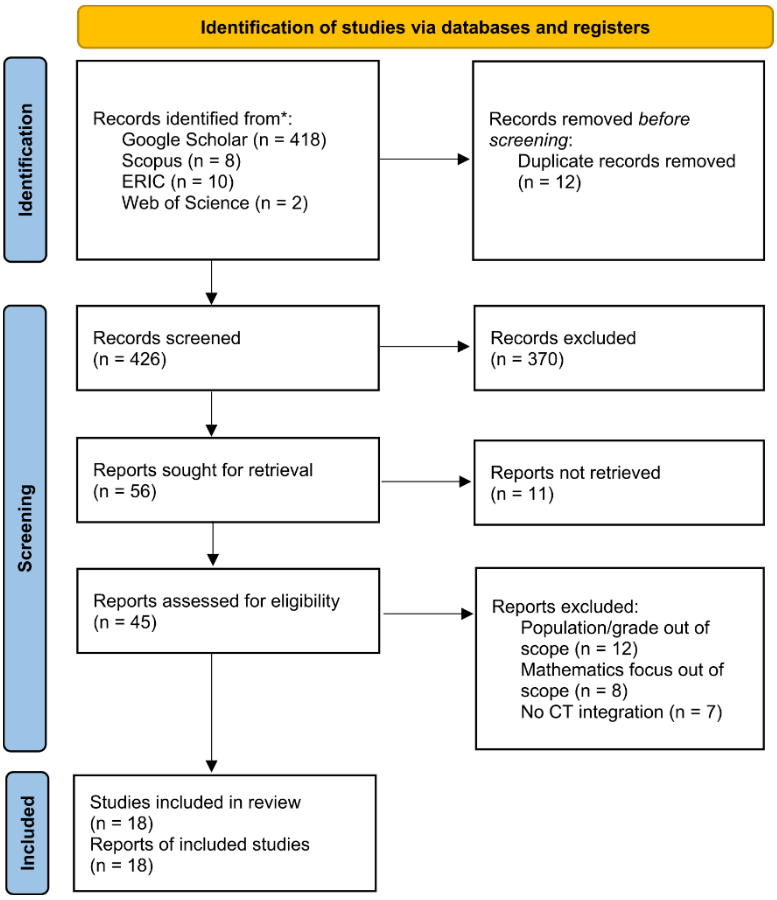

Figure 1. Systematic review flow diagram using the PRISMA 2020 model

2.4.4. Eligibility assessment and operational clarification

During the eligibility assessment, the predefined inclusion criteria were applied and operationalized to ensure consistent classification of studies within the evolving field of CT in mathematics education. Specifically, clarification was needed for studies that reported CT practices implicitly rather than explicitly. Therefore, the review included studies that described related constructs, such as algorithmic thinking, decomposition, sequencing, loops, conditionals, and variable manipulation, as relevant indicators of CT within mathematical tasks.

Similarly, the mathematics criterion was interpreted to include technology-mediated contexts for mathematical problem-solving when word problems, arithmetic structures, or early algebraic reasoning were substantially represented in the learning activities. This approach ensured that studies addressing closely related mathematical problem-solving domains were not excluded solely because of variations in terminology.

In addition to empirical intervention studies, theoretical and methodological publications were included when they significantly contributed to the design of technology-supported tasks or systems that combine CT with mathematical reasoning. These interpretive decisions were documented during the eligibility stage to ensure transparency and consistency in the process of selecting studies.

2.4.5. Exclusions and final inclusion set

Out of the 45 full-text reports evaluated, 27 were excluded, with documented reasons listed below:

- population or grade level out of scope: n = 12
- mathematics focus out of scope: n = 8
- no explicit or implicit CT integration: n = 7

The final review set consisted of 18 studies, each representing a separate report. These studies constitute the complete evidence base analyzed in later stages. The PRISMA 2020 flow diagram in Figure 1 summarizes the counts at each phase (Page et al., 2021a).

The final set of 18 studies formed the basis for the next analysis. Empirical intervention studies guided the investigation of reported learning outcomes (RQ1), while qualitative, review, and theoretical contributions supported the conceptual synthesis of relationships among mathematical topics, CT constructs, and technological affordances (RQ2). The next section presents the results of this analysis.

2.4.6. Coding trustworthiness and analytic rigor

All included studies were coded by an expert reviewer with research experience in CT and technology-enhanced mathematics education. While systematic reviews often use independent double coding, methodological literature shows that single-reviewer coding can be suitable in interpretive or design-focused evidence syntheses, as long as it is supported by transparent procedures and systematic documentation of coding decisions (Petticrew & Roberts, 2006; Grant and Booth, 2009; Booth, Sutton, & Papaioannou, 2016). In this review, the aim was not to perform a statistical meta-analysis but to identify conceptual relationships among CT constructs, mathematical problem-solving areas, and technological tools across different studies. Therefore, the analysis used an interpretive synthesis approach focused on conceptual alignment rather than quantitative aggregation.

To improve analytical rigor and minimize potential bias from single-reviewer coding, several verification procedures were implemented. First, all coding decisions were documented in a structured analytic matrix linking each study to mathematical topics, CT constructs, and technological characteristics. Second, the coding scheme was developed iteratively through repeated readings of the included studies to ensure internal consistency across categories and to better align the framework with the empirical descriptions reported in the primary studies. Third, the final coding tables were systematically rechecked against the full texts of all included articles to confirm that the classifications accurately reflected the intervention descriptions and learning activities documented in the original publications.

These procedures aimed to ensure transparency, auditability, and conceptual consistency in the synthesis process. Similar methods are commonly used in qualitative or interpretive systematic reviews that synthesize diverse evidence to map conceptual relationships across studies (Grant and Booth, 2009; Booth et al., 2016). However, relying on a single-reviewer coding process is a methodological limitation. Although transparent coding protocols and repeated verification processes were used, future systematic reviews could enhance methodological robustness by including independent double coding and inter-rater agreement procedures.

3. Results

The results are organized into three analytical areas. First, an overview of the characteristics of the included studies is provided, including publication trends and study designs. Second, the analysis examines the CT practices discussed in technology-supported mathematics learning environments. Third, the synthesis highlights the technological affordances reported in the studies that support mathematical reasoning and problem-solving processes.

