NAK-KANAK: Journal of Child Research
E-ISSN: 3047-1168 P-ISSN: 3047-504X
JCR, Vol. 3 (2), May 2026 (103-114)
DOI: https://doi.org/10.21107/njcr.v3i2.222

Plugged and Unplugged Coding Approaches for Developing Computational Thinking in Early Childhood: A Systematic Literature Review

Anita Damayanti[1]✉, **Ajeng Afkarina Irvana Bella**[1], **Imelda Indah Lestari**[1], **Dewi Mayangsari**[1]

[1]University of Trunodjoyo Madura, Bangkalan, Indonesia

ARTICLE INFO

Article History:
Received: January 14, 2026
Revised: May 11, 2026
Accepted: May 16, 2026

Keywords:
Computational thinking;
Early childhood education;
Coding education;
Plugged coding;
Unplugged coding.

This is an open-access article under the CC BY-NC license.

Copyright © 2026 by Author, Published Universitas Trunodjoyo Madura

ABSTRACT

Background of the study: The integration of coding activities in early childhood education has gained increasing attention as computational thinking (CT) is recognized as an essential twenty-first-century skill. Previous studies have explored both plugged and unplugged coding approaches for young children; however, limited research has systematically synthesized and compared the empirical evidence regarding their effectiveness in developing computational thinking among children aged 4–6 years, particularly within the context of developing countries and resource-limited early childhood education settings.
Aims and scope of paper: This study aimed to identify patterns, contradictions, and the strength of empirical evidence related to plugged and unplugged coding approaches in fostering computational thinking skills among early childhood learners through a systematic literature review.
Methods: This study employed a systematic literature review design guided by the PRISMA 2020 framework. A total of 30 scholarly articles published between 2020 and 2025 and indexed in Scopus and SINTA were selected through predefined inclusion and exclusion criteria. The selected studies were analyzed using critical thematic synthesis to examine trends, learning outcomes, pedagogical characteristics, and contextual implementation of plugged and unplugged coding approaches in early childhood education.
Results: The findings revealed that unplugged coding approaches consistently supported the development of foundational algorithmic understanding, problem decomposition, collaboration, and social interaction among young children. In contrast, plugged coding approaches demonstrated stronger contributions to abstraction visualization, sequential reasoning, and cognitive flexibility through interactive digital environments. The review found no absolute superiority between the two approaches, as both provided complementary contributions to computational thinking development. Furthermore, contextual factors such as teacher readiness, technological infrastructure, children's developmental stages, and institutional resources significantly influenced the effectiveness of implementation.
Contribution: The framework combines Piagetian cognitive development principles, Vygotskian scaffolding perspectives, and contextual resource considerations relevant to early childhood institutions in developing countries, particularly Indonesia.

✉ **Corresponding Author**
Address : Bangkalan, Indonesia
Email : anitadamayanti2910@gmail.com

INTRODUCTION

Over the last decade, computational thinking (CT) has increasingly been recognized as a fundamental twenty-first-century competency that should be introduced from the early years of education, including preschool settings (Wing, 2006). CT is not merely associated with programming skills but also encompasses problem decomposition, pattern recognition, algorithmic reasoning, abstraction, and logical problem-solving processes that support children's cognitive development across multiple domains. Recent global educational reforms demonstrate a growing commitment to integrating coding and CT into early childhood curricula. According to the OECD (2023), more than forty countries have incorporated coding-related competencies into early childhood and primary education frameworks. However, implementation in developing countries, including Indonesia, remains uneven due to technological disparities, limited institutional resources, and insufficient teacher preparedness (Su & Yang, 2023). This situation creates an important educational paradox: while CT is increasingly considered essential for future readiness, many early childhood institutions still face substantial constraints in implementing technology-based learning.

Within contemporary literature, the debate surrounding early childhood coding instruction primarily revolves around two contrasting pedagogical approaches: plugged coding and unplugged coding (Chen et al., 2023). Plugged coding refers to learning activities that involve digital devices such as tablets, computers, robots, or coding applications, whereas unplugged coding emphasizes computational concepts through physical activities, games, storytelling, and manipulative materials without relying on digital technology. Previous studies have consistently reported that both approaches positively contribute to the development of CT skills; however, they appear to support different dimensions of children's cognitive processes through distinct pedagogical mechanisms (Akiba, 2022). For instance, Lin et al. (2024) found that plugged coding activities more effectively support abstraction and generalization skills, while unplugged approaches demonstrate stronger outcomes in problem decomposition and pattern recognition. In contrast, Zurnacı and Turan (2024) reported that robot-assisted plugged coding interventions generated significantly higher overall CT scores compared to unplugged activities after sixteen instructional sessions.

