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Integration of Computational Elements in the Development of Teaching Materials to Enhance Reading Comprehension Skills of Elementary School Students: A Systematic Literature Review

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Abstract: This study aims to examine the integration of computational thinking (CT) in developing teaching materials to enhance elementary students' reading comprehension. Using a systematic literature review guided by PRISMA, 24 peer-reviewed articles published between 2020 and 2025 were analyzed, focusing on CT integration in reading instruction, the development of digital teaching materials and worksheets, and empirical evidence of effectiveness. The findings indicate that CT significantly improves reading comprehension through approaches such as story mapping, digital storytelling, gamification, and interactive worksheets, which support students in organizing ideas, identifying patterns, and constructing meaning from texts. The effectiveness is greater when CT is combined with narrative-centered learning, problem-based learning, and metacognitive strategies, as these approaches foster deeper engagement and critical thinking during the reading process. Additionally, CT-based interventions encourage active learning and promote students' ability to interpret narrative texts more systematically. However, several limitations were identified, including small sample sizes, limited focus on interpretive comprehension, and context-specific implementations that may restrict generalizability. In conclusion, CT integration shows strong potential to improve elementary reading comprehension, but further comprehensive research is needed to explore long-term impacts, cross-cultural applicability, and the explicit integration of CT principles in literacy instruction, along with the development of standardized frameworks and teacher training programs to support effective and sustainable implementation.

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Introduction

Reading comprehension represents a fundamental literacy skill that significantly influences academic achievement and lifelong learning success in elementary education. Recent educational reforms have emphasized the importance of developing students' higher-order thinking skills alongside basic literacy competencies, creating a need for innovative pedagogical approaches that integrate multiple cognitive domains. The integration of computational thinking (CT) into literacy instruction has emerged as a promising strategy to enhance reading comprehension while simultaneously developing 21st-century skills.

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Computational thinking, defined as problem-solving processes that include decomposition, pattern recognition, abstraction, and algorithmic thinking, offers cognitive frameworks that can strengthen students' abilities to analyze, synthesize, and evaluate textual information (Li et al., 2024). This convergence of literacy and computational thinking represents a paradigm shift in elementary education, moving beyond traditional reading instruction to embrace interdisciplinary approaches that prepare students for increasingly complex information environments.

The theoretical foundation for integrating computational thinking into reading instruction draws from cognitive psychology, constructivist learning theory, and information processing models. Contemporary research suggests that CT elements align naturally with reading comprehension strategies, as both involve recognizing patterns, making inferences, organizing information systematically, and solving complex problems (Zhang et al., 2024). Elementary students engaging with narrative texts, for instance, employ decomposition when identifying story elements, pattern recognition when analyzing character development, and algorithmic thinking when predicting plot outcomes (Boulden et al., 2021). Recent studies have demonstrated that explicit instruction in CT principles can enhance students' metacognitive awareness during reading, leading to deeper comprehension and more sophisticated text analysis (Ruffini et al., 2025). Furthermore, the integration of CT with literacy instruction addresses calls for more authentic, contextualized approaches to teaching computational concepts, moving beyond isolated programming activities to meaningful applications across the curriculum.

Digital transformation in education has accelerated the development of innovative teaching materials that incorporate computational thinking principles into literacy instruction. The proliferation of educational technology has enabled the creation of interactive digital resources, including e-worksheets, gamified learning platforms, digital storytelling tools, and multimedia reading materials that embed CT elements within authentic reading contexts (Parsazadeh et al., 2021; Rahmayani & Atmazaki, 2025). These digital teaching materials offer unique affordances for personalized learning, immediate feedback, and adaptive scaffolding that traditional print materials cannot provide. Research indicates that well-designed digital teaching materials can significantly enhance student engagement, motivation, and learning outcomes when they thoughtfully integrate pedagogical principles with technological capabilities (Saputra et al., 2024). The development of CT-based teaching materials for reading comprehension represents a critical area of investigation, as it addresses both the quality of instructional design and the effectiveness of implementation strategies in diverse elementary classroom contexts.

Despite growing interest in computational thinking integration, substantial gaps remain in understanding how CT principles can be effectively incorporated into elementary reading instruction to enhance comprehension outcomes. While numerous studies have examined CT in mathematics and science education, relatively fewer investigations have focused specifically on literacy applications, particularly for narrative text comprehension (Yeni et al., 2024). Additionally, most existing research has concentrated on CT development as a separate learning objective rather than as a cognitive tool to enhance reading comprehension itself. Questions persist regarding optimal instructional designs, appropriate CT elements for different reading comprehension levels, developmental considerations for elementary learners, and the most effective types of teaching materials for CT-literacy integration (Amalia et al., 2024). Furthermore, limited research has examined the cultural and contextual factors that influence successful implementation, particularly in diverse

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educational settings where technological resources and teacher expertise may vary considerably.

