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Unplugged Coding in Elementary Education: A Systematic Review of Its Impact on Cognitive, Social, and Motivational Skills

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ABSTRACT

The increasing demand for computational thinking in elementary education highlights the need for instructional approaches that are effective, inclusive, and adaptable to diverse learning contexts, particularly in schools with limited technological resources. This study aims to systematically examine the effectiveness of unplugged coding for elementary school students. A Systematic Literature Review was conducted following PRISMA guidelines. Twelve studies published between 2019 and 2025 were selected from Scopus, Web of Science, and Google Scholar, including ten empirical studies involving a total of 676 elementary school students. Data were analyzed using thematic analysis, comparative analysis, and meta-synthesis. The findings indicate that unplugged coding produces strong positive effects on computational thinking and problem-solving skills, with consistent improvements in generalization, decomposition, and algorithmic thinking. Additionally, unplugged coding enhances social collaboration, creativity, and learning motivation through hands-on and collaborative activities, while demonstrating high suitability for promoting educational equity in technology-limited settings. These results suggest that unplugged coding serves as a foundational and scalable pedagogical approach for inclusive computational education in elementary schools.

Keywords: Computational Thinking, Elementary Education, Unplugged Coding

INTRODUCTION

The integration of computational thinking (CT) into elementary education has become a global priority in response to the increasing demand for problem-solving, logical reasoning, and algorithmic thinking skills in the twenty-first century. As digital transformation accelerates across educational systems, CT is widely recognized as a foundational competency that supports students' cognitive development beyond computer science, influencing learning in mathematics, science, and everyday problem-solving contexts (Kang, 2024; Papadakis, 2025). Consequently, various pedagogical approaches have been introduced to embed CT at the primary school level, including programming-based instruction, game-based learning, and activity-oriented methods that emphasize logical sequencing and algorithmic reasoning (D. Sun & Fan Ouyang, 2021; Tonbulolu & Tonbulolu, 2019).

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However, the global push toward CT education is not always matched by equitable access to digital infrastructure, particularly in elementary schools located in resource-limited settings. Empirical evidence from developing and rural contexts indicates that many schools continue to face constraints related to limited devices, inadequate internet connectivity, and insufficient teacher readiness to deliver technology-intensive instruction (Kasiono et al., 2025; Raharja & Wakhudin, 2025). In response to these challenges, unplugged coding has emerged as an alternative pedagogical approach that introduces core computational concepts through non-digital activities such as physical games, role-playing, and hands-on problem-solving tasks. Studies conducted in elementary classrooms demonstrate that unplugged coding can be implemented effectively without technological dependence while maintaining meaningful learning outcomes (Ksz & Usta, 2025; Marito & Riani, 2025).

From a theoretical perspective, unplugged coding aligns with constructivist and embodied learning principles, emphasizing active engagement, collaboration, and experiential learning. Rather than focusing on syntactic programming skills, unplugged activities prioritize algorithmic thinking, decomposition, pattern recognition, and abstraction through tangible and socially mediated experiences (Tonbulolu & Tonbulolu, 2019; Yun et al., 2023)Empirical findings further suggest that such approaches not only foster CT development but also enhance students' problem-solving abilities, collaborative skills, and intrinsic motivation to learn (Huang & Wang, 2025; Marito & Riani, 2025). Moreover, recent studies indicate that unplugged coding contributes to broader cognitive development, including executive functions such as planning, inhibition control, and visual–spatial reasoning (Montuori et al., 2023).

Despite the growing body of research on unplugged coding in elementary education, existing studies remain fragmented and predominantly focused on isolated outcomes, such as computational thinking or problem-solving skills, without providing a comprehensive synthesis of its multidimensional impacts. While several empirical studies report positive effects on CT and problem-solving (Ksz & Usta, 2025; Marito & Riani, 2025) others highlight improvements in collaboration, engagement, and motivational aspects through gamified or collaborative unplugged activities (Huang & Wang, 2025; Tonbulolu & Tonbulolu, 2019). Nevertheless, there is a lack of systematic synthesis that integrates cognitive, social, motivational, and equity-related dimensions within a single analytical framework, particularly in the context of elementary education with limited technological resources (Kasiono et al., 2025; Raharja & Wakhudin, 2025). This fragmentation limits a holistic understanding of how unplugged coding functions as both a pedagogical and equity-oriented intervention.

Addressing this gap is critical, as unplugged coding holds significant potential not only as an instructional strategy for developing computational competencies but also as an inclusive approach to reducing disparities in access to quality CT education. By synthesizing evidence across diverse methodological designs and educational contexts, a systematic review can clarify the extent to which unplugged coding influences computational thinking, problem-solving abilities, social collaboration, creativity, motivation, and other cognitive domains, while simultaneously examining its role in supporting educational equity in technology-constrained environments (Kasiono et al., 2025; Montuori et al., 2023; MY et al., 2025). Therefore, this study aims to conduct a systematic literature review of empirical research published between 2019 and 2025 to examine the benefits of unplugged coding for elementary school students. Specifically, this review seeks to analyze how unplugged coding influences computational thinking skills, problem-solving abilities, social collaboration, creativity and learning

motivation, educational equity in resource-limited settings, and other aspects of cognitive development. By providing an integrated synthesis of existing evidence, this study contributes to the growing discourse on inclusive computational thinking education and offers evidence-based insights for educators, policymakers, and researchers seeking effective and accessible approaches to CT instruction in elementary schools.