3.1. Overview of included studies

Eighteen studies met the inclusion criteria and were analyzed in this review. The selected publications encompass a range of research designs and intervention settings exploring the integration of CT within technology-supported primary mathematics learning environments.

The distribution of publication years shows that most studies were published after 2016, with a notable rise between 2020 and 2025 (Figure 2). This trend in publishing reflects the increasing interest in integrating CT into technology-supported primary mathematics education.

The earliest study included in the review was conducted by Supianto, Hayashi, and Hirashima (2016), which examined the integration of CT concepts into technology-supported mathematics learning activities. Early studies, such as those by Arroyo et al. (2017) and Tsarava et al. (2017), further explored instructional designs that combine unplugged activities with digital learning environments.

Subsequent studies published between 2020 and 2021 (e.g., Moschella and Basso, 2020; Qu and Dai, 2021; Zito et al., 2021) reported the use of a broader range of technology-supported learning environments, including robotics-based systems, tangible programming tools, and digital programming platforms. More recent studies, such as Alrefaei (2025), used quasi-experimental designs with larger participant samples and documented measurable learning outcomes in technology-mediated mathematics learning contexts. Overall, the distribution of studies across publication years shows increasing interest in integrating CT into technology-supported primary mathematics education.

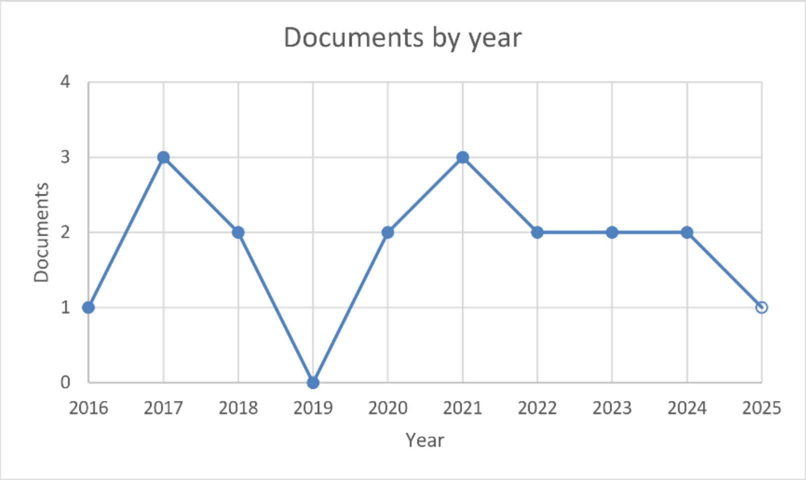

Figure 2. Distribution of included studies by publication year (2016–2025)

The included publications showcase a variety of research designs, such as empirical intervention studies, qualitative investigations, theoretical contributions, and previous reviews. Empirical studies offer insights into instructional interventions and learning outcomes, while theoretical and review articles help synthesize CT practices, task design, and technological tools used in mathematics learning environments. These studies mainly fall into four research categories, illustrating different approaches to technology-enhanced mathematics learning with CT.

1. Experimental, quasi-experimental, and pilot studies (seven of 18; ≈ 39%). These studies assess teaching methods and digital tools and report on the resulting learning outcomes. They often include pre- and post-assessments, comparison or control groups, and statistical analyses such as t-tests or ANOVA. Early classroom projects, also known as pilot studies, are included in this group because they test new designs on a small scale before larger investigations.

2. Qualitative studies (six of 18; ≈ 33%) explore how students learn and how teachers use technology. They utilize interviews, focus groups, classroom observations, or student work to understand learning experiences. Instead of testing a hypothesis, they apply thematic or content analysis to identify patterns and meanings in the data.

3. Review studies (two out of 18; ≈ 11%). These papers summarize previous research rather than collecting new data. Systematic reviews follow the PRISMA process, while narrative reviews provide a structured overview of what is already known and what remains unknown in the field.

4. Theoretical and methodological papers (three out of 18; ≈ 17%) include frameworks, models, or technical designs that link mathematical problem-solving with

CT. They do not contain learner data but provide ideas and systems for future testing and development.

This distribution of study types offers an overview of the current research landscape on integrating technology-supported CT in primary mathematics. Many studies remain exploratory or pilot projects, while large-scale or long-term experimental investigations are still relatively scarce.

While previous reviews have explored CT in primary mathematics or broader mathematical problem-solving, this review offers a design-focused synthesis that links mathematics topics, CT constructs, and digital technologies within primary mathematics learning environments.

Among the included publications, seven empirical intervention studies provide quantitative or quasi-experimental evidence on learning outcomes in grades 3–5 (Table 2). These studies employ a range of technologies, including wearable devices, robotics platforms, programming environments, and game-based systems. The math focus of these interventions generally covers operations, factors, multiples, fractions, and some early algebraic concepts. In these studies, CT is incorporated through both explicit elements (e.g., sequencing, loops, and conditionals) and implicit forms, such as procedural or algorithmic reasoning.

Table 2. Articles of the experimental, quasi-experimental, and pilot studies

Type of research	Amount	References
Trial/Quasi-experimental/Pilot	7	Alrefaei, 2025; Arroyo et al., 2017; Friend et al., 2018; Moschella and Basso, 2020; Qu and Dai, 2021; Tsarava et al., 2017; Zito et al., 2021
Qualitative (interviews/focus groups/case study/observation)	6	Baccaglini-Frank et al., 2020; Cano et al., 2021; Gadanidis et al., 2018; Luo et al., 2022; Passey, 2024; Sulistyani et al., 2024
Reviews (systematic / narrative)	2	Anugrahaeni and Haryanto, 2023; Nordby et al., 2022
Theory/Method (TEL/AI/modeling relevant to WP/AE text understanding & CT design)	3	Hirashima, 2017; Supianto et al., 2016; Zhu et al., 2023

The six qualitative studies explore classroom practices, teacher roles, and student strategies, offering insights into how CT is applied in real settings and guiding task design and learning support. The three theoretical or methodological studies concentrate on models and systems for analyzing word problems, equations, and problem-posing processes, providing conceptual and technical foundations for future task design and assessment.

