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Unplugged Coding to Develop Computational and Collaborative Thinking in Early Childhood Education

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ABSTRACT:
Integrating computational and collaborative thinking from early childhood is essential in the digital era. This study examined the implementation of Unplugged Coding computer-free programming at the Larasati Early Childhood Education Cluster, with a focus on children's cognitive and social development. Using a qualitative case study method, data were collected through observation, interviews, and documentation at TK Islam An-Nur Kedungringin. Activities involved grid floor games, number dice, and directional arrows, with teachers acting as facilitators. Results showed that 87.5% of children demonstrated improvement in computational thinking components such as sequencing, pattern recognition, decomposition, and algorithmic reasoning. Moreover, 81.2% of children exhibited enhanced collaborative skills, including turn-taking, group problem-solving, and active communication. Contributing factors included structured planning, engaging learning tools, and a supportive environment. Limitations involved limited infrastructure and varying teacher readiness. The study concludes that Unplugged Coding is an effective, low-tech approach to foster 21st-century skills in early learners and recommends broader implementation supported by teacher training and curriculum integration.

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1. Introduction

In today's digital education era, digital skills, as one of the 21st-century skills, are recognized as part of problem-solving skills (Fatih Küçükkara & Aksüt, 2021). Computational thinking (CT), defined as a set of problem-solving skills applicable to both computer science and daily life. has become increasingly relevant in response to rapid technological developments and the overflow of information. CT consists of four core components: decomposition, abstraction, pattern recognition, and algorithms, all of which are foundational in solving complex problems by starting with simple ones (Dobgenski et al., 2025). These skills should be introduced early in childhood education, a critical stage for optimizing children's cognitive potential. Play-based learning at this stage is known to enhance creativity, problem-solving, and critical thinking (Cognitive et al., 2024),), while CT and executive function (EF) skills also contribute to long-term learning readiness. Despite its importance, the implementation of computational thinking skills in elementary education in Indonesia remains limited. Many schools have not yet integrated these computational thinking skills into their curricula, resulting in children missing out on opportunities to develop critical analytical and problem-solving skills (Zhang et al., 2025). CT that can be developed through the unplugged coding approach includes four components, namely pattern recognition, algorithms, abstraction, and decomposition (Lee et al., 2023). Pattern recognition is the ability to identify similarities and differences or patterns in a problem. By recognizing patterns, problems become easier to solve, and solutions can be applied to new problems with similar patterns. Algorithms are related to the ability to simplify and organize step-by-step plans for solving problems (Harper et al., 2023). Algorithm design is the process of developing step-by-step solutions to a problem or rules that must be followed to solve a problem. Decomposition is a skill used to break down problems into simpler forms so that they can be solved, developed, and evaluated to understand the complexity of a problem (Dia et al., 2024). Abstraction is the ability to identify and recognize the most important relationships, similarities, and differences in a problem while ignoring or filtering out information that is considered irrelevant in finding a solution. This allows the most essential and relevant data or information to be prioritized. Improvements in students' problem-solving abilities after participating in programming education and CT skills are key factors in acquiring the learning abilities needed in the 21st century (Demir, 2021). Previous research has shown that introducing computational thinking through non-technology-based activities can be an effective alternative, especially in environments with limited access to technology. The CS-Unplugged team-based program has been proven to improve children's computational thinking skills (Capecchi et al., 2022). Unplugged Coding activities involve the use of non-digital activities, such as practical activities and games, to teach computational thinking concepts in the context of scientific disciplines. Many studies focus on the impact of programming skills or

computational media on computational thinking learning (Yeni et al., 2024). The use of unplugged coding activities to develop CT in young children is becoming increasingly popular. The benefits of using unplugged coding activities include cost-effective implementation, the ability to introduce computer science concepts and boost confidence in learning computer programming, as well as providing an active, engaging, and enjoyable learning activity through collaboration with peers (Threekunprapa & Yasri, 2020b). Globally, CT is often taught through programming and digital media. However, non-digital methods—such as unplugged coding—are gaining attention for their accessibility and developmental (Munasinghe et al., 2023); Bers et al., 2019). Coding skills through creative development processes and exploring children's creative processes when they use software and hardware (Tang et al., 2024). The influence of coding activities using tools or without tools can improve children's computational thinking skills (YILMAZ & İZMİRLİ, 2023). These activities include a series of game rules to develop programming concepts (Threekunprapa & Yasri, 2020a). In addition to CT, collaborative learning is essential for early childhood development. It supports communication, cooperation, empathy, and responsibility in social contexts (Çelik & Bati, 2025); (Li et al., 2023); (Polat et al., 2022);(Tuekkhow et al., 2024). Collaborative learning also enhances creativity, social interaction, and emotional support, particularly when integrated through play and group-based learning strategies.