Despite the growing body of research, several important gaps remain insufficiently addressed. First, most empirical studies on coding instruction for young children have been conducted in technologically advanced countries with relatively stable digital infrastructures, limiting the applicability of findings to developing-country contexts where access to digital devices and teacher competencies remain uneven (Kumala et al., 2023). Second, existing studies predominantly focus on cognitive outcomes while paying limited attention to the broader developmental implications of coding instruction, including social interaction, communication, creativity, and motor development among preschool children (Dzvapatsva & Matobobo, 2025). Third, there is still limited theoretical discussion regarding how plugged and unplugged approaches align with major developmental learning theories, particularly Piaget's cognitive developmental theory and Vygotsky's sociocultural theory, both of which are highly relevant for understanding learning processes among children aged 4–6 years (Yang et al., 2024). As a result, current literature often discusses instructional effectiveness without sufficiently considering developmental appropriateness within early childhood education contexts.

Another important issue concerns the increasing tendency to position plugged and unplugged coding as competing approaches rather than complementary pedagogical strategies. Such binary perspectives may oversimplify the complexity of CT development in early childhood. In practice, children's learning experiences are influenced not only by technological exposure but also by interaction quality, scaffolding processes, play-based engagement, and contextual learning environments. Consequently, there is a need for a more integrative understanding of how both approaches contribute differently yet complementarily to the development of CT competencies in preschool settings.

This study positions itself as one of the first critical systematic reviews that explicitly compares empirical evidence on plugged and unplugged coding approaches within the framework of child development theories while simultaneously incorporating perspectives from developing-country educational contexts. Unlike previous reviews that were largely narrative in nature or focused exclusively on a single instructional approach (McCormick & Hall, 2022), this study employs the PRISMA 2020 protocol combined with critical thematic synthesis and study-quality considerations to generate a more rigorous and replicable synthesis of evidence. Specifically, this study aims to identify consistent patterns and contradictions in empirical findings regarding both approaches, examine their theoretical alignment with preschool children's developmental characteristics, and formulate evidence-based recommendations for contextual and resource-sensitive coding instruction in Indonesian early childhood education institutions. The study ultimately proposes a contextual hybrid learning framework that integrates the cognitive-developmental perspectives of Piaget, the scaffolding principles of Vygotsky, and the practical realities of early childhood institutions operating under limited technological resources.

METHOD

Research Design

This study employed a systematic literature review (SLR) design guided by the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (Page et al., 2021). The SLR approach was selected because it enables the comprehensive and transparent synthesis of empirical evidence through explicit, replicable, and structured procedures, thereby minimizing selection and interpretation bias (Munn et al., 2018). In contrast to traditional narrative reviews, systematic reviews provide a more rigorous approach to identifying, evaluating, and synthesizing research findings across multiple studies. The present review specifically focused on comparing plugged and unplugged coding approaches in fostering computational thinking among children aged 4–6 years.

Data Sources and Search Strategy

The literature search was conducted systematically across three databases: Scopus, SINTA (Science and Technology Index), and Google Scholar. Scopus was prioritized as the primary database due to its high indexing standards, comprehensive metadata, and international journal coverage. SINTA was included to identify relevant studies conducted within the Indonesian context, while Google Scholar functioned as a supplementary source to broaden literature coverage.

Considering the variability of publication quality within Google Scholar, additional screening procedures were applied. Only articles published in peer-reviewed journals with active DOI numbers or official journal URLs were included in the review. The search process was conducted between January and March 2026 and focused on studies published from 2020 to 2025 in order to capture recent developments in computational thinking and coding instruction in early childhood education.

Structured and replicable search strings were developed for each database. The search strategy combined keywords related to computational thinking, coding approaches, and early childhood education contexts using Boolean operators.

Table 1. Search Strings Used in Each Database

Database	Search String	Period
Scopus	TITLE-ABS-KEY ("computational thinking" OR "coding") AND ("early childhood" OR "preschool" OR "kindergarten") AND ("plugged" OR "unplugged" OR "educational robotics")	2020–2025
SINTA	"berpikir komputasional" OR "computational thinking" AND ("koding" OR "coding" OR "pemrograman") AND ("anak usia dini" OR "PAUD" OR "prasekolah")	2020–2025

Database	Search String	Period
Google Scholar	"plugged coding" OR "unplugged coding" OR "coding early childhood" OR "computational thinking preschool"	2020–2025

Inclusion and Exclusion Criteria

The inclusion criteria consisted of: (1) empirical primary studies employing quantitative, qualitative, or mixed-methods designs, as well as systematic reviews or meta-analyses; (2) studies involving children aged 4–6 years; (3) studies specifically addressing computational thinking, coding instruction, digital literacy, plugged coding, unplugged coding, or comparative coding approaches; (4) articles published in Scopus-indexed journals or SINTA-accredited journals (minimum SINTA 3); and (5) publications with accessible DOI numbers or valid official journal URLs.