The seven empirical intervention studies in Table 2 provide the empirical basis for addressing the first research question (RQ1), which focuses on reported outcomes of mathematical problem-solving in technology-supported interventions that include CT.

The remaining publications, which are qualitative, review-focused, and theory-focused, primarily address the second research question (RQ2). These studies provide insights into classroom implementation, instructional design, teacher mediation, and the technological tools used to incorporate CT practices into primary mathematics learning environments.

The following section presents a detailed analysis of the empirical intervention studies.

3.2. Empirical evidence from technology-supported mathematics interventions

This section summarizes empirical evidence from intervention studies that examined technology-supported CT activities in primary math classrooms. The analysis highlights how digital tools, including CT such as games, programming environments, and robotics, were used in math learning activities and how learning outcomes were reported across studies.

Seven empirical intervention studies, including trials, quasi-experimental designs, and pilot studies, were reviewed. Each study was coded across six dimensions: design and sample, implementation, math focus, problem-solving measures, effect sizes, and moderators and risk of bias, as shown in Table 3. We also recorded the types of tests used to measure outcomes, such as national math tests, local concept tests, or reasoning tasks, and whether these tools demonstrated good reliability and validity.

Table 3. Dimensions of the studies

Dimension	Example contents
Design and Sample	Design type (Trial, Quasi-Experimental, Pilot), N total, grades, special educational needs (SEN), prior attainment
Implementation	Dosage, teacher support, fidelity
Math Focus	Word Problems; Arithmetic; Algebra; Geometry; General Mathematical Problem Solving
Problem-Solving Measure	Test/instrument name, reliability (α/r), validity evidence
Effect Sizes	Hedges' g (or η^2 converted to g)
Moderators and Risk of Bias	Grade, SEN, prior attainment, randomization, attrition, clustering

To compare results across studies, we used Hedges' g, a standardized effect size that indicates the strength of learning gains. A value of about 0.2 is considered small, 0.5 medium, and 0.8 or higher large. We also checked whether studies reported apparent randomization, complete data, and group comparability to assess their risk of bias. Risk of bias was evaluated using simplified criteria adapted from common practices in educational intervention reviews, focusing on randomization, group comparability, attrition, and reporting transparency. Effect sizes were analyzed descriptively to provide an indicative comparison of reported learning outcomes across studies. Due to substantial differences in study designs, outcome measures, and intervention contexts, a formal meta-analysis was not performed.

This analysis summarizes key characteristics of the empirical intervention studies, including their design, implementation features, and reported learning outcomes. Across the seven empirical studies, most reported positive trends in mathematical problem-solving or related cognitive outcomes across the six dimensions. About 43% of the studies used quasi-experimental or controlled designs, while roughly 57% were pilot classroom trials. The average sample size was approximately 78 students, ranging from 30 to 185 participants, as shown in Table 4.

Despite their small scale, the strength and reliability of these findings varied across study designs. The majority of interventions were multi-session programs, with about 71% lasting ten hours or more and about 86% including some form of teacher support, such as professional development or structured lesson materials. Across the seven empirical studies, teacher support was reported in limited and heterogeneous forms. Most commonly, it included structured lesson materials, brief professional development sessions, and guidance embedded in task design, such as step-by-step instructions or debugging prompts. In several cases, teachers facilitated activities, supported student reflection, and maintained task progression. However, detailed descriptions of teacher practices and their direct impact on learning outcomes were generally limited, making it difficult to draw strong conclusions about the role of teacher support in CT-integrated mathematics interventions. These forms of support helped teachers maintain implementation fidelity and made the activities feasible within regular classroom settings.

Table 4. Distribution of studies across six dimensions

Dimension	**Summary**	**Approx. Percentage / Trend**
Design & Sample	3 quasi-experimental (43%), 4 pilot studies (57%); average sample size about 78 students (range 30–185).	≈ 43% controlled, ≈ 57% pilot
Implementation	Duration ranged from one to 25 hours. Most interventions (5/7) lasted 10 hours or more, and 6/7 reported receiving explicit teacher training or using structured materials.	≈ 71% multi-session, ≈ 86% with teacher support
Math Focus	Arithmetic and word problems dominated (5/7 studies, 71%); geometry in 3/7 (43%); fractions or algebra in 2/7 (29%).	≈ 71% arithmetic/WP focus
Problem-Solving Measure	5/7 studies (71%) used quantitative pre- and post-tests; 2/7 relied mainly on qualitative evidence. Among test-based studies, 4 of 7 reported reliability or validity.	≈ 71% used tests, ≈ 57% reported reliability
Effect Sizes	5/7 studies reported or allowed the computation of Hedges' g. Among them: two large (>0.8), two moderate (0.5–0.8), and one small (<0.5).	≈ 71% reportable, ≈ 29% larger effect sizes
Moderators & Risk of Bias	Grades 3–5 in all; one study focused on SEN (14%); randomization only in one case; 5/7 rated "some concerns", one - "low", one - "high".	≈ 71% some concerns, ≈ 14% low, ≈ 14% high

The mathematical content mainly focused on arithmetic and word problems, appearing in about 71% of the studies, while around 43% addressed geometry, and only about 29% included early algebraic or logical reasoning. This pattern indicates that CT integration has been most commonly explored in number and operations tasks within the analyzed studies. About 71% of the studies employed pre- and post-tests to evaluate learning outcomes, and roughly 57% reported reliability or validity information for their instruments. The remaining projects relied on qualitative observations and interviews, providing useful insights into engagement and motivation but limiting the comparability of test results.

Effect sizes were available or could be calculated in about 70% of the studies. Two studies reported large effect sizes ($g \geq 0.8$), two moderate (0.5–0.8), and one small (≈ 0.4). Some studies reporting larger effect sizes were associated with longer, more structured intervention designs, although the limited number of studies and methodological variability limit direct comparisons, as in the studies by Alrefaei (2025) and Friend et al. (2018). Regarding moderators and bias, all studies involved students in Grades 3–5, with one study (≈ 14%) focusing on students with learning disabilities. Only one study used randomization, and most lacked long-term follow-up. Overall, about 71% were rated as having “some concerns,” one as “low risk,” and one as “high risk.”