Despite the growing body of global research, studies on unplugged coding in Indonesia's early childhood education (ECE) remain limited. Most research focuses on digital tools, while physical, non-technological approaches—especially those involving physical and social interaction—are underexplored (Pollarolo et al., 2024).

In Indonesia, while the ECE sector continues to grow, challenges such as a lack of teacher training, limited digital infrastructure, and parental awareness persist (Alonso-García et al., 2024); (Walker et al., 2023). Integrating CT into ECE is as vital as literacy and numeracy (Robledo-Castro et al., 2025) and educational games like grid board activities have shown promise in supporting both computational and collaborative skills (Alifia et al., 2022).

Observations at the Larasati Early Childhood Education Cluster, particularly TK Islam An-Nur Kedungringin, reveal that conventional methods—such as worksheets focused solely on coloring—still dominate classroom activities. Despite children's enthusiasm for play, teaching strategies remain monotonous, lacking innovation in integrating CT and collaboration. Many teachers are unfamiliar with unplugged coding, despite having unknowingly used similar strategies in their practice. Limited access to digital tools and internet connectivity further hampers innovation in teaching. Educators acknowledge the importance of developing computational and collaborative thinking but cite a lack of training and resources as barriers.

The purpose of this study is to analyze the implementation of unplugged coding in developing early childhood computational and collaborative thinking skills within the Larasati ECE Cluster. Specifically, the research aims to: (1) explore strategies for implementing unplugged coding, (2) examine its influence on children's CT and collaboration, and (3) identify supporting and inhibiting factors affecting its effectiveness in early learning environments with limited technological infrastructure

2. Method

This study used a qualitative approach with a case study design to analyze the implementation of unplugged coding in developing computational and collaborative thinking skills in early childhood through play-based learning activities. This approach was selected to explore how educators perceive, understand, and implement unplugged coding strategies, as well as to identify challenges encountered in the classroom. Educators served as key informants due to their central role in planning and delivering unplugged coding activities.

Data were collected through three primary methods: observation, in-depth interviews, and documentation, and reflective meetings capture the contextual nuances of implementation, teacher practices, and student engagement (Vassallo, 2025). The study was conducted at the PAUD Larasati Cluster in Suruh Sub-district, Semarang Regency, specifically at TK Islam An-Nur, located in Dusun Boromiri, RT 26 RW 05, Kedungringin Village. Participant observation was conducted by engaging directly in unplugged coding learning sessions. Observations focused on children's interactions, teacher strategies, and classroom implementation. In-depth interviews were carried out with teachers and school principals to explore their understanding and experiences in applying unplugged coding. Documentation, including lesson plans, teaching materials, and photos of learning activities, served to validate findings from observation and interviews.

To ensure the trustworthiness of the data, triangulation was applied across the three data sources: interviews, observations, and documentation (Carter et al., 2014); (Ibda et al., 2023). Data analysis was conducted using thematic analysis. The process included transcribing all interviews verbatim, coding the

data manually to identify repeated patterns, and grouping codes into themes relevant to the research questions, such as implementation strategies, child responses, and supporting or inhibiting factors. No software was used for the analysis; instead, the coding process was carried out systematically by the researcher using matrix tables for cross-comparison.

Ethical considerations were prioritized throughout the research process. Before data collection, written permission was obtained from the head of the Larasati Cluster and the principal of TK Islam An-Nur. All participants received a brief explanation of the study's purpose, procedures, and the voluntary nature of participation. Informed consent was obtained from educators and school representatives. Participant anonymity was maintained by assigning pseudonyms, and all data were securely stored to ensure confidentiality and privacy.

Additionally, structured observation sheets and closed-ended questionnaires were used to guide data collection. The research instruments are summarized in Table 1, which presents the instrument grid based on the study's variables.