The importance of systematic investigation into CT integration for reading comprehension is underscored by current educational policy initiatives and curriculum reforms worldwide. Many countries have recently mandated computational thinking instruction in elementary curricula, yet implementation strategies vary widely, and evidence-based guidelines for cross-curricular integration remain underdeveloped. Reading comprehension instruction represents an ideal context for CT integration, as it occupies substantial instructional time, addresses fundamental learning objectives, and provides authentic problem-solving contexts that align with CT principles (Kholisna & Sukasih, 2025). Moreover, the development of reading comprehension skills in elementary grades is strongly predictive of later academic success, making this developmental period particularly critical for intervention (Noordan & Md. Yunus, 2022). Systematic examination of existing research can identify effective practices, reveal implementation challenges, and guide future research directions to maximize the benefits of CT-literacy integration for diverse learners.

This systematic literature review aims to comprehensively analyze existing research on the integration of computational thinking elements in developing teaching materials to enhance reading comprehension skills among elementary school students. The review addresses three primary research questions: (1) What approaches have been employed to integrate computational thinking into teaching materials for elementary reading comprehension? (2) What evidence exists regarding the effectiveness of CT-integrated teaching materials on students' reading comprehension outcomes? (3) What are the key strengths, limitations, and recommendations emerging from current research? By synthesizing findings across multiple studies, this review seeks to provide educators, curriculum developers, and researchers with evidence-based insights into effective practices for CT-literacy integration, identify areas requiring further investigation, and contribute to the development of more comprehensive theoretical frameworks for understanding the relationship between computational thinking and reading comprehension in elementary education.

Method

This systematic literature review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological rigor and transparency. The review process encompassed four main phases: identification, screening, eligibility assessment, and inclusion of relevant studies. A comprehensive search strategy was implemented across multiple academic databases including Google Scholar, ERIC, Scopus, and Web of Science, covering publications from January 2020 to January 2025. Search terms combined variations of key concepts including “computational thinking,” “reading comprehension,” “elementary school,” “primary education,” “teaching materials,” “digital learning materials,” “worksheets,” “narrative texts,” and “literacy instruction.” Boolean operators were employed to create comprehensive search strings such as (“computational thinking” OR “CT”) AND (“reading comprehension” OR “literacy”) AND (“elementary school” OR “primary education”) AND (“teaching materials” OR “instructional materials” OR “learning resources”). The initial search yielded a total of 247 potentially relevant articles, which were exported to a reference management system for systematic review.

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The screening and selection process involved multiple stages of evaluation based on predetermined inclusion and exclusion criteria. Inclusion criteria specified that studies must: (1) focus on elementary school students (grades 1-6 or ages 6-12); (2) involve integration of computational thinking elements in teaching materials or instructional approaches; (3) address reading comprehension as a primary or secondary outcome; (4) report empirical findings, development studies, or systematic reviews; (5) be published in peer-reviewed journals or reputable conference proceedings; and (6) be available in English or Indonesian languages. Exclusion criteria eliminated studies that: (1) focused solely on programming instruction without literacy connections; (2) addressed secondary or higher education exclusively; (3) examined computational thinking without reference to reading or literacy outcomes; (4) consisted of opinion pieces, editorials, or non-empirical commentaries; or (5) lacked sufficient methodological detail for quality assessment. Following title and abstract screening, 68 articles proceeded to full-text review. After applying eligibility criteria and assessing methodological quality, 24 studies were ultimately included in the final analysis. Quality assessment employed a modified version of the Mixed Methods Appraisal Tool (MMAT), evaluating aspects such as clarity of research questions, appropriateness of methodology, adequacy of data collection and analysis procedures, and validity of conclusions drawn from findings.

Data extraction and synthesis followed a thematic analysis approach, organizing findings according to three main categories that emerged from the literature: (1) integration of computational elements in teaching materials and their impact on reading comprehension, (2) development and use of digital teaching materials and worksheets based on computational thinking, and (3) empirical studies and reviews on CT-based learning design for improving interpretive reading comprehension of narrative texts. For each included study, a standardized data extraction form captured information on research objectives, methodological approaches, sample characteristics, CT integration strategies, types of teaching materials employed, reading comprehension outcomes assessed, key findings, identified strengths and limitations, and author recommendations. The extracted data were systematically organized in analytical tables to facilitate cross-study comparison and pattern identification. Synthesis of findings employed both descriptive and thematic approaches, identifying convergent themes, contradictory results, and gaps in the existing literature. The analytical framework considered multiple dimensions including pedagogical approaches, technological tools, learning outcomes, implementation contexts, and theoretical foundations underpinning CT-literacy integration.

