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Unlocking Young Minds : The Impact of Unplugged Coding on Elementary Students' Computational Thinking

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Abstract: This study aims to analyze the effectiveness of the unplugged coding method in improving elementary students' computational thinking skills, identify the CT components that develop, and evaluate its potential as a contextual, inclusive, and sustainable learning solution. This study employs a systematic literature review using the PRISMA technique, selecting 31 journal articles were indexed in reputable databases such as Scopus and SINTA published between 2021 and 2025. The articles were analyzed thematically based on relevance to CT and unplugged methods in elementary education. Results show that the unplugged coding method is an effective and contextually relevant approach to enhancing computational thinking (CT) skills in elementary school students. The effectiveness of this method is reflected in the development of key CT components and its positive contribution to student motivation and engagement in learning. Scientifically, these findings support the argument that strengthening CT does not necessarily rely on digital technology, but can be achieved through contextual and hands-on learning strategies. Therefore, unplugged coding has the potential to serve as a strategic alternative in primary informatics education, particularly in resource-constrained settings. As an implication, this study recommends the development of national teaching guidelines and policies to systematically support the integration of the unplugged approach into the curriculum. Further experimental research across diverse school contexts is needed to assess its long-term impact and to enrich best practices in implementation.

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Introduction

The advancement of information technology has brought significant changes to the field of education, demanding the integration of 21st-century skills from an early age. One of the most crucial skills is computational thinking (CT)-the ability to think logically, systematically, and efficiently in solving problems. CT is not only essential in computer science but also underpins learning processes across various disciplines such as mathematics, science, and even literacy. Therefore, instilling this skill at the elementary school level has become increasingly relevant amid the global digital transformation (Syamsiah et al., 2024).

Numerous studies emphasize the importance of strengthening CT from early education. Zaidiah et al. (2024) argue that coding instruction in elementary schools can foster logical and critical thinking patterns, while Christi & Rajiman (2023) highlight CT's contribution to enhancing children's mathematical reasoning. However, the implementation of CT learning in Indonesian elementary schools remains uneven. Major challenges include limited technological infrastructure, insufficient teacher training, and a lack of learning media suited to children's developmental characteristics (Awaluddin & Hadi, 2025).

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To address these challenges, the unplugged coding approach has emerged as an innovative alternative. This method enables students to learn CT concepts without digital devices, instead using physical activities such as games, simulations, or tangible manipulative. A study Syamsiah et al. (2024) shows that this approach effectively enhances decomposition and algorithmic thinking in elementary student. Furthermore, Zafrullah et al. (2024) demonstrate that daily-life-based unplugged activities can foster analytical thinking in a fun and contextual manner.

The strength of the unplugged approach lies in its ability to bridge the digital divide, particularly in underdeveloped, remote, and frontier regions where access to computers and the internet is still very limited. In addition to being cost effective, this method is considered more suitable for elementary aged children, who are active, and learn best through concrete experiences. Unfortunately, many school have yet to adopt this approach optimally due to limited teacher understanding and the lack of practical teaching material (Puspa et al., 2024).

In this context, unplugged coding holds strategic value as a method that is not only inclusive but also adaptive to local conditions. Integrating CT into cultural and everyday contexts, such as using local characters in problem scenarios or traditional games for algorithmic thinking, has been shown to enhance students' emotional engagement and conceptual understanding (Christi & Rajiman, 2023). However, despite the growing number of studies exploring the benefits of unplugged coding, there remains a notable research gap. Most existing studies focus primarily on general cognitive outcomes or isolated CT components, such as abstraction or algorithmic thinking (Syamsiah et al., 2024), without offering a comprehensive analysis of how unplugged coding impacts CT holistically in young learners. Furthermore, while unplugged activities have been applied in classroom settings, few studies examine their effectiveness across diverse educational contexts particularly in schools with limited digital infrastructure. This gap highlights the lack of evidence regarding how unplugged coding methods can be systematically applied to unlock broader CT competencies in elementary students. Therefore, further research is needed to investigate the impact of unplugged coding approaches on the overall development of computational thinking skills, especially in early education settings where access to digital tools remains limited. Nevertheless, there is still a lack of systematic literature reviews that specifically evaluate the effectiveness of this approach in Indonesian elementary education.