Taken together, the reviewed intervention studies suggest that CT-oriented digital activities may support mathematical problem-solving processes in primary education contexts. However, the available evidence remains limited due to small sample sizes, heterogeneous study designs, and the absence of long-term follow-up in most studies. Consequently, the findings should be interpreted as indicative rather than conclusive evidence regarding the potential role of CT-integrated digital learning environments in primary mathematics education.

3.3. Integration of computational thinking constructs in mathematics and technology contexts

This section examines how CT is incorporated into primary mathematics tasks and digital learning environments, the types of teacher support that promote effective integration, and the assessment methods used to measure CT and problem-solving development. While RQ1 looked at reported mathematical problem-solving outcomes in technology-enhanced CT interventions on mathematical learning, RQ2 focuses on the mechanisms—how specific designs, task features, and pedagogical supports help students connect mathematical reasoning with CT practices.

To answer this question, all 18 included studies were systematically coded along three analytical axes:

1. Mathematics content domain (e.g., word problems, arithmetic structures and strategies, geometry, early algebraic reasoning);
2. CT constructs operationalized (e.g., algorithm design, sequencing and loops, conditionals, abstraction and data representation, debugging and iterative refinement);
3. Type of technological environment (e.g., block-based programming, tangible robotics, game-based or app-based learning systems, adaptive or analytics-driven platforms).

This coding revealed not only the distribution of CT constructs across content areas but also how CT is enacted, such as whether CT practices are used to structure problem-solving steps, represent mathematical relationships, automate procedures, test strategies, or reflect on errors. The three axes together form a Math–CT–Technology Alignment Map that highlights how different combinations of mathematical content, CT practices, and technological tools lead to distinct pedagogical patterns.

Throughout the collection, several common design patterns appeared. Robotics environments typically blend arithmetic and geometry with loops, sequencing, and debugging, allowing students to improve commands and visualize mathematical relationships through repeated movements. Programming tools often help with word problems by involving students in mapping variables, working with conditionals, and designing algorithms, sometimes enhanced by adaptive or AI-driven feedback. Game-based and mobile apps frequently include pattern recognition, decomposition, and step-by-step reasoning in arithmetic or early algebra activities, usually supported by teacher-led scaffolding or prompts.

The alignment map provides a conceptual framework for understanding how CT integration is applied across studies and the educational conditions associated with its implementation. The next subsection explains this alignment model, examining how CT-informed designs work together with teaching facilitation and assessment methods to support multi-step mathematical problem-solving in primary education.

3.3.1. Mathematics, CT, and technology alignment map

In this review, the alignment map highlights recurring relationships among mathematical topics, CT constructs, and the technological environments used to support them. The analysis emphasizes repeated alignments across studies, the technology affordances that enable these practices, the design implications suggested by these patterns, and the gaps that remain in the current research landscape.

The first perspective examines strong, repeated alignments, such as patterns that appear across studies, to show how certain math topics connect with specific CT skills and tools. These alignments illustrate how CT practices, mathematical topics, and technological environments are combined across the reviewed studies, providing a descriptive view of instructional design patterns in technology-supported primary mathematics learning.

The second perspective focuses on the affordances of technology, meaning what each tool makes easy to do (for example, robotics supports loops and debugging). This helps us understand why specific CT–math links occur more often and how they are implemented in classrooms.

The third perspective identifies design takeaways, or practical principles for teachers and designers, such as how to scaffold tasks, sequence activities, and assess learning. The final perspective highlights gaps and opportunities, including missing CT constructs (such as conditionals), weak connections between certain math areas (for example, fractions) and CT, and limited reporting of test reliability. Together, these perspectives provide a descriptive foundation for analyzing recurring instructional patterns across the reviewed studies.

3.3.2. Coding framework and procedures

We examined each of the 18 studies along three main aspects: the mathematics topic, the CT elements, and the technology used. This enabled us to compare studies consistently, despite their different tools and designs.

Mathematics topics were grouped into five categories: WP (word problems), ARITH (basic arithmetic, including operations, factors, multiples, and fractions), ALGEB (introductory algebra or equations), GEOM (geometry), and GEN (general mathematics problem-solving). These categories emphasized word problems and arithmetic while also encompassing a broader range of problem-solving tasks commonly used in elementary schools.

CT elements were categorized as either explicit (EXPL) when authors used the term “computational thinking” or mentioned specific CT skills, or implicit (IMPL) when such skills were present but not labeled as CT. If no CT elements were found, they were marked as NONE. Individual CT skills, such as algorithmic thinking, sequencing, loops, conditionals, abstraction, decomposition, pattern recognition, variables, and debugging, were grouped into five broader categories: ALG-DES (algorithm design), CTRL-FLOW (control flow, including loops and conditionals), ABSTR-DEC (abstraction and decomposition), DATA-VAR (variables and data), and DBG (debugging and testing). Each study could include multiple CT codes, but we identified a single main or “primary” code representing its primary instructional focus.

Technologies were also categorized based on how they supported learning: PROG (programming, such as Scratch or Blockly), PHYS-COMP (physical computing, including robotics or tangible interfaces), GAME/APP (learning games and applications), ANALYTICS/AI (tools that use analytics, intelligent tutoring, or natural language processing), and ICT (general computer use without a specific tool). When a study involved more than one tool, we noted the primary one and classified the others as secondary. For example, a robotics activity utilizing Scratch was categorized as PHYS-COMP (primary) and PROG (secondary).

Each study was assigned up to three mathematics codes and up to four CT codes to reflect that technology-mediated mathematics tasks often involve multiple mathematical topics and CT practices simultaneously. This multi-coding approach captures instructional complexity without oversimplification, while the set limits ensure clarity and comparability across studies. Coding decisions were based on descriptions in the Methods, Tasks, and Appendices sections of each study. When information was unclear, we made conservative choices and added notes with page references to clarify the context.

Finally, we examined how mathematics, CT, and technology are interconnected. For example, word problems often relate to DATA-VAR and ABSTR-DEC (working with variables and deconstructing problems); arithmetic connects to CTRL-FLOW and DBG (loops and testing); algebra is associated with DATA-VAR and CTRL-FLOW (variables and logic); and geometry links to ALG-DES and ABSTR-DEC (step-by-step planning and abstraction). We also identified common links between technology and CT skills, such as robotics supporting loops and debugging, programming involving variables and control flow, and AI tools emphasizing data and abstraction. These patterns helped us understand how CT concepts are integrated into math learning designs.