Table 1: Research Instrument Grid

Research Aspect	Aspects of Indicator Research	Research Aspects Sub Indicators	Research Aspects Data Collection Techniques	
Unplugged Coding Learning Strategy	Strengthening Basic Literacy in PAUD Through Unplugged Coding Learning	Unplugged Coding Learning Activities	Interview	Observation
	Availability of supporting facilities	Availability of physical facilities (classroom, teaching aids, materials)	Interview,	Documentation
Computational and Collaborative Thinking Skills	Principles of computational thinking	Learning Activities That Stimulate Computational Thinking	Interview	Observation
	Collaborative Learning	Collaborative Concepts in Learning Activities	Interview	Documentation
Supporting and Inhibiting Factors	Support from educators	Availability of Training, Pedagogical Skills	Interview	Observation
	Parental participation	Parent involvement in learning activities	Documentation	Observation
	Implementation obstacles	Limited creativity, Collaborative skills	Interview	Observation

3. Result and Discussion

3. 1. Result

This study aimed to describe the implementation of the unplugged coding approach on computational and collaborative thinking in early childhood at TK Islam An-Nur Kedungringin. Data were collected through observation, interviews, and documentation based on instruments covering the implementation strategy and indicators of computational and collaborative thinking.

The implementation strategy was carried out in three main stages: Planning, Implementation, and Evaluation. The details are presented in Table 2.

Table 2. Stages of Unplugged Coding Implementation at TK Islam An-Nur Kedungringin

Stage	Form of Implementation
Planning	Teachers prepared RPPH by incorporating unplugged coding activities such as grid games, logic tasks, and simple algorithms using non-digital tools.
Implementation	Children participated in activities using materials such as number dice, grid boards, and arrow symbols. Instructions were followed collaboratively.

Stage	Form of Implementation
Evaluation	Teachers observed children's responses, asked reflective questions, and recorded learning outcomes related to CT and collaboration

During the observation period (four weeks), researchers noted that the planning phase was consistently carried out in all observed sessions. 100% of observed learning plans (n=4 RPPH documents) included unplugged coding elements. The materials prepared—such as grid boards and number dice—were designed to support hands-on and age-appropriate activities.

In the implementation phase, activities such as rolling dice, walking based on the number, and arranging directional arrows were observed in all 4 learning sessions. Approximately 87.5% of children (14 out of 16) demonstrated engagement in pattern recognition and sequencing during these tasks. These physical activities supported the development of basic algorithmic thinking.

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Figure 1. Implementation of Learning Activities Using the Unplugged Coding Approach at TK Islam An-Nur Kedungringin

In the evaluation phase, teachers observed learning outcomes using anecdotal records and photographs. According to teacher interviews, 81.2% of children (13 out of 16) showed improvements in collaborative behaviors such as turn-taking, role sharing, and group interaction. Meanwhile, 75% of children (12 out of 16) were able to follow multi-step instructions related to CT components.

Table 3. Forms of Evaluation in Learning Activities

Evaluation Variable Aspect	Aspect	Description
Computational Thinking	Observation of decomposition, pattern recognition, algorithms, and abstraction	Carried out during and after the activity by teachers.
Collaborative	Peer interaction and cooperation	Evaluated through natural observation.
Activity Reflection	Teacher reflection for improvement	Adjustments made to methods or materials

Documentation such as children's work, photos, and videos was collected in each session and served as supporting evidence. Teachers also conducted informal interviews with children after activities. In 3 out of 4 sessions, some children were invited to share their learning experiences verbally, offering insight into their understanding and boosting oral expression.

The results indicate that unplugged coding activities were consistently implemented with active participation from both children and teachers. Patterns of increasing engagement and collaboration were observed across all sessions, with gradual improvement in children's ability to follow instructions and work as a team.

3.2. Qualitative Results

From the evaluation process, unplugged coding activities were carried out holistically, using a child-friendly and flexible approach without neglecting the essence of computational thinking and collaborative skills. Through direct observation focused on the process rather than the final result, teachers were able to provide positive feedback to build children's confidence. Teachers at TK Islam An-Nur also conducted authentic documentation as proof of the children's development. With this evaluation approach, teachers could monitor the children's development comprehensively while also improving future unplugged coding activities. This study showed that several factors influenced the implementation strategy of the unplugged coding approach

and had a positive impact on computational thinking and collaborative abilities in early childhood. These included the teacher's ability to plan in a structured and purposeful way through play-based learning, conducting assessments naturally via observation, notes, and reflection during the activity, and serving as facilitators. Facilities and infrastructure, including choosing engaging media suited to children's interests, and teamwork in groups, were also crucial.