The scientific novelty of this study lies in its exclusive focus on unplugged coding as and applicable, enjoyable, and relevant alternative for CT instruction amid limited resources. This study not only maps the effectiveness of this approach based on recent studies bur also identifies the CT components that develop through its implementation and the challenges faced in elementary school setting. This study aims to analyze the effectiveness of the unplugged coding method in improving elementary students' computational thinking skills, identify the CT components that develop, and evaluate its potential as a contextual, inclusive, and sustainable learning solution.

Research Method

The research method employed in this study is a systematic literature review using the PRISMA (Preferred Reporting Items for Systematic Review and Meta Analysis) analysis technique (Gunawan et al., 2024). The PRISMA technique offers a structured and transparent framework for conducting systematic literature reviews, ensuring that the selected sources are credible and relevant to the research objectives. According to Gunawan et al.(2024), this technique involves four key stages: identification, screening, eligibility, and inclusion. In the

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identification stage, researchers collect potential articles by searching academic databases such as Google Scholar and Scopus using relevant keywords like "unplugged coding method elementary school" and "computational thinking elementary school." During the screening stage, titles and abstracts are reviewed to eliminate duplicate and irrelevant articles. The eligibility stage involves evaluating the full texts of the remaining articles based on predefined inclusion and exclusion criteria, such as a focus on elementary education, unplugged coding, or computational thinking with empirical results. Finally, the inclusion stage narrows the list to peer-reviewed articles indexed in Scopus or Sinta 2 to 6 and published between 2021 and 2025. This systematic procedure, as emphasized by Gunawan et al. (2024), enhances the accuracy, transparency, and replicability of the review process. Article selection restriction were applied to ensure the relevance, novelty, and validity of the reviewed findings, as well as to narrow the search scope and increase precision in identifying information sources (Akbar & Biyanto, 2022). Furthermore, each article was evaluated based on the criteria outlined in Table 1, as follows:

Table 1. Article Evaluated Criteria

No	Evaluation Criteria	Description
1	Topic Relevance	The article must discuss unplugged coding, computational thinking, or programming in elementary schools.
2	Education Level	The article focuses on elementary school or covers age levels equivalent to elementary school children.
3	Unplugged Method Approach	The article explicitly states the use of nondigital (unplugged) methods.
4	Focus on Computational Thinking (CT)	The article includes CT indicators such as decomposition, pattern recognition, abstraction, and algorithms.

The data analysis in this study uses thematic analysis, a qualitative approach that identifies, analyzes, and interprets themes within textual data. As outlined by Gunawan et al. (2024), this method is appropriate for synthesizing literature findings in a systematic review, particularly when exploring complex educational phenomena such as coding instruction and computational thinking. The thematic analysis allows the researcher to extract key concepts across multiple articles and organize them into meaningful categories that reflect the research focus.

In this study, the analysis process began with familiarization carefully reading and re-reading the selected articles to become immersed in the content. Then, initial codes were generated to capture relevant data segments related to unplugged coding, coding skills development, and learning motivation in elementary students. These codes were subsequently grouped into broader themes based on patterns of similarity, contrast, or theoretical relevance. This process followed an inductive deductive logic: inductively identifying insights from the data while aligning them with the conceptual framework of the study (Akbar & Biyanto, 2022). The final themes were reviewed, refined, and interpreted to answer the research questions and support conclusions regarding the impact of unplugged coding approaches in elementary education.

Results and Discussion

The systematic literature review in this study was conducted using the PRIMA technique, which consists of four main stages: identification, screening, eligibility, and inclusion. In the identification stage, a total of 89 articles were retrieved from academic databases such as Google Scholar and Scopus using relevant keywords including "unplugged

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coding method elementary school" and "computational thinking elementary school." At the screening stage, titles and abstracts were reviewed to eliminate 31 duplicates and 20 articles that were deemed irrelevant based on initial criteria. This left potentially eligible articles for further evaluation. During the eligibility stage, the full texts of these articles were assessed in detail using predefined inclusion and exclusion criteria. Only studies that focused on elementary education, unplugged coding, or computational thinking and presented empirical results were considered. After a thorough assessment, 7 additional articles were excluded due to a lack of empirical data of limited relevance to the research variables.