3.3.3. Strong, repeated alignments between Math topics and CT constructs

A key finding of this review is the emergence of consistent and recurring alignments between specific mathematical topics and CT constructs. These patterns reflect common ways in which CT is embedded within mathematics instruction, particularly when supported by digital tools. Table 5 presents the consistent patterns identified across the 18 studies reviewed. In this review, strong, repeated patterns are understood as design frameworks observed in multiple studies that systematically link particular mathematical topics with specific CT practices. For example, arithmetic tasks frequently involve loops and debugging; word problems require variable mapping and decomposition; geometry emphasizes step-by-step algorithmic planning; and algebra relies on variable reasoning combined with conditional logic. By identifying these recurring pairings, the table illustrates how CT is integrated into mathematical reasoning. It highlights the main pathways through which problem-solving processes are structured and supported by digital tools, providing insight into how CT practices are operationalized in primary classroom contexts.

Table 5. Strong, repeated alignments

Math Code	CT Constructs (codes)	Amount (n)	References
ARITH (factors & multiples)	CTRL-FLOW (loops/iteration) + ABSTR-DEC (pattern recognition) + DBG (debugging/testing)	5	Arroyo et al., 2017; Cano et al., 2021; Moschella and Basso, 2020; Qu and Dai, 2021; Tsarava et al., 2017
WP (word problems)	DATA-VAR (variable mapping) + ABSTR-DEC (schema spotting, decomposition)	7	Alrefaei, 2025; Anugrahaeni and Haryanto, 2023; Friend et al., 2018; Hirashima, 2017; Sulistyani et al., 2024; Supianto et al., 2016; Zhu et al., 2023
GEOM (geometry)	ABSTR-DEC (shape/constraint abstraction) + ALG-DES (procedural drawing, step planning)	5	Alrefaei, 2025; Arroyo et al., 2017; Baccaglini-Frank et al., 2020; Friend et al., 2018; Gadanidis et al., 2018
ALGEB (introductory equations)	DATA-VAR (variables) ± CTRL-FLOW (conditionals/case logic)	4	Baccaglini-Frank et al., 2020; Gadanidis et al., 2018; Tsarava et al., 2017; Zito et al., 2021;

Across the 18 studies, the strongest connections are found between word problems (WP) and CT concepts related to data/variables (DATA-VAR) and abstraction/decomposition (ABSTR-DEC), as seen in 7 studies (≈ 39%), as shown in Table 5. These tasks often require learners to identify given and unknown quantities, represent them as variables, and break down the problem structure, skills that directly link CT reasoning with mathematical modeling.

Arithmetic (ARITH) topics appear in 5 studies (about 28%) and are consistently linked to control flow (CTRL-FLOW) and debugging (DBG) through iterative or loop-based activities in robotics and programming. Students plan sequences, test outputs, and refine their logic, thereby mirroring algorithmic thinking.

Geometry (GEOM) appears in 5 studies (≈ 28%), aligning with abstraction and algorithm design (ALG-DES), especially in drawing or movement tasks where learners develop procedural plans for geometric constructions.

Finally, algebra (ALGEB) appears in four studies (≈ 22%), combining variable reasoning (DATA-VAR) with occasional conditional logic (CTRL-FLOW). These patterns indicate that CT integration is most common in word-problem and arithmetic tasks across the analyzed studies.

The patterns described in this section are further illustrated in Figure 3, which shows the frequency of co-occurrence between mathematical topics and CT constructs.

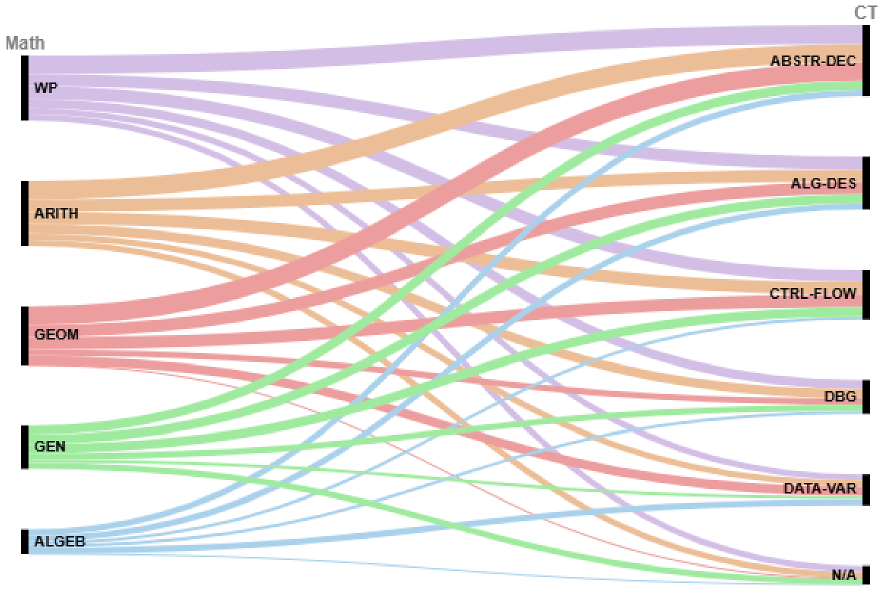

Figure 3. Repeated alignments between mathematics topics and CT constructs

The diagram shows how math topics and CT constructs are connected in the reviewed studies. Each line indicates the co-occurrence of a mathematics topic and a CT construct in the reviewed studies, with line thickness representing how frequently they appear together across studies. Although line thickness varies to indicate relative frequency, differences may appear visually subtle due to the limited number of studies and overlapping connections across categories.

The most common links are between word problems (WP) and arithmetic (ARITH), as well as CT constructs such as abstraction and decomposition (ABSTR-DEC), algorithm design (ALG-DES), and control flow (CTRL-FLOW). These constructs help students break problems into steps, plan solutions, and manage sequences or conditions in digital tasks. Geometry (GEOM) also connects to these CT skills, mainly through the use of data and variables (DATA-VAR) in modeling or programming activities. Algebra (ALGEB) and general (GEN) areas show fewer links, suggesting that CT ideas are less frequently applied in these areas. The codes indicate that problem-solving in WP and ARITH most strongly involves key CT practices.