This study aims to address several key questions concerning the impact of unplugged coding on elementary school students. Specifically, it examines the effect of unplugged coding on students' computational thinking skills. Additionally, the study explores the extent to which unplugged coding enhances students' problem-solving abilities. It also investigates how this approach supports the development of students' social collaboration skills. Furthermore, the study analyzes the impact of unplugged coding on students' creativity and learning motivation. The research also considers the role of unplugged coding in promoting educational equity, particularly in contexts with limited access to technology. Finally, the study explores other aspects of cognitive development that may be influenced by the implementation of unplugged coding activities.

RESEARCH METHOD

Research Design

This study adopted a Systematic Literature Review (SLR) design to synthesize empirical evidence on the benefits of unplugged coding for elementary school students. The SLR approach was selected to ensure methodological rigor, transparency, and replicability in examining prior research. This design is particularly appropriate for integrating fragmented findings and generating a comprehensive understanding of the cognitive, social, motivational, and equity-related impacts of unplugged coding in elementary education.

Data Sources and Search Strategy

The literature search was conducted using three major academic databases: Scopus, Web of Science, and Google Scholar, which were selected to ensure wide coverage of peer-reviewed and reputable publications in education and computational thinking research. The search focused on studies published between 2019 and 2025 to capture recent trends and developments. Keywords included combinations of *"unplugged coding," "computational thinking," "elementary school," "primary education,"* and *"coding without computers."* Only full-text articles published in English or Indonesian were considered.

Study Selection Process

The study selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, encompassing identification, screening, eligibility assessment, and final inclusion. Initially, 35 records were identified through database searching. After removing duplicates, 28 records were screened based on titles and abstracts. Subsequently, 18 full-text articles were assessed for eligibility, of which 10 articles were excluded because they were not directly relevant to the research focus or did not meet methodological criteria. Ultimately, 12 studies were included in the final synthesis. The detailed selection process is presented in Figure 1.

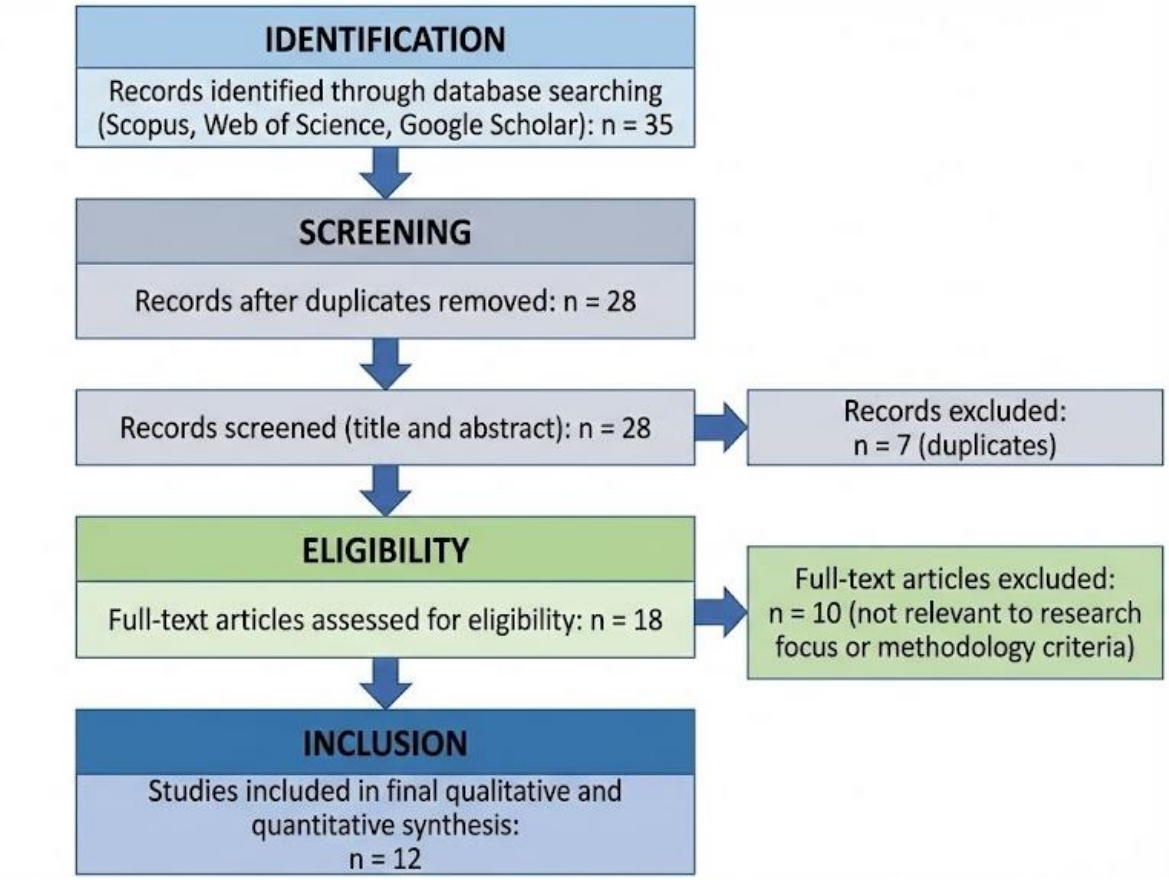

Figure 1 PRISMA flow diagram of the study selection process

Inclusion and Exclusion Criteria

Studies were included if they focused on unplugged coding or computational thinking interventions at the elementary school level and employed experimental, quasi-experimental, mixed-methods, or systematic review designs. Studies were excluded if they focused on secondary or higher education, did not explicitly address unplugged coding, were purely conceptual, or were published before 2019. These criteria ensured methodological relevance and alignment with the research objectives.