In the final inclusion stage, 31 articles published between 2021 and 2025 and indexed in Scopus or SINTA 2 to 6 were selected for analysis. These articles were written in either English or Indonesian and directly addressed the variables under study. This rigorous selection process ensured that the literature used was high quality, relevant, and capable of supporting the research objectives. The unplugged coding in elementary education, with consistent themes emerging across multiple studies regarding its impact on logical thinking, algorithmic understanding, and student engagement. These findings provided the foundation for further thematic analysis presented in the following discussion. This literature review examines 31 scientific articles published over the past five years that discuss the implementation of the unplugged coding method at the elementary school level. Of the total, 24 articles (77%) report a positive and significant impact on improving elementary students' computational thinking (CT) skills. Meanwhile, the remaining 7 articles are theoretical or compare the unplugged approach with other instructional methods. The distribution of these findings is presented in Tables 2 and 3 below

Table 2. Article with Positive and Significant Impact

No	Author(s) & Year	Title/Topic	SINTA Category
1	Mukarommah et al., (2021)	Implementation of basic computer	SINTA 5
2	Nurhopipah et al., (2021)	Computer science learning without computers (unplugged activities) to train children's logic skills	SINTA 3
3	Giyartini et al., (2022)	Implementation of computational thinking unplugged in dance learning in foreign elementary schools.	SINTA 4
4	Marifah et al., (2022)	The role of CT in elementary schools, the unplugged approach, and its integration into the national curriculum	SINTA 5
5	Suryanto et al., (2022)	Training in coding introduction for elementary school teachers using Scratch Jr.	SINTA 5
6	Fauzi et al., (2022)	Effectiveness of learning modules with an unplugged computational thinking approach vs a scientific approach	SINTA 5
7	Arzaki et al., (2023)	Computational thinking training for elementary school teachers with unplugged and Berbras approaches	SINTA 4
8	Megawati et al., (2023)	Implementation of computational thinking in mathematics learning in elementary schools	SINTA 5
9	Giyartini et al., (2023)	Computational thinking unplugged in dance learning in elementary schools	SINTA 3
10	Inasari et al., (2023)	Development of computational thinking test instruments with the Rasch model	SINTA 5

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No	Author(s) & Year	Title/Topic	SINTA Category
11	Christi & Rajiman, (2023)	The importance of computational thinking in mathematics learning	SINTA 5
12	Zafrullah et al., (2024)	Bibliometric analysis of computational thinking usage in children's schools	SINTA 6
13	Herowati et al., (2024)	Strengthening CT in elementary schools with Scratch games and unplugged activities	SINTA 5
14	Prameswara & Pramudita, (2024)	Comparison of CS unplugged and plugged-in learning approaches	SINTA 3
15	Puspa et al., (2024)	Developing game media to introduce CT in elementary schools with a fun approach	SINTA 5
16	Syamsiah et al., (2024)	The impact of unplugged coding education on computational thinking skills of elementary school children	SINTA 3
17	Ayub et al., (2024)	CT training for teachers through Berbras and unplugged activities	SINTA 4
18	Purnani et al., (2024)	Scaffolding strategies to improve computational thinking skills in geometry material	SINTA 5
19	Listyana et al., (2024)	Development of coding-based flipbook media for elementary school students	SINTA 2
20	Ardiansyah et al., (2024)	Computational thinking in IPAS learning in elementary schools	SINTA 5
21	Ragil et al., (2024)	The relationship between linguistic intelligence and computational thinking skills of elementary school students	SINTA 2
22	Pambudi et al., (2024)	Integration of STEAM and CT based on local wisdom to understand friction in elementary schools	SINTA 5
23	Anggraini et al., (2025)	Unplugged CT training for early childhood teachers	SINTA 4
24	Awaluddin & Hadi, (2025)	Integration of coding and AI in elementary schools	SINTA 5

Table 3. Theoretical or Comparative Articles

No	Author(s) & Year	Title/Topic	SINTA Category
1	Suhendar et al., (2021)	Building creative, systematic, and logical thinking through coding learning	SINTA 3
2	Fajriyah et al., (2022)	Comparison of plugged vs unplugged in CT for early childhood	SINTA 4
3	Noviyanti et al., (2023)	The effect of differentiated learning on elementary students' computational thinking skills	SINTA 2
4	Wiria & Alberida, (2023)	Problem-solving and collaboration in biology learning	SINTA 5
5	Nishom et al., (2023)	Introduction to coding for teachers and students (high school)	SINTA 4
6	Zaidiah et al., (2024)	Coding training with Scratch for elementary students	SINTA 4
7	Widianto et al., (2024)	The relationship between linguistic intelligence and computational thinking in grade V elementary school	SINTA 5

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Based on the analysis of the 31 reviewed articles, it was found that the unplugged coding method consistently contributes positively to enhancing elementary students' computational thinking skills. The most prominent aspects of computational thinking that showed improvement include decomposition, pattern recognition, abstraction, and algorithms. For instance, in the study by Syamsiah et al. (2024), students participated in an "algorithm walk" activity to solve simple problems. This activity trained students to arrange systematic steps to achieve specific goals. This phenomenon can be scientifically explained through the theory of embodied cognition, which states that learning involves processing abstract information. This approach also aligns with Vygotsky's view, which emphasizes the importance of social and contextual activities in forming higher cognitive functions. In other words, the unplugged method not only trains logical thinking conceptually but also shapes structured thinking patterns through enjoyable real-world activities.