3.3.4. Strong, repeated alignments between mathematical topics, CT constructs, and technologies

In this review, strong alignments indicate recurring design patterns across multiple studies that systematically link specific mathematics topics to particular CT practices, often with technology support. These alignments reflect stable, pedagogically meaningful connections that can inform the design of integrated learning activities. For example, arithmetic topics such as factors and multiples are frequently associated with control flow concepts (e.g., loops and iteration) and debugging, particularly in physically interactive (PHYS-COMP) tasks involving robots or tangible tools (Table 6).

Table 6. Technology affordances

Technology Code	Typical Math Focus (codes)	Main CT Constructs (codes)	Amount (n)	References
PHYS-COMP	ARITH, GEOM	ALG-DES → CTRL-FLOW → DBG cycles (sequencing, loops, debugging)	5	Arroyo et al., 2017; Baccaglini-Frank et al., 2020; Moschella and Basso, 2020; Qu and Dai, 2021; Zito et al., 2021
PROG	ALGEB, ARITH	DATA-VAR + CTRL-FLOW (variables, loops, conditionals)	5	Friend et al., 2018; Gadanidis et al., 2018; Luo et al., 2022; Nordby et al., 2022; Tsarava et al., 2017;
GAME/APP	ARITH, GEOM	ALG-DES + CTRL-FLOW (events, iteration)	5	Alrefaei, 2025; Arroyo et al., 2017; Cano et al., 2021; Tsarava et al., 2017; Zito et al., 2021
ANALYTICS /AI	WP	DATA-VAR + ABSTR-DEC (variable mapping, schema decomposition)	3	Hirashima, 2017; Supianto et al., 2016; Zhu et al., 2023
ICT	ARITH, WP	DATA-VAR (representation, pattern recognition, implicit CT)	2	Alrefaei, 2025; Anugrahaeni and Haryanto, 2023

Word problems (WP) typically involve data variability (mapping knowns and unknowns) and abstract decomposition (schema breakdown), often supported by analytics/AI environments that help learners model and test problem structures. GEOM (geometry) links to ALG-DES (step-by-step planning) and ABSTR-DEC (algorithmic drawing and constraint abstraction) through programming or physical computing tools. Meanwhile, ALGEB (introduction to equations) connects to DATA-VAR and, when present, to CTRL-FLOW/COND (case logic) within PROG environments, such as Scratch or Blockly.

Across the 18 studies, three technology types—PHYS-COMP, PROG, and GAME/APP—appeared in five studies (about 28%), indicating a balanced use of robotics, programming, and game-based tools in primary mathematics. The ANALYTICS/AI group was featured in three studies (about 17%), mainly for word-problem analysis and feedback, while ICT alone was used in two studies (about 11%), primarily for general arithmetic tasks. These proportions suggest that most digital interventions use technologies that support iterative reasoning, control flow, and variable manipulation—skills often linked to mathematical problem-solving in the reviewed studies.

The Math–CT–Technology Alignment Map (Figure 4) summarizes how CT is integrated into primary mathematics across the 18 studies. The size of each annular sector reflects the relative frequency of each category across the reviewed studies. The three layers represent the reviewed categories: mathematical topics (WP, ARITH, GEOM, ALGEB, GEN), CT constructs (ABSTR-DEC, ALG-DES, CTRL-FLOW, DATA-VAR, DBG, N/A), and technology types (PROG, GAME/APP, PHYS-COMP, ICT, ANALYTICS/AI).

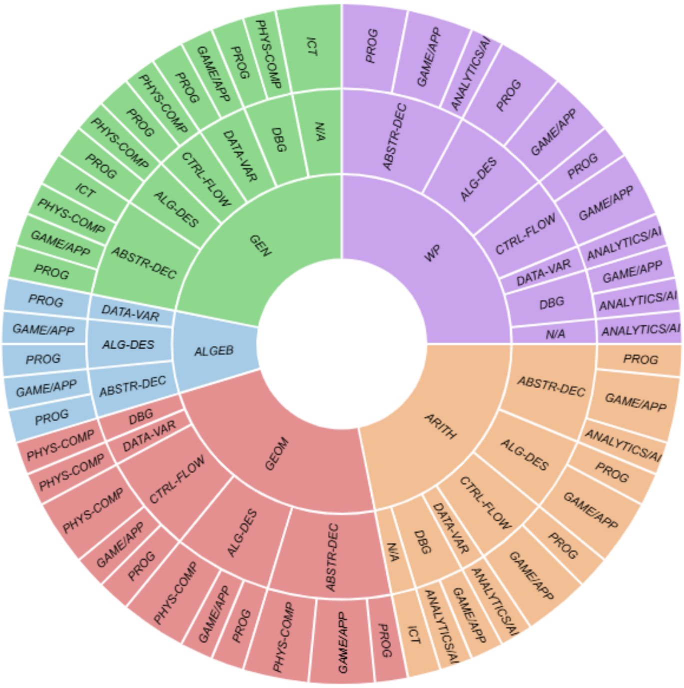

Figure 4. Math–CT–Technology alignment map

Across the studies, word problems (WP) were frequently associated with data/variables (DATA-VAR) and abstraction/decomposition (ABSTR-DEC), though the relative frequency of these relationships varied. These associations were primarily supported by programming and analytics/AI tools. Arithmetic (ARITH) was frequently connected to control flow (CTRL-FLOW) and debugging (DBG) in physical computing and game/app development environments. Geometry (GEOM) was associated with algorithm design (ALG-DES) and abstraction/decomposition, commonly within programming and robotics contexts. Algebra (ALGEB) combined data/variables (DATA-VAR) and abstraction/decomposition constructs, usually using programming platforms. General (GEN) activities involved various CT constructs across programming, physical computing, and ICT settings.

The map consolidates empirical evidence from all 18 studies, showing which CT constructs and technologies co-occur with each mathematical topic in technology-mediated primary mathematics tasks. Although all categories are connected across the map, differences in sector size reflect relative frequency rather than exclusive relationships and may appear subtle due to overlapping distributions across studies.