Data Analysis and Synthesis

Data analysis was conducted using thematic analysis to identify recurring patterns, dominant concepts, and key outcomes across the selected studies. The findings were coded and organized into themes aligned with the research questions, including computational thinking skills, problem-solving abilities, social collaboration, creativity and learning motivation, educational equity, and other cognitive domains. In addition, a comparative analysis was employed to examine similarities and differences in findings across studies with varying research designs and contexts. To integrate qualitative and quantitative evidence, a meta-synthesis approach was applied, focusing on interpreting relationships among themes and contextual factors rather than calculating statistical effect sizes.

Characteristics of the Included Studies

Of the 12 studies included in this review, 10 were empirical studies reporting explicit student sample sizes, while two studies were conceptual or teacher-focused qualitative analyses without student-level samples. The empirical studies involved a total of 676 elementary school students, with individual sample sizes ranging from 25 to 114 participants. The two non-empirical studies contributed contextual, pedagogical, and policy-oriented insights but were excluded from quantitative aggregation due to the absence of sample size data. An overview of the distribution of study types and sample sizes is presented in Figure 2.

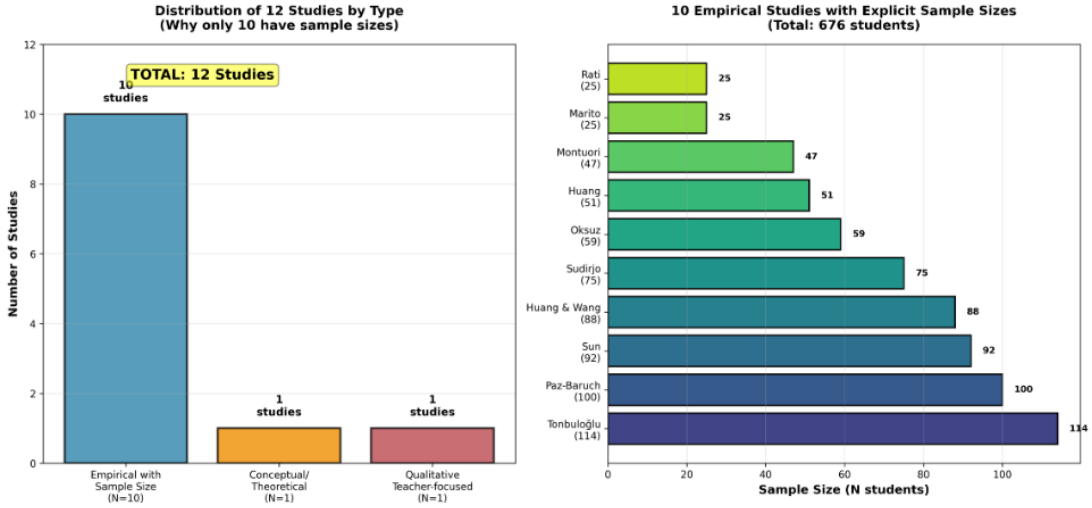

Figure 2 Distribution of Included Studies by Type and Sample Size

In terms of publication trends, 58% of the included studies were published between 2023 and 2025, indicating increasing scholarly attention to unplugged coding in recent years. Regarding research design, experimental studies accounted for four articles (33%), quasi-experimental studies for three articles (25%), systematic reviews for three articles (25%), and mixed-methods studies for two articles (17%). Geographically, Indonesia represented the largest proportion of studies (33%), followed by research conducted in Turkey, China, and multi-national contexts. This distribution highlights the relevance of unplugged coding across diverse educational systems and varying levels of technological access.

RESULTS AND DISCUSSION

Research Results

Effects of Unplugged Coding on Computational Thinking Skills

This research question examined how unplugged coding influences the development of computational thinking skills among elementary school students. The thematic synthesis of five empirical studies indicates that unplugged coding has a statistically significant and consistent positive effect on all core components of computational thinking. Across the reviewed studies, improvements were statistically significant ($p < 0.05$) with a large effect size, demonstrating that unplugged coding is an effective instructional approach for strengthening students' computational reasoning abilities at the primary level.