In addition to cognitive aspects, several articles also show that the unplugged method has a positive affective dab social impacts. For example, Fitriyah in Syamsiah et al. (2024) reported that using logic cards and puzzle dimes in unplugged activities could increase students' enthusiasm, learning motivation, and social interaction. This can be explained through Kolb's experiential learning theory, which states that concrete experiences form the primary basis for deeper understanding. According to Piaget, elementary school-aged children are in the concrete operational stage, thus greatly benefiting from learning strategies involving direct manipulation of objects and real situations. Therefore, the unplugged method proves to be in line with the cognitive and affective developmental needs of students at this level.

Furthermore, an interesting finding from this literature review is the flexibility of the unplugged method across subjects. Not limited to informatics, this approach is also used in teaching mathematics, arts, and even languages. For example, Giyartini et al. (2023) successfully applied algorithmic thinking concepts in dance lessons, while Fauzi et al. (2022) used the computational thinking approach to enhance students' mathematical logic skills. This shows that CT is not various learning contexts. Conceptually, this is based on the idea of transversal skills, which are skills that can be transferred and applied across different fields.

Additionally, the unplugged method offers practical solutions for schools with limited access to technology, as explained by Zaidiah et al. (2024). In underdeveloped, remote, and frontier regions where computer availability is very limited, this approach allows CT learning to continue without reliance on digital devices. From the perspective of contextual teaching and learning (CTL), using real environments and local resources in learning enriches students' experiences and makes concepts easier to understand. Thus, this method becomes an inclusive and socially relevant approach, especially in the context of equalizing education quality.

However, several implementation challenges remain in various studies. Puspa et al. (2024) highlight the low understanding of teachers regarding computational thinking concepts and the lack of learning media suitable for the local context. Without adequate training and explicit curriculum support, this method risks becoming an additional activity with little impact on comprehensive CT development of national unplugged-based teaching modules and the systematic integration of computational thinking into thematic learning in elementary schools.

Conceptually, this study's findings reinforce the understanding that unplugged coding is not merely an alternative approach but a scientifically valid pedagogical method for developing computational thinking (CT) skills in elementary school students. This approach

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emphasizes that CT, which includes decomposition, pattern recognition, and algorithms, does not always have to be taught through digital devices or screen-based programming. Instead, experience-based methods, such as logic games, simulation, and physical activities, can meaningfully facilitate children's cognitive development.

Therefore, theoretically, this study expands the conceptual framework of elementary informatics education, highlighting that CT is a cross-disciplinary skill that can be cultivated through active and contextual learning. It affirms the constructivist perspective (such as those proposed by Vygotsky and Kolb) that conceptual understanding develops more effectively through learning experiences involving social interaction, problem-solving, and reflection on real-world experiences.

Conclusion

This literature review demonstrates that the unplugged coding method is an effective and contextually relevant approach to enhancing computational thinking (CT) skills in elementary school students. The effectiveness of this method is reflected in the development of key CT components and its positive contribution to student motivation and engagement in learning. Scientifically, these findings support the argument that strengthening CT does not necessarily rely on digital technology, but can be achieved through contextual and hands-on learning strategies. Therefore, unplugged coding has the potential to serve as a strategic alternative in primary informatics education, particularly in resource-constrained settings. As an implication, this study recommends the development of national teaching guidelines and policies to systematically support the integration of the unplugged approach into the curriculum. Further experimental research across diverse school contexts is needed to assess its long-term impact and to enrich best practices in implementation.

Recommendation

Future research should employ experimental methods across diverse elementary school contexts to examine the long-term effectiveness of the unplugged coding approach. Systematic teacher training is necessary to enhance the implementation of computational thinking (CT) in classrooms. Moreover, the development of standardized teaching modules and national integration guidelines is crucial, especially for schools with limited digital infrastructure. Challenges such as low CT literacy among teachers and the lack of contextual learning resources must be addressed through supportive police and multi-stakeholder collaboration.

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