The first factor supporting the success of implementing the unplugged coding approach on computational thinking and collaboration in early childhood was the careful and targeted planning by educators at TK Islam An-Nur. Based on interviews and observations, TK Islam An-Nur has four teachers and one educational staff member, the principal. Each class is taught by two educators. Their backgrounds include Early Childhood Education degrees and high school diplomas. One teacher was participating in the Teacher Professional Education Program. The school foundation often conducts teacher competency training, but still requires continuous training specifically related to unplugged coding implementation. Therefore, the researcher also played a major role in delivering more specific material and guiding educators through the planning, implementation, and evaluation stages of unplugged coding aligned with children's interests and needs. Starting from determining learning objectives, choosing appropriate media, and designing simple but meaningful activities, this proper planning helped teachers convey difficult concepts like algorithms and logic in a way that was more understandable to children through play. Teachers also acted as facilitators so children did not feel burdened and could enjoy playing.

The second factor was the availability of infrastructure. Facilities are one of the most important components in the operation of an educational institution. The better the facilities available, the more effectively the learning goals can be achieved. In this study, the availability of infrastructure was essential in implementing the unplugged coding approach. A safe, comfortable, enjoyable, and meaningful learning environment gave children memorable and beneficial experiences for their development. A joyful learning atmosphere created intrinsic motivation—the desire to learn coming from within the child. Based on observations and interviews, the institution had provided some classroom facilities and learning tools that supported unplugged coding implementation, but there were still areas that needed improvement. Teachers at TK Islam An-Nur had selected attractive and interest-based tools and media. Visual and concrete media greatly helped early childhood children learn through direct experience. They could see, touch, and move according to instructions, making unplugged coding concepts real and enjoyable, stimulating their computational thinking and collaboration. Media such as floor grids, number dice, and other visual aids strongly supported the learning. Children were more interested and found it easier to follow the activities. However, educators stated that their available resources were still inadequate and more tools and infrastructure were needed to meet student needs.

The third factor was teamwork in groups. The concept of collaboration played a vital role in the successful implementation of unplugged coding for developing computational thinking and collaboration skills. Working in groups meant children played and learned with peers to achieve common goals, such as completing a game, solving problems, or constructing directions. In unplugged coding activities, this involved organizing steps together, discussing, and taking turns performing tasks. Teamwork encouraged children to think computationally in a collaborative way. They learned to break down big tasks (decomposition) into smaller steps with their friends—for example, reaching a goal on a game board. Children discussed logical and sequential steps to help a character reach its goal (algorithmic). Pattern recognition was introduced in the movement steps. Abstraction was applied by focusing only on the important parts of the game. Based on observations, children were very enthusiastic during these activities, though some still needed guidance in group play. To address this, educators guided and provided solutions for teamwork concepts, which also aimed to improve their socio-emotional development

4. Discussion

The results of this study on the implementation of unplugged coding at TK Islam An-Nur Kedungringin show that the stages of Planning, Implementation, and Evaluation significantly influenced the development of computational and collaborative thinking in early childhood. In the planning stage, teachers designed non-digital, play-based activities using tools such as grid boards and number dice. These activities helped children grasp basic CT concepts—decomposition, pattern recognition, sequencing (algorithms), and abstraction—through concrete and enjoyable experiences. During implementation, children actively followed step-by-step instructions, worked in groups, and used physical movements to internalize computational logic. The evaluation stage used natural observation and documentation to capture children's learning outcomes holistically.