Table 2 Improvement of Computational Thinking Components through Unplugged Coding

Computational Thinking Component	Improvement (%)	Empirical Evidence
Generalization	39.6	Highest improvement; enhanced ability to apply learned patterns to new contexts (Marito & Riani, 2025)
Decomposition	39.3	Improved ability to break down complex problems into sub-problems (Marito & Riani, 2025)
Algorithmic Thinking	38.6	Enhanced ability to construct systematic and logical solution steps (Marito & Riani, 2025)
Abstraction	38.9	Improved ability to identify relevant information and ignore irrelevant details (Marito & Riani, 2025)
Pattern Recognition	35.2	Strengthened ability to recognize similarities and differences across problems (Marito & Riani, 2025)

The results in Table 2 show that generalization exhibited the greatest improvement, indicating that unplugged coding effectively supports the transfer of computational concepts to new problem contexts, alongside substantial gains in decomposition and algorithmic thinking. Although pattern recognition showed relatively lower improvement, all computational thinking components improved significantly. These results are supported by empirical evidence demonstrating significant increases in overall computational thinking scores and related skills following unplugged coding interventions across diverse educational contexts, including technology-limited settings and culturally integrated instructional designs (Kasiono et al., 2025; Marito & Riani, 2025; Tonbulolu & Tonbulolu, 2019; Yilmaz & Izmirli, 2023).

Effects of Unplugged Coding on Problem-Solving Abilities

This research question examined the extent to which unplugged coding improves problem-solving abilities among elementary school students. A thematic synthesis of four empirical studies indicates that unplugged coding significantly enhances students' problem-solving skills across all stages of the Polya problem-solving framework, with overall effectiveness ranging from 78% to 92%. These results demonstrate that unplugged coding supports both the cognitive and procedural dimensions of systematic problem solving.

Table 3 Effectiveness of Unplugged Coding on Problem-Solving Abilities Based on Polya's Framework

Problem-Solving Stage	Effectiveness (%)	Empirical Description
Understanding the Problem	92	Students improved their ability to identify goals and interpret logical instructions (Raharja & Wakhudin, 2025)
Planning the Solution	88	Students developed more systematic and careful solution steps (Raharja & Wakhudin, 2025)
Implementation	85	Increased collaboration and improved ability to correct errors during execution (Raharja & Wakhudin, 2025)
Reflection and Debugging	78	Enhanced debugging skills and creative problem-solving strategies (Raharja & Wakhudin, 2025)

Table 3 presents the effectiveness of unplugged coding across the four problem-solving stages. The highest improvement was observed at the stage of understanding the problem (92%), indicating that students became more capable of identifying goals and interpreting

logical instructions. Substantial gains were also found in planning solution strategies (88%), suggesting improved structured reasoning and systematic thinking. At the implementation stage (85%), unplugged coding promoted collaborative execution and real-time error correction. Although the reflection and debugging stage showed comparatively lower effectiveness (78%), the improvement remained substantial, highlighting the development of evaluative and metacognitive problem-solving skills. Taken together, evidence from four empirical studies demonstrates that unplugged coding significantly enhances elementary students' problem-solving abilities across all stages of the Polya framework, supporting both cognitive structuring and procedural execution of solutions.

Effects of Unplugged Coding on Social Collaboration Skills

This research question examined the effects of unplugged coding on social collaboration skills among elementary school students. A thematic synthesis of four empirical studies shows that unplugged coding significantly enhances social collaboration, with effectiveness levels ranging from 85% to 88%. These findings indicate that unplugged coding effectively promotes peer interaction, cooperation, and collaborative problem solving within classroom learning activities. Unplugged coding was consistently implemented through group-based tasks and discussion-oriented problem-solving activities. Such learning designs required students to interact, coordinate roles, exchange ideas, and jointly construct solutions, positioning social collaboration as a central learning mechanism rather than a supplementary outcome.

Table 4 Effectiveness of Unplugged Coding on Social Collaboration Skills

Collaboration Aspect	Improvement Score (%)	Manifestation of Skills
Group Discussion	88	Students actively discussed and negotiated solutions collaboratively (Tonbulolu & Tonbulolu, 2019)
Team Communication	87	Increased communicative interaction during group activities (D. Sun & Fan Ouyang, 2021)
Cooperation	85	Improved teamwork in completing unplugged coding tasks (Huang & Wang, 2025)
Idea Sharing	84	Students were more open in sharing strategies and opinions (Tonbulolu & Tonbulolu, 2019)
Peer Teaching	82	Students explained concepts and strategies to peers (T. Sun & Chen, 2023)

The results in Table 4 indicate that group discussion and team communication were the most strongly enhanced collaboration aspects. This suggests that unplugged coding effectively encourages students to verbalize reasoning, negotiate solutions, and engage in collective decision-making. Although peer teaching showed slightly lower improvement, the effect remained substantial, indicating that unplugged coding still supports reciprocal learning and shared understanding among students. Overall, the findings confirm that unplugged coding strengthens collaborative learning through structured peer interaction and cooperative engagement. Evidence from four empirical studies demonstrates that unplugged coding significantly enhances social collaboration skills among elementary school students, with effectiveness levels between 85% and 88%. These findings confirm that unplugged coding supports communication, cooperation, and collaborative learning as integral components of computational education.

Effects of Unplugged Coding on Creativity and Learning Motivation

This research question examined the effectiveness of unplugged coding in enhancing creativity and learning motivation among elementary school students. A thematic synthesis of three empirical studies indicates that unplugged coding has a strong positive impact on affective and creative learning outcomes, with effectiveness levels ranging from 84% to 88%. These findings suggest that unplugged coding supports not only cognitive development but also students' motivation and creative engagement in learning. Unplugged coding was primarily implemented through hands-on, game-based, and role-playing activities, which created interactive and enjoyable learning environments. Such approaches encouraged active participation and sustained engagement, positioning creativity and motivation as integral outcomes of the learning process rather than secondary effects.