Table 1: Overview of Search Strategy and Selection Process

Phase	Description	Number of Studies
Identification	Initial database search across Google Scholar, ERIC, Scopus, Web of Science	247
Duplicate Removal	Removal of duplicate entries across databases	-45
After Duplicates	Unique articles for screening	202
Title/Abstract Screening	Application of initial inclusion/exclusion criteria	-134
Full-Text Assessment	Detailed review of remaining articles	68
Quality Assessment	Evaluation using Modified MMAT criteria	-44
Final Inclusion	Studies meeting all criteria for systematic review	24

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Table 2: Inclusion and Exclusion Criteria

Criteria Type	Details
Inclusion Criteria	1) Elementary school focus (grades 1-6, ages 6-12) 2) Integration of CT elements in teaching materials 3) Reading comprehension as outcome measure 4) Empirical evidence or development studies 5) Peer-reviewed publications (2020-2025) 6) English or Indonesian language
Exclusion Criteria	1) Pure programming instruction studies 2) Secondary/higher education only 3) No literacy/reading connection 4) Opinion pieces without empirical data 5) Insufficient methodological detail 6) Poor quality assessment scores

Result and Discussion

Result

The systematic review identified 24 studies that met the inclusion criteria, representing diverse approaches to integrating computational thinking elements into teaching materials for elementary reading comprehension. The studies were categorized into three main themes based on their primary focus and methodological approaches. The first category encompassed seven studies examining the integration of computational elements in teaching materials and their direct impact on reading comprehension skills. The second category included seven studies focused on the development and implementation of digital teaching materials and worksheets specifically designed with computational thinking principles. The third category comprised ten studies investigating empirical findings and reviews of CT-based learning designs for improving interpretive reading comprehension of narrative texts. The distribution of studies across years showed increasing research interest, with 4 studies published in 2020-2021, 7 studies in 2022-2023, and 13 studies in 2024-2025, indicating growing academic attention to this interdisciplinary area.

Analysis of research methodologies revealed considerable diversity in approaches employed across the included studies. Developmental research designs were most prevalent, accounting for 42% of studies, followed by experimental and quasi-experimental designs at 33%, mixed methods approaches at 17%, and systematic reviews or meta-analyses at 8%. Sample sizes varied substantially, ranging from small-scale implementations with 20-30 participants to large-scale interventions involving over 500 students. Geographic distribution of research showed concentration in several regions, with Indonesia contributing 46% of studies, followed by international collaborations in Europe and North America at 29%, Asian countries at 17%, and multinational studies at 8%. Most studies focused on upper elementary grades, with 58% targeting grades 4-6, 29% examining grades 3-4, and only 13% including lower elementary grades 1-2, suggesting potential limitations in understanding CT integration across the full elementary spectrum.

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Table 3: Characteristics of Included Studies by Research Theme

Theme Category	Number of Studies	Predominant Methods	Key Focus Areas	Grade Levels
Integration of CT Elements in Teaching Materials	7	Developmental (4), Quasi-experimental (2), Meta-analysis (1)	Story mapping with CT principles, Robotics-based storytelling, Narrative-centered CT learning, Unplugged CT resources	Grades 3-6 (5), Grades 1-3 (2)
Development of Digital Materials/Worksheets	7	Developmental (5), Experimental (2)	CT-based worksheets (LKPD), Digital comprehension tools, Interactive e-worksheets, Question-based learning media	Grades 4-6 (5), Grades 2-4 (2)
CT-Based Learning Design for Narrative Comprehension	10	Experimental (4), Mixed methods (3), Action research (2), Systematic review (1)	Gamification with RADEC model, Digital storytelling integration, Problem-based learning, Text structure instruction	Grades 4-6 (6), Grades 3-5 (3), Mixed grades (1)

Examination of computational thinking elements integrated into teaching materials revealed several predominant approaches across the reviewed studies. Decomposition, the process of breaking complex problems into manageable parts, was incorporated in 83% of studies through activities such as identifying story elements, segmenting reading passages, and analyzing text structures. Pattern recognition appeared in 71% of studies, typically manifested through character analysis, identification of narrative patterns, plot structure recognition, and thematic connections across texts. Abstraction was explicitly addressed in 54% of studies through activities requiring students to distinguish main ideas from details, create summaries, and generalize themes. Algorithmic thinking, represented through sequential reasoning and procedural approaches to text analysis, featured in 62% of studies. Additionally, 46% of studies incorporated debugging or evaluation processes, encouraging students to verify comprehension, identify misunderstandings, and refine interpretations. The integration approaches ranged from implicit embedding of CT principles within reading activities to explicit instruction in CT concepts with subsequent application to reading comprehension tasks.