The findings reveal that 87.5% of children were able to engage in algorithmic and pattern-based thinking during activities, while 81.2% showed positive developments in collaborative skills such as turn-taking, group participation, and communication. These results support Vygotsky's theory of social learning, which emphasizes peer interaction and guided support (scaffolding). They are also in line with prior studies

(Musfiati, 2023); (Chen et al., 2023) demonstrating the effectiveness of unplugged coding in enhancing cognitive and social-emotional competencies in early learners. The results of the study showed that students at An-Nur Islamic Kindergarten in Kedungringin began to understand sequential instructions and think according to the commands given, such as turning left or right. These results support research that computational thinking is a basic 21st-century skill that can be taught to everyone, including children, even without using a computer (Dağ et al., 2023). Compared to previous research, these findings align with recent literature supporting this conclusion, as stated by stating that unplugged coding activities using simple tools such as boards or cards have a significant impact on developing computational thinking skills, with large average positive effects. Additionally, this research aligns with a study conducted by (Bers et al., 2019) which found that unplugged coding is effective for developing computational thinking concepts without the use of digital tools. These findings also support the study by (Lee & Junoh, 2019) that the unplugged coding approach is easy to implement and that unplugged coding activities, such as number dice, boards, and simple tools, can be used to develop computational thinking skills in young children. A challenge in this research is that, based on observations, not all teachers possess the skills to be effective facilitators; some tend to over-assist or fail to provide sufficient space for children to explore. This is supported by the findings of Ran & Jianyong (2022) that improving teacher competence is very important, but adequate training is still lacking.

Practical Implications

This study provides several concrete implications for early childhood education practice:

a. Teacher Development: There is a need for structured professional training on unplugged coding to help educators design meaningful activities aligned with children's developmental stages. Capacity-building programs can address the gap in teacher confidence and creativity.
b. Curriculum Enrichment: Integrating unplugged coding into the PAUD curriculum can offer a low-cost, developmentally appropriate approach to 21st-century learning. Schools with limited digital access—like TK Islam An-Nur—can still implement computational thinking through tactile and social play-based methods.
c. Assessment Practices: The study highlights the importance of authentic and naturalistic assessment (e.g., anecdotal notes, photos, student reflections) to evaluate skills that are difficult to capture in traditional tests, especially in young children.

Policy Implications

From a policy perspective, this study offers evidence to support the following actions:

a. National Early Childhood Curriculum Guidelines should include computational and collaborative thinking explicitly, not only as cross-cutting competencies but also as measurable developmental outcomes.
b. Inclusion of Unplugged Methods in Training Modules: Teacher certification and in-service training programs under the Ministry of Education can incorporate unplugged coding as a core competency for PAUD teachers.
c. Support for Low-Tech Innovation: Policies should encourage and fund non-digital innovations that align with the needs of rural or under-resourced schools, thus promoting equitable access to future-ready learning across Indonesia.

Strengths, Limitations, and Future Research

One strength of this study is its adaptability to low-tech environments, offering an inclusive educational innovation. However, its scope is limited to a single institution and may not generalize to other PAUD contexts with different characteristics. Differences in child personality, teacher readiness, and institutional culture may influence outcomes.

Future research should expand to multiple institutions and longer durations to observe sustained effects. Further studies could explore the dynamics of teacher-child interactions during unplugged coding, including emotional scaffolding, conflict resolution, and peer support. Broader investigations into school leadership, parental involvement, and education policies can deepen understanding of factors influencing implementation success

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5. *Conclusion*

The implementation of unplugged coding at the Larasati Early Childhood Education Cluster, specifically at TK Islam An-Nur Kedungringin, was successfully carried out using a play-based approach with concrete tools such as grid boards, number dice, and floor games. Teachers acted as facilitators, guiding children through step sequencing, pattern recognition, and basic problem-solving activities.

The study found that unplugged coding effectively supported the development of children's computational thinking skills, particularly in understanding logic and simple algorithms, and enhanced collaborative abilities, such as working in groups, expressing ideas, and listening to peers. These activities also fostered an engaging, interactive learning environment aligned with children's developmental needs.

Key success factors included teacher readiness, supportive school leadership, engaging learning materials, and active child participation.

Recommendations

To maximize the benefits of unplugged coding in early childhood education:

a. For Teachers: Continuous professional development is needed to strengthen teachers' skills in designing and facilitating unplugged coding activities that integrate computational thinking concepts with thematic learning.
b. For School Leaders: Provide institutional support through the provision of learning tools, time allocation, and regular training programs that promote innovation in 21st-century learning methods.
c. For Parents: Encourage unplugged coding reinforcement at home through interactive games such as puzzles, board games, and role-play activities that stimulate logical thinking and teamwork.

These recommendations aim to build synergy between school and home, promote sustainability in coding-based programs, and support the broader goal of preparing children for future learning challenges while respecting their developmental stages.

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