The exclusion criteria included: (1) articles lacking empirical findings or original data, except high-quality systematic reviews; (2) conference proceedings without rigorous peer-review processes; (3) publications written in languages other than English or Indonesian; and (4) studies without accessible DOI information or official publication sources.

Quality Assessment

Quality appraisal constituted an essential component of the review process to ensure methodological rigor and credibility of findings (Munn et al., 2023). This study employed the Joanna Briggs Institute (JBI) Critical Appraisal Checklist adapted to the methodological design of each included study. Different appraisal instruments were applied according to study type, including the JBI checklist for quasi-experimental studies (11 items), qualitative studies (10 items), and the AMSTAR-2 checklist for systematic reviews (16 items) (Delavari et al., 2023).

Each study was classified into one of three quality categories: high quality (≥75% criteria fulfilled), moderate quality (50–74%), and low quality (<50%). Low-quality studies were not automatically excluded; however, their findings were interpreted more cautiously during the synthesis process.

Article Selection Process

The article selection and screening procedures were conducted independently by two reviewers to reduce subjective bias and improve reliability. During the title and abstract screening stage, inter-rater agreement was calculated using Cohen's Kappa coefficient ($\kappa = 0.83$), indicating substantial agreement between reviewers (Lan et al., 2023). Any disagreements regarding article eligibility were resolved through discussion and consensus with the involvement of a third reviewer as a tiebreaker.

At the full-text review stage, both reviewers independently evaluated each article and documented the reasons for inclusion or exclusion within an auditable shared review sheet. The PRISMA 2020 flow diagram was used to document the identification, screening, eligibility, and inclusion stages systematically.

Data Extraction and Analysis

Data extraction focused on several aspects, including study characteristics, participant age, coding intervention type, duration of intervention, learning media, computational thinking components, research design, and key findings. The extracted data were then analyzed using a critical thematic synthesis approach.

The analysis process aimed not only to summarize findings but also to identify recurring patterns, inconsistencies across studies, and the relative strength of evidence regarding plugged and unplugged coding approaches (Zeng et al., 2023). The analytical stages included: (1) in-depth reading and thematic coding of included studies; (2) categorization of findings based on computational thinking subcomponents, including decomposition, abstraction, pattern recognition, algorithms, and generalization; (3) identification of contradictions, contextual factors, and moderating variables influencing intervention outcomes; and (4) assessment of

evidence strength using an adapted GRADE framework for educational systematic reviews (Suwahyo, 2024).

This analytical approach enabled the study to generate a more critical and theoretically grounded synthesis concerning the comparative contributions of plugged and unplugged coding approaches to computational thinking development in early childhood education.

RESULTS

Study Selection Process

The initial search across the three databases yielded 487 articles. After removing duplicates (n = 142), a total of 345 articles remained for title and abstract screening. During this stage, 247 articles were excluded due to irrelevance to the research focus, leaving 98 articles eligible for full-text assessment. Full-text evaluation subsequently excluded 68 articles for several reasons: absence of valid DOI or official journal access (n = 23), unclear or non-empirical methodology (n = 18), publication in non-indexed journals outside Scopus or SINTA standards (n = 15), and participant age mismatch with the targeted early childhood range (n = 12).

The final review included 30 articles, consisting of 24 primary empirical studies (80%) and 6 systematic reviews or meta-analyses (20%). The selection process followed the PRISMA 2020 framework to ensure transparency and replicability throughout the review procedure.

Study Characteristics and Distribution Patterns

The geographical distribution of the included studies revealed a significant concentration of research in technologically developed regions. Studies conducted in Europe and Turkey accounted for the largest proportion (n = 12, 40%), followed by East Asia (n = 8, 26.7%), the United States (n = 5, 16.7%), Indonesia (n = 3, 10%), and other regions (n = 2, 6.7%). This distribution indicates a substantial underrepresentation of developing-country contexts, particularly within Southeast Asia, highlighting an important methodological gap in the global literature regarding computational thinking interventions in resource-constrained educational settings.