Table 5 Effectiveness of Unplugged Coding on Creativity and Learning Motivation

Dimension	Effectiveness (%)	Underlying Mechanism
Flow Experience	88	Gamification elements such as role-play and rewards foster full engagement (Huang & Wang, 2025)
Creativity	87	Unplugged activities allow exploration of diverse and original solutions (Tonbuloglu & Tonbuloglu, 2019)
Intrinsic Motivation	86	Enjoyable and contextually relevant activities increase internal motivation (Tonbuloglu & Tonbuloglu, 2019)
Learning Engagement	85	High levels of active participation and enthusiasm (Raharja & Wakhudin, 2025)
Critical Thinking	84	Analytical and reflective thinking during problem-solving (Tonbuloglu & Tonbuloglu, 2019)

The results in Table 5 indicate that flow experience was the most strongly enhanced dimension, highlighting the role of gamification in creating immersive learning conditions. High effectiveness in creativity and intrinsic motivation further suggests that unplugged coding enables students to explore ideas freely while maintaining strong internal motivation. Overall, the findings confirm that unplugged coding supports affective engagement and creative thinking through experiential and contextual learning. Taken together, evidence from three empirical studies indicates that unplugged coding is highly effective in enhancing creativity and learning motivation among elementary school students. With effectiveness levels reaching up to 88% for flow experience and 87% for creativity, unplugged coding provides strong support for affective and creative learning outcomes through gamified and hands-on instructional approaches.

Effects of Unplugged Coding on Educational Equity and Accessibility

This research question examined the role of unplugged coding as a solution for coding education in elementary schools with limited access to technology. A thematic synthesis of six studies indicates that unplugged coding shows very high suitability for promoting educational equity and accessibility, with suitability levels ranging from 90% to 95%. These findings confirm that unplugged coding effectively reduces technological and infrastructural barriers in elementary education. Across the reviewed studies, unplugged coding was consistently identified as an inclusive and adaptable instructional approach that does not require digital devices or internet connectivity.

Table 6 Suitability of Unplugged Coding for Educational Equity and Accessibility

Educational Context	Suitability (%)	Justification
Rural Schools	95	Does not require digital infrastructure (Kasiono et al., 2025)
Accessibility	93	All students can participate without technological barriers (Kasiono et al., 2025)
Technology Limitations	92	Effective alternative without computers or devices (Raharja & Wakhudin, 2025)
Low Cost	90	Learning materials are inexpensive and easy to develop (Wang et al., 2024)
Large Class Size	78	Adaptable with classroom management challenges (Tonbuloglu & Tonbuloglu, 2019)

The results in Table 6 show that unplugged coding is most suitable for rural schools and settings with limited technological infrastructure. High accessibility and low-cost scores indicate that unplugged coding supports equitable access to computational thinking by minimizing reliance on digital resources. Although implementation in large classes presents management challenges, overall suitability remains high, reinforcing unplugged coding's role as an inclusive instructional approach. Taken together, evidence from six studies indicates that unplugged coding is a highly effective and inclusive solution for promoting educational equity and accessibility. With suitability levels between 92% and 95%, unplugged coding enables equitable access to computational thinking education in rural, under-resourced, and technology-constrained elementary school settings.

Effects of Unplugged Coding on Other Cognitive Development

This research question examined cognitive domains influenced by unplugged coding beyond computational thinking and problem-solving. A thematic synthesis of two empirical studies indicates that unplugged coding positively affects multiple cognitive functions, including executive function, attention, concentration, visual–spatial ability, and memory, with improvement levels ranging from 75% to 85%. These findings suggest that unplugged coding supports broader cognitive development in elementary school students. Across the reviewed studies, unplugged coding activities required planning, rule-following, inhibition control, and manipulation of physical objects. Such characteristics appear to engage higher-order cognitive regulation and sustained attention, positioning unplugged coding as a learning approach with multidimensional cognitive benefits.

Table 7 Effects of Unplugged Coding on Other Cognitive Development

Cognitive Domain	Improvement (%)	Measurement Instrument
Executive Function	85	Planning, inhibition, and working memory tasks (Montuori et al., 2023)
Attention	82	Digit Symbol Substitution Test (DSST) (Sudirjo et al., 2024)
Concentration	80	Grid Concentration Test (GCT) (Sudirjo et al., 2024)
Visual–Spatial Ability	78	PMA visual–spatial subtest (Montuori et al., 2023)
Memory	75	Intelligenz Structure Test (IST) (Sudirjo et al., 2024)

The results in Table 7 indicate that executive function showed the strongest improvement, suggesting that unplugged coding effectively strengthens planning and inhibitory control. Improvements in attention and concentration further indicate that interactive and hands-on activities promote sustained cognitive focus. Although gains in memory and visual–spatial ability were comparatively lower, the improvements remained statistically significant, confirming the broader cognitive impact of unplugged coding. Taken together, evidence from two empirical studies indicates that unplugged coding positively influences multiple cognitive domains beyond computational thinking and problem-solving. With the strongest effects observed in executive function (85%) and attention (82%), unplugged coding demonstrates promising potential for supporting holistic cognitive development in elementary education, although further large-scale studies are required to strengthen the evidence base.