3.4. Design takeaways

Technology affordances refer to the actions a tool naturally supports for learners and teachers. This review emphasizes the CT moves that a technology enables or makes likely (e.g., sequencing, loops, or debugging), as well as the mathematical concepts it helps highlight (e.g., patterns in factorizations or variable mappings in word problems).

Two recurring design themes appear across the reviewed studies (Figure 5). The first theme, ARITH → ALG-DES → CTRL-FLOW → DBG → PHYS-COMP/PROG, shows up in about 39% of cases. Here, students plan sequences of steps, use loops and events, run and debug their programs, and describe the patterns they find. Typical activities include robot or tangible missions involving multiples and divisibility, or Scratch loops that generate sets of factors (Arroyo et al., 2017; Cano et al., 2021; Luo et al., 2022; Moschella and Basso, 2020; Qu and Dai, 2021; Tsarava et al., 2017; Zito et al., 2021).

A second common strand, WP → DATA-VAR + ABSTR-DEC → ANALYTICS/AI/PROG, accounts for about 39% of the studies. In these tasks, learners map known and unknown variables, break down schemas, compare cases, and sometimes write brief programs to find solutions. Many tasks follow problem-posing or "highlight–extract–relate" routines (Alrefaei, 2025; Anugrahaeni and Haryanto, 2023; Friend et al., 2018; Hirashima, 2017; Sulistyani et al., 2024; Supianto et al., 2016; Zhu et al., 2023).

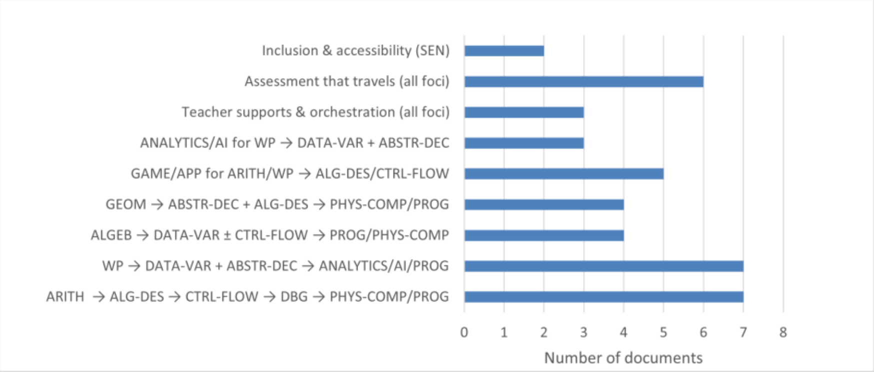

Figure 5. Math–CT–Tech learning design strands (grades 3–5)

Two additional strands are observed in fewer studies. The ALGEB → DATA-VAR ± CTRL-FLOW → PROG/PHYS-COMP strand, found in about 22% of studies, connects variable binding and conditional logic within block-based environments (Baccaglini-Frank et al., 2020; Gadanidis et al., 2018; Tsarava et al., 2017; Zito et al., 2021).

The GEOM → ABSTR-DEC + ALG-DES → PHYS-COMP/PROG strand, also at 22%, emphasizes the abstraction of shape constraints and procedural drawing, such as turtle or robot-based tasks with step-by-step refinement (Arroyo et al., 2017; Baccaglini-Frank et al., 2020; Friend et al., 2018; Gadanidis et al., 2018).

Several cross-cutting patterns are also seen across the reviewed studies. The GAME/APP for ARITH/WP → ALG-DES/CTRL-FLOW combination appears in about 28% of studies, utilizing events, loops, and quick feedback within game-like learning sequences (Alrefaei, 2025; Arroyo et al., 2017; Cano et al., 2021; Tsarava et al., 2017; Zito et al., 2021).

The ANALYTICS/AI for WP → DATA-VAR + ABSTR-DEC pattern (≈ 17%) uses intelligent feedback and pattern dashboards to support schema recognition and variable mapping (Hirashima, 2017; Supianto et al., 2016; Zhu et al., 2023).

Three horizontal layers frame the overall design picture (Figure 5). Teacher supports and orchestration were reported in about 17% of the studies, including worked examples, debug checklists, short PD sessions, and structured “launch–explore–debug–share” cycles (Baccaglini-Frank et al., 2020; Nordby et al., 2022; Passey, 2024).

Transfer-oriented assessment approaches are present in about 33% of studies, combining accuracy, transfer, and time/error metrics, with several reporting reliability (α/ω) and delayed checks (Anugrahaeni and Haryanto, 2023; Arroyo et al., 2017; Cano et al., 2021; Nordby et al., 2022; Tsarava et al., 2017; Zito et al., 2021).

Inclusion and accessibility (SEN) are addressed in about 11% of tasks, where adaptations are made through accessible interfaces, tailored feedback, or subgroup analysis (Alrefaei, 2025; Cano et al., 2021).

Taken together, these elements and supporting conditions demonstrate how technology, CT practices, and mathematical tasks are integrated in the reviewed studies. Common patterns, such as loops and debugging in arithmetic tasks, variable mapping in word problems, and algorithmic planning in geometry and algebra, provide an overview of how CT-informed learning designs are used in primary mathematics settings.

4. Gaps and opportunities

The analysis of the 18 reviewed studies highlights several common gaps and potential areas for further development in integrating CT into primary mathematics learning settings.

1. CT constructs are inconsistently defined. Many studies mention CT generally without clarifying specific learner-level components. Conditionals and explicit decomposition are seldom included in task design (Zito et al., 2021). Only a few studies, like those by Luo et al. (2022), Tsarava et al. (2017), and Arroyo et al. (2017), have made these constructs more visible.

Opportunity: Make the steps of abstraction and decomposition clear in word-problem tasks, such as linking givens to variables and relations, and include control flow or conditionals in comparison or multi-case problems.

2. Topic coverage is limited. Fractions and ratios appear in arithmetic-focused studies (Alrefaei, 2025; Luo et al., 2022; Zito et al., 2021) but show relatively limited explicit connections with CT constructs.

Opportunity: Enhance CT integration in these topics by using control flow (iteration and accumulation), abstraction (invariants), and data-variable mapping to support proportional reasoning.