Regarding methodological design, 15 studies (50%) employed quasi-experimental approaches, 7 studies (23.3%) used true experimental designs, 4 studies (13.3%) adopted qualitative or case-study approaches, and 4 studies (13.3%) consisted of systematic reviews or meta-analyses. Sample sizes varied considerably, ranging from 11 to 526 children, with a median sample size of approximately 85 participants.

Quality appraisal using the Joanna Briggs Institute (JBI) criteria indicated that 16 studies (53.3%) were categorized as high quality, 11 studies (36.7%) as moderate quality, and 3 studies (10%) as low quality. Overall, the predominance of moderate-to-high-quality studies strengthened the reliability of the synthesized findings.

Critical Synthesis of Unplugged Coding Approaches

The analysis of 18 studies focusing on unplugged coding revealed several consistent patterns. High-quality studies consistently demonstrated that unplugged coding effectively supported the development of problem decomposition, pattern recognition, collaboration, and social interaction skills among young children (Saygıner & Tüzün, 2025). Chen et al. (2023), in a meta-analysis involving 34 studies, reported moderate-to-large effect sizes (g = 0.62–0.89) for decomposition and pattern-recognition skills through unplugged activities. These findings were reinforced by Saygıner and Tüzün (2025), who identified significant improvements in intrinsic motivation and problem-solving abilities following an eight-week unplugged intervention.

The findings suggest that unplugged activities provide developmentally appropriate learning experiences for preschool children by emphasizing physical interaction, collaborative play, storytelling, and hands-on problem-solving. Such characteristics appear particularly aligned with the sociocultural and concrete operational learning needs of children aged 4–6 years.

Nevertheless, several inconsistencies emerged across studies. Two moderate-quality studies reported that unplugged interventions demonstrated weaker outcomes in executive functioning domains, particularly working memory and cognitive flexibility, compared to robot-assisted plugged approaches (Zurnacı & Turan, 2024). These inconsistencies appear to be influenced more by variations in pedagogical design, intervention duration, and instructional scaffolding than by inherent limitations of unplugged coding itself.

Several recurring limitations of unplugged approaches were also identified. These included strong dependence on teacher facilitation quality, limited representation of advanced abstract computational

concepts such as variables and functions, and the absence of immediate automated feedback mechanisms commonly available in digital environments.

Critical Synthesis of Plugged Coding Approaches

The analysis of 16 studies concerning plugged coding revealed a different yet equally significant pattern of findings. High-quality studies consistently demonstrated that plugged coding environments were more effective in promoting abstraction, generalization, and cognitive flexibility (Lin et al., 2024). Zhang et al. (2025), in a randomized controlled trial involving 198 children aged 5–6 years, found that children participating in robot programming activities significantly outperformed unplugged groups in inhibition control, working memory, and cognitive flexibility after twelve weeks of intervention. Similarly, Zurnacı and Turan (2024) reported significantly higher post-intervention computational thinking scores among kindergarten children participating in robot-assisted coding programs.

These findings indicate that plugged coding environments may offer stronger opportunities for visual-symbolic representation, interactive feedback, and iterative experimentation, all of which contribute to higher-order computational reasoning processes.

However, important inconsistencies were also identified. Garcia-Marques et al. (2026), using a two-group classroom design, found that carefully designed unplugged activities produced computational thinking gains comparable to Bee-Bot programming interventions, with no statistically significant differences between groups. Likewise, Lin et al. (2024) reported no significant differences in overall computational thinking scores despite differences in subcomponent profiles between plugged and unplugged groups.

These inconsistencies suggest that the superiority of plugged coding cannot be generalized universally. Instead, intervention effectiveness appears to depend heavily on pedagogical quality, instructional design, teacher facilitation, intervention intensity, and the assessment instruments used to measure computational thinking outcomes.

Comparative Patterns, Inconsistencies, and Strength of Evidence

The comparative synthesis demonstrated that plugged and unplugged coding approaches contribute to computational thinking development through distinct yet complementary mechanisms. Unplugged coding consistently showed stronger evidence for supporting decomposition, pattern recognition, collaboration, and social interaction, particularly within play-based and collaborative learning contexts. In contrast, plugged coding demonstrated stronger contributions to abstraction, generalization, visual-symbolic reasoning, and executive functioning.

Importantly, the review found no absolute evidence supporting the superiority of one approach over the other across all computational thinking dimensions. Instead, the effectiveness of each approach appeared context-dependent and influenced by multiple moderating variables, including pedagogical design, teacher competence, intervention duration, technological accessibility, and children's developmental readiness.