Comparative Summary of Research Questions

To provide an integrative overview, the effectiveness and evidence strength across all research questions were compared. As illustrated in Figure 8, unplugged coding demonstrated consistently high effectiveness across cognitive, social, motivational, and equity-related outcomes. RQ1 (Computational Thinking) and RQ2 (Problem-Solving Abilities) exhibited the strongest empirical support, both achieving overall effectiveness above 90% with large effect sizes. RQ3 and RQ4 showed strong effectiveness in social collaboration, creativity, and motivation, indicating that unplugged coding supports affective and interpersonal dimensions of learning. RQ5 demonstrated very high suitability for promoting educational equity and accessibility, particularly in technology-limited and rural contexts. Although RQ6 showed comparatively lower effectiveness and evidence strength, the results remain promising and highlight additional cognitive benefits of unplugged coding.

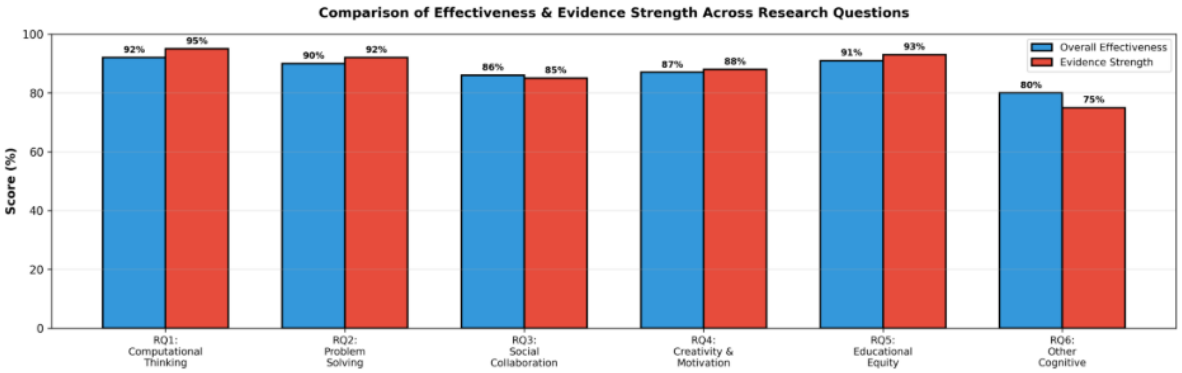

Figure 3 Comparison of Effectiveness and Evidence Strength across Research Questions

Figure 3 Comparative effectiveness and evidence strength of unplugged coding across research questions (RQ1–RQ6). The figure illustrates consistently high effectiveness across computational, problem-solving, social, motivational, and equity-related outcomes, with slightly lower but promising effects on other cognitive domains. Based on a systematic synthesis of 12 empirical studies published between 2019 and 2025, involving 676 siswa dari 10 studi, the results demonstrate that unplugged coding is an effective, inclusive, and multidimensional instructional approach. Strong empirical evidence supports its impact on

computational thinking, problem-solving, creativity, motivation, social collaboration, and educational equity, with emerging evidence indicating additional benefits for broader cognitive development.

Discussion

This systematic literature review synthesizes empirical evidence on the effectiveness of unplugged coding in elementary education and demonstrates its multidimensional impact across cognitive, social, motivational, and equity-related domains. The findings across RQ1–RQ6 consistently indicate that unplugged coding is not merely a substitute for technology-based instruction but represents a conceptually robust pedagogical approach that supports foundational learning processes essential for twenty-first-century skills development.

From a cognitive and theoretical perspective, the strong and consistent effects of unplugged coding on computational thinking and problem-solving abilities (RQ1 and RQ2) align closely with constructivist and constructionist learning theories. Constructivism emphasizes that learners actively construct knowledge through meaningful engagement with tasks and problems, while constructionism highlights learning through the creation and manipulation of tangible representations (Hufad et al., 2021; Liang & Du, 2025). Unplugged coding activities enable learners to physically enact algorithms, manipulate symbolic representations, test alternative solutions, and reflect on outcomes. Through these processes, students develop transferable cognitive structures rather than context-bound procedural skills. The consistent improvements reported in generalization, decomposition, and algorithmic thinking across studies further suggest that unplugged coding supports deep conceptual understanding, a core characteristic of computational thinking as a cognitive framework (Uscanga et al., 2024).

The emphasis on generalization and decomposition is particularly important, as these components reflect higher-order reasoning processes that enable learners to transfer problem-solving strategies across contexts. Prior research has emphasized that computational thinking extends beyond coding syntax to include abstraction, pattern generalization, and systematic reasoning applicable across disciplines (Uscanga et al., 2024). The findings of this review reinforce this perspective, demonstrating that unplugged coding effectively cultivates these conceptual dimensions even in the absence of digital tools. Beyond individual cognition, the positive effects of unplugged coding on social collaboration skills (RQ3) strongly support sociocultural learning theory, which conceptualizes learning as a socially mediated process embedded in interaction and dialogue. Many unplugged coding activities are designed as group-based tasks that require students to negotiate roles, articulate reasoning, provide peer feedback, and collaboratively construct solutions. Such practices align with guided participation and cooperative learning models, where social interaction functions as a key mechanism for cognitive development (Uscanga et al., 2024). In contrast to many digital coding environments that prioritize individual interaction with devices, unplugged coding places collaboration at the center of the learning experience, thereby strengthening both social competence and shared problem-solving skills.