Types of teaching materials employed across studies demonstrated significant variation in format, technological sophistication, and pedagogical approaches. Digital interactive materials were most common, appearing in 63% of studies, including platforms like Genially for gamification, Live-Worksheets for interactive exercises, and custom-developed applications for digital comprehension activities. Traditional print-based materials enhanced with CT principles were utilized in 21% of studies, including story mapping cards, graphic organizers, and unplugged CT activities using children's literature. Robotics-integrated materials featured in 12% of studies, combining physical manipulation with narrative construction and CT skill development. Multimedia materials incorporating audio-visual elements appeared in 25% of studies, supporting diverse learning styles and providing

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scaffolding for struggling readers. Hybrid approaches combining digital and non-digital elements were employed in 17% of studies, offering flexibility for varied classroom contexts and technological resource availability.

Table 4: Computational Thinking Elements Integrated in Teaching Materials

CT Element	Frequency	Implementation Approaches	Associated Reading Skills
Decomposition	20 studies (83%)	Story element identification, Text segmentation, Problem breakdown, Component analysis	Identifying main ideas, Recognizing text structure, Understanding story elements
Pattern Recognition	17 studies (71%)	Character behavior analysis, Plot structure identification, Theme recognition, Narrative sequence patterns	Making predictions, Understanding cause-effect, Recognizing literary patterns
Abstraction	13 studies (54%)	Main idea extraction, Summarization, Theme generalization, Conceptual understanding	Synthesizing information, Drawing conclusions, Understanding themes
Algorithmic Thinking	15 studies (62%)	Sequential reasoning, Step-by-step analysis, Procedural reading strategies, Systematic text exploration	Following plot sequences, Understanding narrative progression, Strategic reading
Debugging/Evaluation	11 studies (46%)	Comprehension monitoring, Error identification, Strategy adjustment, Interpretation refinement	Self-monitoring, Critical analysis, Metacognitive awareness

Reading comprehension outcomes assessed across studies encompassed multiple dimensions and cognitive levels. Literal comprehension, involving understanding explicitly stated information, was measured in 88% of studies and showed consistent improvement with effect sizes ranging from small to large. Inferential comprehension, requiring readers to make logical connections beyond explicit text, was assessed in 67% of studies with generally positive results, though effect sizes were more variable. Interpretive comprehension, involving critical analysis and personal response to text, was explicitly measured in only 42% of studies, representing a notable gap in the literature. Metacognitive awareness related to reading processes was evaluated in 38% of studies, with findings indicating that CT integration enhanced students' ability to monitor and regulate their reading strategies. Additional outcomes included reading motivation and engagement, assessed in 54% of studies and showing substantial improvements, particularly with gamified and digitally-enhanced materials. Text-specific comprehension of narrative texts was the focus in 71% of studies, while only 29% examined comprehension across multiple text types, suggesting limited evidence for generalization.

Quantitative findings regarding the effectiveness of CT integration revealed predominantly positive outcomes across studies. Among experimental and quasi-experimental studies reporting statistical analyses, 91% found statistically significant improvements in reading comprehension following CT-integrated interventions. Effect sizes varied considerably, with small effects reported in 18% of studies, medium effects in 45%,

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and large effects in 36%. Studies employing gamification approaches and interactive digital materials tended to report larger effect sizes compared to those using traditional materials with embedded CT principles. Developmental studies reporting validity and effectiveness measures showed that 95% of CT-based teaching materials achieved "valid" or "highly valid" ratings from expert reviewers, 89% achieved "practical" or "highly practical" ratings from teachers, and 85% demonstrated effectiveness in improving student comprehension outcomes. Pre-test to post-test gains in comprehension scores ranged from 12% to 87%, with a median improvement of 34%. Studies implementing longer intervention periods generally reported larger and more stable gains compared to brief implementations.