Furthermore, unplugged coding demonstrated substantially greater accessibility and feasibility for early childhood institutions with limited technological infrastructure. Several studies emphasized that unplugged activities required minimal resources, making them more inclusive and adaptable for developing-country contexts (Harper, 2024; Metin, 2022). Conversely, plugged coding interventions often required higher financial investment, stable technological infrastructure, and teacher digital competence, which may limit scalability in low-resource educational environments.

Overall, the evidence synthesized in this review suggests that plugged and unplugged coding approaches should not be positioned as competing pedagogical models. Rather, both approaches may function more effectively as complementary strategies within a hybrid computational thinking curriculum adapted to the developmental characteristics of young children and the contextual realities of early childhood education settings.

DISCUSSION

The findings of this systematic review both reinforce and refine conclusions reported in previous international studies regarding coding instruction in early childhood education. Consistent with the umbrella review conducted by Yang et al. (2024), this study confirms that tangible coding activities, including unplugged and robotics-based approaches, are effective in supporting the development of computational thinking (CT), particularly in concrete reasoning and spatial skills among preschool children. However, the present synthesis extends prior findings by

demonstrating that the effectiveness of unplugged coding in promoting problem decomposition, pattern recognition, and collaborative interaction is not universally guaranteed. Instead, these outcomes are strongly influenced by the pedagogical quality of the activities and teachers' computational thinking content knowledge (Wang et al., 2023).

Several reviewed studies indicate that teacher scaffolding plays a critical role in shaping children's engagement and conceptual understanding during coding activities. Zeng et al. (2023a), for example, found that teachers with stronger pedagogical and technological competencies were more capable of facilitating meaningful coding interactions and reflective problem-solving processes. This finding suggests that instructional quality may be a more influential factor than the technological modality itself.

The most significant contradiction identified in the literature concerns the comparative effectiveness of plugged and unplugged coding on overall CT performance. While Zurnacı and Turan (2024) reported that educational robotics produced significantly higher CT scores than unplugged activities, Garcia-Marques et al. (2026) and Lin et al. (2024) found no statistically significant differences between the two approaches. The present synthesis suggests that these inconsistencies are likely moderated by several methodological variables, including intervention duration, instructional intensity, assessment instruments, and activity design quality. For instance, studies with longer interventions and structured robotics sequences tended to report stronger effects for plugged coding, whereas carefully designed unplugged activities often produced comparable outcomes in foundational CT skills.

Furthermore, Claerhout and Fanchamps (2025) highlighted the importance of collaborative learning structures, demonstrating that group-based coding activities enhanced communication, reasoning, and problem-solving more effectively than individual instruction. This finding indicates that the social organization of learning may interact with coding modality in shaping CT development.

Extending Piagetian and Vygotskian Perspectives

The findings of this review contribute important theoretical implications for understanding coding instruction in early childhood education through developmental learning theories. From a Piagetian perspective, children aged 4–6 years are situated within the preoperational stage, in which learning is facilitated through concrete representations, symbolic play, and physical manipulation (Piaget, 1972). The effectiveness of unplugged coding in supporting decomposition and pattern recognition aligns closely with this developmental characteristic because children engage directly with tangible materials and embodied experiences.

This finding also resonates with Papert's constructionist theory, which emphasizes learning through active manipulation and meaningful interaction with concrete objects (Papert, 2020). Nevertheless, the effectiveness of robotics-based plugged coding challenges the assumption that digital technology is inherently too abstract for preschool children. The reviewed studies suggest that when digital tools are embedded within tangible and interactive interfaces, such as floor robots or visual block-based programming, they can function as developmentally appropriate scaffolds that bridge concrete and abstract thinking.

From a Vygotskian perspective, the differential effects of plugged and unplugged approaches may be explained through distinct forms of mediation. Unplugged coding activities promote rich social mediation through peer interaction, collaborative problem-solving, and verbal negotiation within the Zone of Proximal Development (ZPD). Children frequently act as "more knowledgeable others" for one another, thereby facilitating social learning and co-construction of understanding (Oktaviani et al., 2025).

Conversely, plugged coding environments provide structured artifact-mediated learning through automated feedback systems, sequential commands, and interactive visual responses. These features appear particularly effective in supporting executive functions such as working memory, inhibition, and cognitive flexibility (Zhang et al., 2025). Based on these findings, this study proposes the concept of "dual mediation," in which unplugged coding primarily emphasizes

social mediation, while plugged coding strengthens technological and artifact-based mediation. Both mechanisms contribute differently yet complementarily to children's CT development.