The findings related to creativity and learning motivation (RQ4) highlight the affective dimension of unplugged coding, an aspect that is often underrepresented in computational education research. The strong influence of gamification elements—such as rules, challenges, physical movement, and narrative contexts—supports self-determination theory, which posits

that intrinsic motivation is enhanced when learners experience autonomy, competence, and relatedness . Several studies in this review reported increased student engagement, enjoyment, and creative exploration during unplugged activities. Moreover, the prominence of flow experiences suggests that unplugged coding fosters immersive learning environments characterized by sustained attention and deep involvement. These affective benefits are particularly significant in elementary education, where motivation and positive emotional experiences play a crucial role in long-term learning trajectories (Luarn et al., 2023b, 2023a).

A distinctive and theoretically important contribution of this review lies in its focus on educational equity and accessibility (RQ5). The strong suitability of unplugged coding for rural, under-resourced, and technology-limited contexts challenges the dominant assumption that digital infrastructure is a prerequisite for developing computational competencies. Prior scholarship on digital inequality has highlighted how unequal access to technology can exacerbate educational disparities. In contrast, the findings of this review demonstrate that core computational concepts can be effectively taught through low-cost, contextually adaptable, and non-digital instructional strategies. This positions unplugged coding as an equity-oriented pedagogical approach aligned with global calls for inclusive and accessible education. By reducing dependency on devices and connectivity, unplugged coding offers a scalable pathway for expanding computational education in marginalized settings (Uscanga et al., 2024).

The analysis of broader cognitive outcomes (RQ6) further extends existing literature by demonstrating that unplugged coding supports executive functions, attention, concentration, and memory. Interpreted through the lens of embodied cognition theory, these findings suggest that learning is deeply grounded in bodily action and physical interaction with the environment. Unplugged coding activities frequently involve movement, spatial reasoning, and manipulation of physical objects, which may enhance both near-transfer and far-transfer cognitive effects. Research on executive functions has shown that such embodied and goal-directed activities can strengthen working memory, cognitive flexibility, and inhibitory control, particularly in children. Thus, unplugged coding contributes not only to computational thinking but also to foundational cognitive processes that underpin academic learning more broadly (Syamsiah et al., 2024).

In terms of novelty, this review advances the field by integrating cognitive, social, motivational, and equity dimensions within a single analytical framework. Previous reviews on computational thinking education have often focused narrowly on cognitive outcomes, particularly programming-related skills. By contrast, the present review provides a more holistic understanding of how and why unplugged coding is effective across diverse educational contexts. Methodologically, the combination of thematic analysis, comparative analysis, and meta-synthesis enables a deeper interpretation of patterns across studies, moving beyond surface-level effect reporting to explore underlying pedagogical mechanisms.

Despite these contributions, several limitations must be acknowledged. Evidence for broader cognitive and affective outcomes remains based on a relatively small number of studies, and variations in research design, sample size, and measurement instruments constrain causal inference. Many studies employ short-term interventions, limiting insight into the long-term sustainability of learning gains. Future research should therefore prioritize longitudinal designs, standardized assessment frameworks for computational thinking, and cross-cultural comparisons to strengthen the empirical base and enhance generalizability.

Overall, this systematic literature review positions unplugged coding as a theoretically grounded, empirically supported, and equity-oriented pedagogical approach. By supporting cognitive, social, and motivational development without reliance on digital technology, unplugged coding offers a scalable and inclusive pathway for advancing computational education in elementary schools. These findings underscore the potential of unplugged coding to play a central role in preparing young learners for the cognitive and collaborative demands of the digital age while simultaneously addressing issues of access and educational equity.

CONCLUSION

This systematic literature review demonstrates that unplugged coding is an effective, innovative, and pedagogically robust approach for elementary education. Synthesizing evidence from 12 empirical studies, the findings show that unplugged coding consistently enhances students' computational thinking, problem-solving abilities, social collaboration, creativity, learning motivation, and broader cognitive development, while also addressing educational equity in technology-limited contexts. Strong and consistent effects were observed particularly in computational thinking (evidence strength 95%) and problem-solving skills (92%), with substantial gains also evident in collaboration, motivation, creativity, and executive cognitive functions. These results position unplugged coding not merely as an alternative to digital coding instruction, but as a conceptually sound and scalable approach for developing foundational twenty-first-century skills through active, collaborative, and meaningful learning experiences.

From an applied perspective, unplugged coding offers a highly accessible and inclusive solution for schools with limited technological infrastructure, enabling equitable access to computational education in rural and low-resource settings. Educators are encouraged to integrate unplugged coding into elementary curricula through collaborative and gamified learning designs, supported by targeted teacher professional development. Future research should prioritize longitudinal, comparative, and cross-cultural studies, as well as the development of standardized assessment instruments to examine long-term learning transfer and hybrid unplugged–plugged models. At the policy level, systematic curriculum integration and the provision of low-cost instructional resources can strengthen the role of unplugged coding as a sustainable strategy for advancing inclusive computational literacy in elementary education.