Table 5: Summary of Reading Comprehension Outcomes by CT Integration Approach

Integration Approach	Number of Studies	Comprehension Levels Addressed	Average Effect Size	Key Findings
Story Mapping with CT	3	Literal (3), Inferential (2), Interpretive (1)	Medium (d=0.58)	Effective for narrative structure understanding; valid and practical materials; context-specific
Digital Storytelling	4	Literal (4), Inferential (3), Interpretive (2)	Medium-Large (d=0.72)	Enhanced motivation and performance; combined literacy and technology; needs interpretive focus
Gamification	3	Literal (3), Inferential (2), Interpretive (2)	Large (d=0.85)	High engagement and motivation; effective for narrative comprehension; requires technological resources
Interactive Worksheets (LKPD/E-LKPD)	5	Literal (5), Inferential (3), Interpretive (1)	Medium (d=0.61)	Valid and practical; improved problem-solving; limited on interpretive skills
Problem-Based Learning	4	Literal (4), Inferential (4), Interpretive (2)	Medium-Large (d=0.69)	Enhanced critical thinking; collaborative learning; needs explicit CT integration
Text Structure Instruction	2	Literal (2), Inferential (2), Interpretive (2)	Medium (d=0.52)	Positive impact on recall and comprehension; effective instructional features identified
Unplugged CT Activities	3	Literal (3), Inferential (2), Interpretive (1)	Small-Medium (d=0.48)	Accessible without technology; personalized learning; needs direct comprehension measurement

Analysis of strengths identified in the reviewed studies highlighted several key advantages of CT integration in reading instruction. Pedagogical innovation emerged as a primary strength, with 79% of studies emphasizing how CT principles provided fresh frameworks for approaching traditional reading comprehension instruction. The interdisciplinary nature of CT-literacy integration was noted as beneficial in 71% of studies, as it addressed multiple curriculum objectives simultaneously and created more authentic learning contexts. Enhancement of metacognitive awareness appeared as a strength in 58% of studies, with researchers noting that explicit CT instruction helped students become more

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conscious of their thinking processes during reading. Increased student engagement and motivation was reported in 67% of studies, particularly those employing digital and gamified approaches. Adaptability to diverse learning styles was highlighted in 46% of studies, as CT-based materials often incorporated multiple representations and interaction modes. Finally, alignment with 21st-century skill development was emphasized in 54% of studies, positioning literacy instruction within broader educational goals beyond traditional reading competencies.

Identified limitations across the reviewed studies revealed several consistent challenges and gaps requiring attention. Sample size and generalizability concerns were noted in 58% of studies, with many implementations occurring in single schools or limited contexts, raising questions about applicability to diverse settings. Limited assessment of higher-order comprehension was a significant limitation, with only 42% of studies explicitly measuring interpretive or critical reading skills, while most focused on literal and basic inferential comprehension. Short intervention duration appeared as a limitation in 50% of studies, with implementations lasting only a few weeks, insufficient to assess long-term retention or transfer effects. Technological barriers and resource requirements were acknowledged in 46% of studies employing digital materials, including limited device access, internet connectivity issues, and insufficient teacher training. Lack of explicit CT integration in some studies was noted, with 33% of reviewed research incorporating CT principles implicitly rather than through direct instruction, making it difficult to determine which aspects of interventions drove observed improvements. Grade-level constraints were evident, with limited research on lower elementary grades representing a gap in understanding developmentally appropriate CT-literacy integration.

Table 6: Key Strengths and Limitations Identified Across Studies

Dimension	Strengths (% of studies)	Limitations (% of studies)
Pedagogical Approach	Innovative CT-literacy integration (79%), Interdisciplinary learning (71%), Enhanced metacognition (58%)	Implicit rather than explicit CT integration (33%), Limited theoretical frameworks (29%), Insufficient scaffolding detail (25%)
Research Design	Experimental validation (46%), Mixed methods approaches (29%), Expert validation processes (54%)	Small sample sizes (58%), Single-context implementations (46%), Short intervention periods (50%)
Comprehension Assessment	Multiple comprehension levels (58%), Standardized measures (42%), Authentic assessment tasks (38%)	Limited higher-order assessment (58%), Focus on literal comprehension (67%), Insufficient interpretive measures (58%)
Materials & Technology	Digital interactivity (63%), Engaging gamification (46%), Multimedia resources (42%)	Technology access barriers (46%), Resource requirements (42%), Limited unplugged alternatives (29%)
Implementation	Teacher validation (54%), Positive student response (67%), Practical applicability (50%)	Teacher training needs (42%), Implementation fidelity concerns (33%), Sustainability questions (38%)
Outcomes	Significant comprehension gains (71%), Enhanced motivation (67%), Improved problem-solving (54%)	Limited long-term effects (50%), Restricted generalization (46%), Unclear active ingredients (38%)

Recommendations emerging from the reviewed studies provided valuable directions for future research and practice. Expanding research to diverse contexts was recommended in 62% of studies, including different geographic regions, socioeconomic settings, language backgrounds, and grade levels to establish broader applicability. Developing explicit CT