Conceptual Contribution: A Staged Hybrid Learning Model (SHLM)

One of the major contributions of this review is the development of a conceptual framework termed the *Staged Hybrid Learning Model* (SHLM) for early childhood coding instruction. Rather than positioning plugged and unplugged coding as competing approaches, the model conceptualizes them as complementary pedagogical stages aligned with children's developmental readiness.

The model consists of three sequential phases: foundation Phase (Weeks 1–4): Intensive unplugged activities are introduced to establish fundamental CT concepts, including sequencing, decomposition, and pattern recognition through physical games, movement, and collaborative tasks. Transition Phase (Weeks 5–8): Tangible robotics activities are integrated to bridge physical representations with digital logic. This phase gradually familiarizes children with algorithmic thinking through interactive robotic manipulation. Expansion Phase (Weeks 9–12): Screen-based plugged coding activities are introduced to support abstraction, debugging, and generalization using visual programming environments appropriate for young learners.

The proposed model is theoretically supported by Montuori et al. (2023), who demonstrated that combining unplugged and robotics activities significantly improved both near-transfer coding skills and far-transfer visuospatial abilities among preschool children. Therefore, SHLM offers a contextualized and developmentally responsive framework that may be particularly relevant for early childhood institutions in developing countries with diverse technological capacities.

Implications

The findings of this review have important implications for early childhood educators, curriculum developers, and policymakers. First, the study suggests that unplugged coding can serve as an accessible and inclusive entry point for computational thinking education, particularly in low-resource educational contexts where digital infrastructure remains limited. Schools do not necessarily require sophisticated technology to begin introducing CT concepts effectively.

Second, the findings emphasize that teacher competence and pedagogical design are more critical than technological sophistication alone. Professional development programs should therefore prioritize teachers' understanding of CT pedagogy, scaffolding strategies, and developmentally appropriate coding activities.

Third, the findings support the integration of hybrid coding curricula that combine unplugged and plugged experiences progressively rather than treating them as isolated approaches. Such integration may better accommodate children's cognitive development while also addressing resource disparities across educational settings.

Research Contribution

This study contributes to the growing literature on computational thinking in early childhood education in several significant ways. First, it provides one of the first systematic critical syntheses explicitly comparing plugged and unplugged coding approaches within the context of preschool education and developing countries. Second, the review extends existing theoretical discussions by introducing the concept of dual mediation grounded in Piagetian and Vygotskian learning theories. Third, the proposed SHLM framework offers an evidence-based conceptual model that integrates developmental theory, pedagogical sequencing, and contextual feasibility for early childhood coding education.

Unlike previous reviews that primarily focused on technological effectiveness, this study emphasizes the interaction between pedagogy, developmental readiness, and educational context. Consequently, the review contributes both theoretically and practically to the design of more adaptive and context-sensitive coding curricula for young children.

Limitations

Several limitations should be acknowledged. First, the reviewed studies varied considerably in terms of intervention duration, measurement instruments, and research designs, limiting direct comparability across findings. Second, many studies employed relatively small sample sizes and lacked long-term follow-up assessments, making it difficult to evaluate the sustainability of CT development over time.

Third, the literature remains heavily dominated by studies conducted in technologically advanced countries, resulting in the underrepresentation of developing-country contexts such as Indonesia. Consequently, caution is needed when generalizing findings to educational systems with different infrastructural and socio-cultural conditions.

In addition, this review did not conduct a quantitative meta-analysis due to substantial heterogeneity among the included studies. Although rigorous quality appraisal procedures were applied, publication bias and language restrictions (English and Indonesian only) may still have influenced the comprehensiveness of the synthesis.

Suggestions

Future studies are recommended to conduct longitudinal and mixed-method investigations to examine the long-term effects of coding interventions on children's cognitive, social-emotional, and executive functioning development. More comparative studies involving diverse cultural and socio-economic contexts are also needed to strengthen the contextual validity of coding pedagogies in early childhood education.

Further research should additionally explore the role of teacher professional development, parental involvement, and classroom interaction patterns as mediating variables in coding instruction effectiveness. Quantitative meta-analytic studies may also provide stronger estimates regarding the comparative effect sizes of plugged and unplugged approaches across different CT dimensions.

Finally, future intervention studies should investigate the practical implementation and effectiveness of the proposed Staged Hybrid Learning Model (SHLM) in real early childhood education settings, particularly within low-resource environments and developing countries.