3. Technology affordances are underutilized. Physical computing effectively supports algorithm design, control flow, and debugging, but rarely extends to conditional logic or data logging. Programming tasks often focus on loops and variables without connecting to algebraic reasoning. Analytics and AI tools are often linked to data-variable mapping in word problems but are seldom used for formative feedback (Arroyo et al., 2017; Baccaglini-Frank et al., 2020; Friend et al., 2018; Hirashima, 2017; Moschella and Basso, 2020; Supianto et al., 2016; Zhu et al., 2023).

Opportunity: In physical computing, add sensor-condition and debugging tasks (Arroyo et al., 2017; Qu and Dai, 2021); in programming, connect data-variable reasoning with algebraic testing (Gadanidis et al., 2018; Tsarava et al., 2017); and in analytics/AI, transform word-problem parsing into real-time scaffolding and feedback (Hirashima, 2017; Supianto et al., 2016).

4. Assessment reporting practices differ widely across studies. Many studies use researcher-developed tools with little evidence of reliability or validity and seldom include delayed assessments (Alrefaei, 2025; Anugrahaeni and Haryanto, 2023; Arroyo et al., 2017; Cano et al., 2021; Moschella and Basso, 2020; Nordby et al., 2022; Tsarava et al., 2017; Zito et al., 2021).

Opportunity: Future research could benefit from using shared, validated problem-solving tools, clearer reporting of reliability metrics, and the inclusion of delayed measures that capture longer-term learning effects.

5. Study designs and reporting of implementation features vary among the reviewed studies. Most are small-scale pilots with limited randomization, small sample sizes, and inconsistent reporting of intervention duration, teacher training, and fidelity (Nordby et al., 2022).

Opportunity: Develop more robust quasi-experimental or cluster-randomized designs with clear comparison groups, pre-registration, standardized dosage reporting, and documented implementation fidelity.

6. Consideration of diverse learner populations and classroom settings remains limited. Only a few studies address learners with hearing impairments or learning disabilities (Alrefaei, 2025; Cano et al., 2021), but broader inclusion of diverse learners and classroom environments is uncommon.

Opportunity: Expand designs to include more diverse student groups, report subgroup effects and accessibility adaptations, and document classroom orchestration practices (Baccaglini-Frank et al., 2020; Passey, 2024).

The reviewed studies indicate that physical computing environments are often connected to control flow and debugging practices, programming tools with variable reasoning, and analytics or AI-supported systems involving abstraction and decomposition in word-problem contexts. Future research could benefit from combining these technological capabilities with clearer CT construct definitions, more rigorous study designs, more comprehensive assessment methods, and greater inclusion of diverse learning environments to build a more complete evidence base for CT-integrated mathematics learning in grades 3–5.

5. Conclusions

This systematic review examined 18 studies on how technology-enhanced learning environments include CT in primary mathematics instruction for students in grades 3–5. Positive trends were observed in students’ problem-solving and reasoning skills across the intervention studies, although the strength of the evidence varies due to differences in study designs, sample sizes, and assessment methods.

Analysis of all studies revealed clear patterns linking mathematical domains, CT constructs, and technology types. Word problems were often associated with decomposition, abstraction, and variable use; arithmetic tasks with sequencing, control flow, and debugging; geometry with algorithmic design; and early algebra with conditional reasoning. Programming, robotics, and game-based environments were the most frequently used technologies to implement these constructs. CT practices appear to support processes by which pupils externalize, organize, and refine mathematical reasoning within digital environments.

Regarding RQ1, the findings suggest that CT-integrated interventions may support mathematical problem-solving, though evidence remains limited.

Regarding RQ2, the results indicate that CT is most often implemented through programming, robotics, and game-based environments, with limited evidence on teacher support and assessment practices..

Seven intervention studies were reviewed for the first research question, focusing on reported mathematical problem-solving outcomes across factors such as study design, teaching duration, mathematical emphasis, assessment tools, and reliability. Most interventions included multiple sessions with teacher support and used pre- and posttests to evaluate learning. The majority of studies showed improvements in students' mathematical problem-solving or related cognitive skills, though the strength and consistency of these results varied by study design. Some studies with larger effect sizes were associated with longer, more structured intervention programs.

All studies were classified by mathematical topic, CT construct, and technology type for the second research question. Clear patterns emerged: word problems were often linked to abstraction, decomposition, and the use of data or variables; arithmetic was connected to control flow and debugging through robotics and programming; geometry was linked to algorithm design and abstraction; and algebra involved variable reasoning and conditional logic. Programming, physical computing, and game-based tools were the most common technologies supporting these connections.

The reviewed literature indicates that CT practices are often integrated into digital mathematics learning environments through programming, robotics, and game-based tools. The study shows that these environments can support students’ engagement in multi-step mathematical problem-solving by structuring reasoning, illustrating relationships among quantities, and enabling iterative testing of solution strategies. However, current evidence is limited by small sample sizes, inconsistent study designs, and a scarcity of long-term assessments. More research using rigorous experimental and longitudinal methods is needed to strengthen the empirical evidence supporting CT-integrated mathematics learning in primary education.

6. Limitations and future work

The evidence base remains limited in several ways. Sample sizes in intervention studies were small, study designs varied, and assessment methods were inconsistent across mathematics and CT outcomes. Many studies lacked long-term follow-up, detailed reporting on implementation fidelity, or analysis of different effects for diverse learners.

The second limitation relates to the coding and screening procedures. A single researcher handled the study selection and coding processes. Although the coding framework was applied systematically and verified during analysis, the lack of independent double screening may affect the reproducibility of classification decisions.

The third limitation concerns the search strategy. Although multiple academic databases were used, most records came from Google Scholar. While this approach helped include interdisciplinary and emerging studies, it might also have skewed the balance of the retrieved literature and reduced the reproducibility of the search results.

The fourth limitation is the inclusion of various types of publications, such as theoretical papers, review articles, and empirical studies. While this broadens the overall understanding of CT integration in technology-supported math learning environments, it also weakens conclusions about intervention effectiveness..

Future research should employ more rigorous experimental and long-term study designs, develop validated tools to assess computational and mathematical reasoning, and examine how teacher support and learning analytics influence learning. Expanding research to include a broader range of mathematical topics and more diverse school settings will also be essential to developing scalable, evidence-based CT-integrated mathematics interventions.

Acknowledgments

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