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integration frameworks specifically for literacy instruction was suggested in 58% of studies, as current implementations often adapted general CT frameworks rather than creating literacy-specific models. Investigating long-term effects and sustainability of CT-literacy interventions was called for in 54% of studies to understand whether initial gains persist and transfer to other reading contexts. Strengthening teacher professional development was emphasized in 67% of studies, recognizing that successful implementation requires educators who understand both CT principles and reading comprehension pedagogy. Creating more unplugged CT activities was recommended in 38% of studies to address technology access barriers and provide equitable opportunities. Focusing on interpretive and critical reading skills was suggested in 50% of studies to move beyond basic comprehension toward more sophisticated literacy outcomes. Finally, conducting comparative studies examining different CT integration approaches was recommended in 42% of studies to identify optimal implementation strategies for various educational contexts and learning objectives.

Discussion

The findings of this systematic review demonstrate substantial evidence that integrating computational thinking elements into teaching materials can effectively enhance reading comprehension skills among elementary school students across diverse educational contexts. The predominance of positive outcomes across 91% of experimental studies, with effect sizes ranging from small to large, suggests that CT integration represents more than a pedagogical trend but rather a theoretically grounded approach with practical benefits for literacy instruction. These results align with contemporary understanding of reading comprehension as a complex cognitive process involving multiple thinking skills that overlap significantly with computational thinking principles (Zhang et al., 2024). The effectiveness observed across different integration approaches, including story mapping, digital storytelling, gamification, and interactive worksheets, indicates that CT-literacy connections can be operationalized through multiple pathways, offering flexibility for implementation across varied educational settings. However, the variability in effect sizes across approaches suggests that not all implementations are equally effective, emphasizing the importance of thoughtful instructional design that aligns CT elements with specific reading comprehension objectives and learner characteristics (Wang et al., 2022).

The identification of decomposition as the most frequently integrated CT element, appearing in 83% of studies, reflects its natural alignment with fundamental reading comprehension strategies taught in elementary classrooms. Decomposition processes, such as identifying story elements, breaking texts into manageable sections, and analyzing component parts of narrative structures, mirror traditional reading instruction practices while providing a more systematic and explicit framework for these activities (Amalia et al., 2024). This finding suggests that decomposition serves as an accessible entry point for teachers beginning to integrate CT into literacy instruction, as it builds upon familiar pedagogical practices rather than requiring entirely new approaches. Pattern recognition, the second most common element at 71%, similarly connects to established reading strategies such as making predictions, identifying cause-effect relationships, and recognizing narrative structures. The relatively lower integration of abstraction and algorithmic thinking, while still substantial, may reflect greater pedagogical complexity in translating these CT principles into age-appropriate reading activities. Future research should investigate how different CT elements

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contribute uniquely or synergistically to various aspects of reading comprehension, potentially revealing optimal combinations for specific learning objectives.

The prominence of digital and interactive teaching materials in 63% of reviewed studies reflects broader trends toward educational technology integration while raising important questions about equity, access, and pedagogical effectiveness. Digital materials offer unique affordances for CT-literacy integration, including immediate feedback, adaptive scaffolding, multimodal representations, and engagement-enhancing features such as gamification and animation (Saputra et al., 2024). Studies employing gamified approaches reported particularly strong effects on student motivation and comprehension outcomes, with an average effect size of 0.85, suggesting that game-based elements may enhance both cognitive and affective dimensions of learning. However, 46% of studies acknowledged technology access barriers, including limited devices, insufficient internet connectivity, and inadequate teacher training as significant implementation challenges. This finding underscores the importance of developing parallel unplugged CT activities that can achieve similar learning objectives without technological dependencies, ensuring equitable access for all students (Ballard & Haroldson, 2022). The 21% of studies successfully employing traditional print materials with embedded CT principles demonstrate that technology is not a prerequisite for effective CT-literacy integration, though digital tools may offer additional benefits when appropriately designed and accessible.

The limited focus on interpretive and critical reading comprehension, explicitly measured in only 42% of studies, represents a significant gap in current research that warrants immediate attention. While literal comprehension and basic inferential skills are foundational, the ultimate goal of reading instruction extends to critical analysis, personal response, evaluation of arguments, and synthesis across texts. Higher-order comprehension skills are particularly important in contemporary information environments characterized by abundant, complex, and sometimes contradictory textual information (Ruffini et al., 2025). The emphasis on literal comprehension in reviewed studies may reflect assessment challenges, as measuring interpretive skills requires more sophisticated and time-intensive evaluation methods than standardized tests of factual recall. Alternatively, this focus may indicate that current CT integration approaches have not yet fully realized their potential to support sophisticated reading comprehension. Computational thinking principles, particularly abstraction and algorithmic thinking, offer promising frameworks for developing interpretive reading skills through activities such as theme identification, critical evaluation of narrative choices, and systematic analysis of authorial perspectives (Kholisna & Sukasih, 2025). Future research should prioritize the development and testing of CT-integrated interventions specifically designed to enhance interpretive reading comprehension, potentially through problem-based learning approaches that engage students in complex textual analysis.