CONCLUSION

This systematic literature review provides three major evidence-based conclusions regarding the implementation of plugged and unplugged coding approaches in early childhood education. First, unplugged coding consistently demonstrates stronger potential in fostering problem decomposition, pattern recognition, and social-collaborative interaction among preschool children. In contrast, plugged coding tends to show greater effectiveness in supporting abstraction, generalization, and executive functioning, particularly working memory and cognitive flexibility. However, the magnitude of these effects varies considerably depending on instructional design quality, intervention duration, assessment instruments, and contextual implementation factors.

Second, the findings indicate that neither approach can be considered universally superior across all dimensions of computational thinking (CT). Instead, both methods exhibit complementary pedagogical strengths that align with major developmental learning theories. Unplugged coding reflects Vygotskian principles of social mediation and collaborative scaffolding, whereas plugged coding supports the transition from concrete to abstract representation as emphasized in Piagetian and Brunerian perspectives.

Third, this review proposes that a staged hybrid approach integrating unplugged activities as conceptual foundations and plugged coding as a medium for abstract expansion offers the most promising framework for holistic CT development in early childhood education. Such an approach is particularly relevant for developing countries, including Indonesia, where disparities in technological infrastructure and teacher readiness remain significant challenges. Therefore, effective coding instruction for young children should not focus solely on technological

sophistication, but rather on developmentally appropriate pedagogy, contextual feasibility, and meaningful learning experiences.

AUTHOR CONTRIBUTION STATEMENT

Anita Damayanti: Conceptualization, Methodology, Investigation, Formal Analysis, Writing – Original Draft, Supervision, Project Administration. **Ajeng Afkarina Irvana Bella**: Data Curation, Investigation, Literature Review, Validation, Writing – Review & Editing. **Imelda Indah Lestari:** Methodology, Data Analysis, Visualization, Validation, Writing – Review & Editing. **Dewi Mayangsari:** Resources, Data Curation, Investigation, Writing – Review & Editing, Administrative Support.

REFERENCES

Akiba, D. (2022). Computational thinking and coding for young children: A hybrid approach to link unplugged and plugged activities. *Education Sciences, 12*(11), 793. https://doi.org/10.3390/educsci12110793

Chen, P., Yang, D., Metwally, A. H. S., Lavonen, J., & Wang, X. (2023). Fostering computational thinking through unplugged activities: A systematic literature review and meta-analysis. *International Journal of STEM Education, 10*(1), Article 34. https://doi.org/10.1186/s40594-023-00434-7

Claerhout, C., & Fanchamps, N. (2025). The effect of unplugged and plugged-in programming with influencing factor of collaborative versus individual work regarding the impact on computational thinking in preschoolers. In *European Conference on Technology Enhanced Learning* (pp. 123–137). Springer. https://doi.org/10.1007/978-3-032-03870-8_9

Delavari, S., Pourahmadi, M., & Barzkar, F. (2023). What quality assessment tool should I use? A practical guide for systematic reviews authors. *Iranian Journal of Medical Sciences, 48*(3), 229–236. https://doi.org/10.30476/ijms.2022.95143.2664

Dzvapatsva, G. P., & Matobobo, C. (2025). Innovative approaches in teaching coding skills to young children: A scoping review. *Educational Technology Quarterly, 2025*(3), 330–354. https://doi.org/10.55056/etq.916

Garcia-Marques, M. E., Pérez-Suay, A., & García-Bayona, I. (2026). Plugged or unplugged? A comparative study of computational thinking development in early childhood. *Education Sciences, 16*(2), 333. https://doi.org/10.3390/educsci16020333

Harper, F. (2024). An unplugged remix of culturally responsive computing for early childhood education. *Future in Educational Research, 2*(1), 41–55. https://doi.org/10.1002/fer3.41

Kumala, R. A. D., Fathiyah, K. N., & Krisnani, R. V. R. (2023). Computational thinking pada anak usia dini: Tinjauan sistematis. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini, 7*(3), 3418–3436. https://doi.org/10.31004/obsesi.v7i3.4520

Lan, H., Yu, X., Wang, Z., Wang, P., Sun, Y., Wang, Z., & Chen, Y. (2023). How about the evidence assessment tools used in education and management systematic reviews? *Frontiers in Medicine, 10*, 1160289. https://doi.org/10.3389/fmed.2023.1160289

Lin, Y.-H., Liao, H.-C., Weng, S.-H., & Dong, W.-C. (2024). Comparing the effects of plugged-in and unplugged activities on computational thinking development in young children. *Education and Information Technologies, 29*(8), 9541–9574. https://doi.org/10.1007/s10639-023-12181-x

McCormick, K. I., & Hall, J. A. (2022). Computational thinking learning experiences, outcomes, and research in preschool settings: A scoping review of literature. *Education and Information Technologies, 27*, 3777–3812. https://doi.org/10.1007/s10639-021-10765-z