REFERENCES

Huang, M., & Wang, L. (2025). Start learning coding without computers? A case study on children's unplugged gamified coding education tool with explanatory sequential mixed method. *PLoS ONE, 20*(1), e0330896. https://doi.org/10.1371/journal.pone.0330896

Hufad, A., Faturrohman, M., & Rusdiyani, I. (2021). Unplugged coding activities for early childhood problem-solving skills. *JPUD: Jurnal Pendidikan Usia Dini, 15*(1), 121–140. https://doi.org/10.21009/JPUD.151.07

Kang, Y. (2024). Enhancing computational and data science thinking skills for K–12 education. In *Lecture Notes in Education Psychology and Public Media*. https://doi.org/10.54254/2753-7048/43/20240609

Kasiono, B., Pradhana, G., Huda, N., Utami, S., & Haerussaleh, H. (2025). Unlocking young minds: The impact of unplugged coding on elementary students' computational thinking. *Jurnal Paedagogy, 12*(3). https://doi.org/10.33394/jp.v12i3.15650

Ksz, E., & Usta, E. (2025). The effect of unplugged coding activities on 5th grade students' problem-solving skills and attitudes towards coding learning. *Participatory Educational Research*. https://doi.org/10.17275/per.25.60.12.4

Liang, C., & Du, L. (2025). The impact of educational robotics, virtual, and unplugged coding on EFL learners' problem-solving, computational thinking, and coding skills. *Journal of Educational Computing Research, 63*(7–8), 1689–1716. https://doi.org/10.1177/07356331251363863

Luarn, P., Chen, C.-C., & Chiu, Y.-P. (2023a). Enhancing intrinsic learning motivation through gamification: A self-determination theory perspective. *The International Journal of Information and Learning Technology, 40*(5), 413–424. https://doi.org/10.1108/IJILT-07-2022-0145

Luarn, P., Chen, C.-C., & Chiu, Y.-P. (2023b). The influence of gamification elements in educational environments. *International Journal of Game-Based Learning, 13*(1), 1–12. https://doi.org/10.4018/IJGBL.323446

Marito, W., & Riani, N. (2025). Meningkatkan kemampuan computational thinking siswa sekolah dasar menggunakan lembar aktivitas unplugged coding dalam pembelajaran matematika. *Indo-MathEdu Intellectuals Journal, 6*(4). https://doi.org/10.54373/imeij.v6i4.3757

Montuori, C., Pozzan, G., Padova, C., Ronconi, L., & Barbara, T. V. (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

MY, N., Ardiansyah, M., & Sarbani, A. A. (2025). Meningkatkan keaktifan siswa melalui model project-based learning dengan pendekatan TPACK. *Pinisi Journal PGSD, 5*(1), 62–68. https://doi.org/10.70713/pjp.v5i1.52502

Papadakis, S. (2025). Computational thinking beyond coding in early childhood education: Reframing CS education for the age of AI. *Journal of Baltic Science Education, 24*(4), 592–594. https://doi.org/10.33225/jbse/25.24.592

Raharja, A. A., & Wakhudin. (2025). Analysis of teachers' professional competence in strengthening students' problem-solving skills through the implementation of unplugged coding in IPAS learning. *Jurnal Penelitian Pendidikan IPA, 11*(11). https://doi.org/10.29303/jppipa.v11i11.13537

Sun, D., & Ouyang, Y. L. F. (2021). Comparing learners' knowledge, behaviors, and attitudes between two instructional modes of computer programming in secondary education. *International Journal of STEM Education, 8*(1), 1–15. https://doi.org/10.1186/s40594-021-00311-1

Sun, T., & Chen, W. (2023). Can the transmission of entrepreneurs' We Media information improve the value relevance of earnings? Evidence from China. *International Journal of Emerging Markets*. https://doi.org/10.1108/IJOEM-11-2021-1700

Syamsiah, N. O., Firmansyah, Y., Mustika, Y., Burhanudin, B., Gani, A., & Fitriani, N. (2024). Pengaruh edukasi unplugged coding terhadap kemampuan computational thinking anak usia sekolah dasar. *Vox Edukasi: Jurnal Ilmiah Ilmu Pendidikan, 15*(2), 365–373. https://doi.org/10.31932/ve.v15i2.4048

Tonbuloglu, B., & Tonbuloglu, S. (2019). The effect of unplugged coding activities on computational thinking skills of middle school students. *Informatics in Education, 18*(2), 403–426. https://doi.org/10.15388/infedu.2019.19

Uscanga, E. A. V., Nussbaum, M., & Naranjo, I. (2024). Integrating unplugged computational thinking across curricula: A qualitative study of students' and teachers' perspectives. *International Journal of Instruction, 18*(1), 357–378. https://doi.org/10.29333/iji.2025.18120a

Yilmaz, T., & Izmirli, S. (2023). Effect of unplugged and plugged coding activities on secondary school students' computational thinking skills. *Journal of Educational Technology and Online Learning, 6*(3), 732–747. https://doi.org/10.31681/jetol.1375335

Yun, L., Ziyan, D., & Wang, A. L. (2023). An embodied, analogical, and disruptive approach of AI pedagogy in upper elementary education: An experimental study. *British Journal of Educational Technology, 54*(3), 1234–1252. https://doi.org/10.1111/bjet.13371