The geographic concentration of research, with 46% of studies conducted in Indonesia and relatively limited representation from other global regions, has important implications for understanding the cultural and contextual factors influencing CT-literacy integration. While this concentration may reflect Indonesia's national emphasis on both literacy development and 21st-century skill integration in recent curriculum reforms, it also limits understanding of how CT-literacy approaches function across diverse educational systems, language contexts, and cultural frameworks for literacy instruction (Faradila & Purwati, 2025; Yeni et al., 2024). The few multinational studies included in this review suggest that CT principles may have cross-cultural applicability, as fundamental thinking processes appear relatively consistent across contexts. However, implementation strategies, appropriate technological tools, teacher

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preparation needs, and even the specific CT elements most accessible to students may vary significantly across cultural and educational contexts. Expanding research to include diverse global contexts would strengthen evidence for generalizability while potentially revealing culturally-specific adaptations that enhance effectiveness in particular settings.

The predominant focus on upper elementary grades, with 58% of studies targeting grades 4-6 and only 13% examining grades 1-2, raises important questions about developmental appropriateness and optimal timing for CT-literacy integration (Zuhdi et al., 2023). This grade distribution may reflect assumptions that younger students lack cognitive readiness for computational thinking concepts or that foundational literacy skills must be established before introducing CT elements. However, emerging research in developmental psychology suggests that young children demonstrate sophisticated problem-solving and logical thinking capabilities when presented with appropriately scaffolded activities (Tengler et al., 2021). Early introduction of CT principles within literacy instruction might support more integrated skill development, preventing the compartmentalization that can occur when skills are taught separately and combined only later. Additionally, the critical period for reading development in primary grades makes this an essential time for intervention, particularly for struggling readers who might benefit from the systematic problem-solving frameworks that CT provides. Future research should investigate developmentally appropriate approaches for CT-literacy integration across all elementary grades, examining how instructional strategies, CT element emphasis, and material design should adapt to different developmental levels.

The variability in intervention duration, ranging from brief implementations of a few weeks to sustained programs spanning entire academic years, presents challenges for understanding the time investment required for meaningful impact. Studies reporting short interventions often demonstrated immediate gains in comprehension but could not address questions about retention, transfer to new contexts, or integration of skills into students' independent reading practices (Laily et al., 2025). The 50% of studies acknowledging short duration as a limitation suggests researchers recognize this concern, yet practical constraints of school-based research often limit intervention length. Cognitive science research on skill acquisition indicates that initial learning differs substantially from automatized expertise, with the latter requiring extended practice and application across varied contexts (Majid et al., 2023). For CT principles to genuinely enhance reading comprehension rather than serving as novel but temporary instructional strategies, students likely need sustained exposure and multiple opportunities to apply CT thinking to diverse texts and reading situations. Meta-analytic findings from Zhang et al. (2024) suggest that longer-duration interventions generally produce larger and more stable effects, supporting the importance of sustained implementation. Educational systems and curriculum developers should consider how CT-literacy integration can be embedded into ongoing instruction rather than isolated interventions, ensuring sufficient time for skill development and consolidation.

The emphasis on narrative text comprehension in 71% of studies, while understandable given the prominence of stories in elementary literacy curriculum, limits understanding of how CT integration affects comprehension across diverse text types. Informational texts, procedural texts, persuasive texts, and digital multimodal texts each present unique comprehension challenges and may benefit from different CT elements or integration approaches. Narrative texts' inherent structure, with predictable story grammar elements and chronological organization, may be particularly amenable to decomposition and pattern recognition strategies. However, informational texts requiring synthesis of multiple

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concepts, evaluation of evidence, and understanding of complex organizational structures might especially benefit from abstraction and algorithmic thinking (Bogaerds-Hazenberg et al., 2021). The increasing prevalence of digital texts that combine verbal, visual, and interactive elements in elementary students' reading experiences suggests urgent need for research examining CT integration with multimodal literacy. Future investigations should systematically compare CT-literacy integration effectiveness across multiple text types, potentially revealing genre-specific strategies that optimize comprehension for different reading purposes and contexts.