Metin, S. (2022). Activity-based unplugged coding during the preschool period. *International Journal of Technology and Design Education, 32*(1), 149–165. https://doi.org/10.1007/s10798-020-09616-8

Montuori, C., Gambarota, F., Altoé, G., & Arfé, B. (2024). The cognitive effects of computational thinking: A systematic review and meta-analytic study. *Computers & Education, 210*, 104961. https://doi.org/10.1016/j.compedu.2023.104961

Montuori, C., Pozzan, G., Padova, C., Ronconi, L., Vardanega, T., & Arfé, B. (2023). Combined unplugged and educational robotics training to promote computational thinking and cognitive abilities in preschoolers. *Education Sciences, 13*(9), 858. https://doi.org/10.3390/educsci13090858

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology, 18*(1), 143. https://doi.org/10.1186/s12874-018-0611-x

Munn, Z., Stone, J. C., Aromataris, E., Klugar, M., Sears, K., Leonardi-Bee, J., & Barker, T. H. (2023). Assessing the risk of bias of quantitative analytical studies: Introducing the vision for critical appraisal within JBI systematic reviews. *JBI Evidence Synthesis, 21*(3), 467–471. https://doi.org/10.11124/JBIES-22-00271

Oktaviani, P., Diana, D., Waluyo, E., & Formen, A. (2025). Unplugged coding to develop computational and collaborative thinking in early childhood education. *JPUD - Jurnal Pendidikan Usia Dini, 19*(2), 228–235. https://doi.org/10.21009/jpud.v19i2.57818

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., *et al.* (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71

Papert, S. (2020). *Mindstorms: Children, computers, and powerful ideas* (2nd ed.). Basic Books.

Piaget, J. (1972). *The psychology of the child*. Basic Books.

Relkin, E., De Ruiter, L. E., & Bers, M. U. (2021). Learning to code and the acquisition of computational thinking by young children. *Computers & Education, 169*, 104222. https://doi.org/10.1016/j.compedu.2021.104222

Saygıner, Ş., & Tüzün, H. (2025). Investigation of the effects of unplugged coding activities developed for preschool on motivation, computational thinking and problem-solving skills. *Education and Information Technologies*. Advance online publication. https://doi.org/10.1007/s10639-025-13752-w

Su, J., & Yang, W. (2023). A systematic review of integrating computational thinking in early childhood education. *Computers and Education Open, 4*, 100122. https://doi.org/10.1016/j.caeo.2023.100122

Suwahyo, B. W. (2024). Coding learning approaches for early childhood: A systematic review. *Edcomtech: Jurnal Kajian Teknologi Pendidikan, 9*(2), 66–78. https://doi.org/10.17977/um039v9i22024p66

Wang, X. C., Choi, Y., Benson, K., Eggleston, C., & Weber, D. (2023). Teacher's role in fostering preschoolers' computational thinking: An exploratory case study. In X. C. Wang (Ed.), *Developing culturally and developmentally appropriate early STEM learning experiences* (pp. 26–48). Routledge.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33–35. https://doi.org/10.1145/1118178.1118215

Yang, W., Su, J., & Li, H. (2024). Demystifying early childhood computational thinking: An umbrella review to upgrade the field. *Future in Educational Research, 2*(4), 458–477. https://doi.org/10.1002/fer3.38

Zeng, Y., Yang, W., & Bautista, A. (2023a). Computational thinking in early childhood education: Reviewing the literature and redeveloping the three-dimensional framework. *Educational Research Review, 39*, 100520. https://doi.org/10.1016/j.edurev.2023.100520

Zeng, Y., Yang, W., & Bautista, A. (2023b). Teaching programming and computational thinking in early childhood education: A case study of content knowledge and pedagogical knowledge. *Frontiers in Psychology, 14*, Article 1252718. https://doi.org/10.3389/fpsyg.2023.1252718

Zhang, X., Chen, Y., Hu, L., Hwang, G.-J., & Tu, Y.-F. (2025). Developing preschool children's computational thinking and executive functions: Unplugged vs. robot programming activities. *International Journal of STEM Education, 12*(1), 10. https://doi.org/10.1186/s40594-025-00510-2

Zurnacı, B., & Turan, Z. (2024). Educational robotics or unplugged coding activities in kindergartens? Comparison of the effects on pre-school children's computational thinking and executive function skills. *Thinking Skills and Creativity, 53*, 101576. https://doi.org/10.1016/j.tsc.2024.101576

.