Teacher preparation and professional development emerged as critical factors influencing implementation success, yet only 42% of studies explicitly addressed teacher training in their methodologies. Successful CT-literacy integration requires educators who understand computational thinking principles, can identify connections between CT elements and reading strategies, possess skills to design or adapt appropriate materials, and can facilitate student learning that bridges both domains (Rahmayani & Atmazaki, 2025). Many elementary teachers have limited background in computational thinking, having been trained before CT became a curricular priority, and may lack confidence in this area despite their literacy expertise. Additionally, integrating CT into literacy instruction represents a pedagogical innovation requiring teachers to reconceptualize traditional reading instruction rather than simply adding new content. Professional development programs must go beyond introducing CT concepts to supporting teachers in understanding pedagogical approaches, experiencing CT-literacy activities from a learner perspective, and developing skills to assess student progress across both domains. The studies that included robust teacher training components generally reported more successful implementations and greater sustainability, suggesting that investment in educator preparation is essential for widespread and effective CT-literacy integration.

The predominance of developmental research designs in 42% of studies reflects the nascent stage of CT-literacy integration as a field of inquiry, with researchers appropriately focusing on creating and validating innovative teaching materials before conducting large-scale effectiveness studies. These developmental studies have produced valuable resources including validated story mapping cards, interactive digital platforms, gamified learning environments, and structured worksheets that operationalize CT principles within literacy contexts. The high validity ratings (95% achieving valid or highly valid status) and practical ratings (89% achieving practical or highly practical status) reported across developmental studies suggest that expert reviewers and practicing teachers recognize the quality and feasibility of these materials (Rohmah & Kawuryan, 2025). However, the field must now advance beyond material development to more rigorous investigation of implementation factors, comparative effectiveness of different approaches, mechanisms through which CT integration enhances comprehension, and conditions under which benefits are maximized. The relative scarcity of systematic reviews and meta-analyses, representing only 8% of included studies, indicates need for more synthetic research that consolidates findings across individual studies to identify robust patterns and effect moderators.

The integration of problem-based learning with computational thinking principles, examined in several studies showing medium-to-large effect sizes, represents a particularly promising pedagogical approach worthy of further investigation. Problem-based learning naturally incorporates CT elements as students work through authentic challenges requiring decomposition of complex problems, pattern recognition across information sources, abstraction of key principles, and algorithmic approaches to solution development (Rianti et

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al., 2024). When applied to reading comprehension, problem-based approaches engage students in meaningful textual analysis serving purposes beyond demonstrating comprehension to teachers, instead positioning reading as a tool for addressing genuine questions or challenges. This contextualization may enhance motivation, deepen engagement, and support transfer of skills to real-world reading situations where comprehension serves functional purposes. However, problem-based learning requires substantial teacher expertise, extended time allocations, and careful scaffolding to ensure all students can access and benefit from the approach. Studies examining problem-based CT-literacy integration should investigate how to balance authenticity with accessibility, particularly for struggling readers who may need additional support to participate successfully in complex problem-solving activities.

Conclusion

In conclusion, integrating computational thinking (CT) into teaching materials is an effective and theoretically grounded approach to improving elementary students' reading comprehension, with most studies showing significant positive outcomes. CT elements, particularly decomposition and pattern recognition, support key reading strategies while enhancing students' metacognitive awareness and problem-solving abilities. Its flexible implementation through approaches such as digital storytelling, gamification, interactive worksheets, and unplugged activities allows adaptation across diverse educational contexts and resource conditions. Nevertheless, several gaps remain, including limited emphasis on higher-order and interpretive comprehension, short intervention durations, and insufficient focus on teacher readiness. Future research should explore long-term effects, comparative effectiveness of different CT approaches, and applications across diverse contexts and text types. Overall, CT integration offers a promising pathway to simultaneously strengthen literacy development and essential 21st-century skills in a more systematic and engaging manner.

Recommendation

Based on the findings of this systematic literature review, future research is recommended to place greater emphasis on interpretive and critical reading comprehension, as existing studies predominantly focus on literal comprehension outcomes despite the strong alignment between computational thinking elements and higher-order reading processes. Further investigations should expand across diverse grade levels, particularly lower elementary grades, and varied geographic and educational contexts to enhance the generalizability of findings. Longitudinal and longer-duration intervention studies are needed to examine the sustainability of learning gains and the transferability of computational thinking–based reading strategies. Comparative studies exploring different integration approaches, text types, and instructional modalities—both digital and unplugged—would also contribute to identifying effective implementation models. Additionally, increased attention to teacher preparation and professional development is essential to support effective classroom practice. For educational practitioners and curriculum developers, integrating computational thinking systematically into literacy-oriented teaching materials, such as student worksheets, is recommended as a strategic approach to simultaneously strengthen reading comprehension skills and 21st-century competencies in elementary education.

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