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# Examining the Emergence of Computational Thinking through Unplugged Coding Games in Early Childhood: Evidence from a Multiple Case Study in Indonesia

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## Abstract

**Purpose** – Computational Thinking (CT) is widely recognized as a key competency in 21st-century education; however, its implementation in early childhood settings remains predominantly associated with digital technologies, leaving its development in low-resource contexts underexplored. This study aims to examine how CT skills emerge through unplugged coding games in early childhood education and to identify the contextual factors shaping their implementation.
**Design/methods/approach** – This study employed a qualitative multiple case study design across three early childhood education settings in Surakarta, Indonesia. Data were collected through six weeks of non-participatory classroom observations and semi-structured interviews with teachers. Observational data were analyzed using a computational thinking framework, while interview data were examined inductively to uncover enabling and constraining factors.
**Findings** – Findings reveal that unplugged coding games, grounded in concrete materials and play-based activities, facilitate the emergence of core CT skills, including sequencing, decomposition, pattern recognition, abstraction and problem-solving. These skills develop through embodied, collaborative, and iterative play processes, where children actively construct solutions within meaningful contexts. However, teachers tend to mediate these processes implicitly, often without explicitly recognizing or articulating them as CT practices, which may limit pedagogical intentionality.
**Research implications/limitations** – The study is limited to three cases within a single regional context and a relatively short observation period, which may constrain the transferability of findings. Nevertheless, it contributes to the conceptualization of CT as a socially mediated and play-based learning process in early childhood, extending beyond technology-centric approaches.
**Practical implications** – The findings highlight the feasibility of integrating CT into early childhood education through unplugged, play-based pedagogies, offering an accessible and contextually adaptable approach for low-resource settings.
**Originality/value** – This study advances the CT literature by demonstrating that computational thinking can emerge through non-digital, play-based interactions in early childhood contexts, challenging dominant technology-driven paradigms and providing empirical evidence from the Global South to broaden theoretical and geographical representation in the field.

**Keywords** Computational thinking, Early childhood education, Unplugged coding games, Play-based learning

**Paper type** Research paper

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# 1. Introduction

The development of digital technology has transformed the way individuals think, learn, and solve problems in everyday life. In the educational context, this change has emphasized the importance of developing computational thinking (CT) as a key 21st-century competency that supports logical, systematic, and problem-solving abilities. CT is no longer viewed solely as computer programming skills, but as a thinking approach that can be applied in various learning contexts and everyday life (Angeli et al., 2016). Therefore, various countries have begun integrating CT into their educational curricula, starting at the elementary school level, and even extending to early childhood education. However, the implementation of CT in early childhood education still faces conceptual and pedagogical challenges. The developmental characteristics of early childhood, which emphasize play, exploration, and concrete experiences, require a different learning approach than CT instruction at higher levels of education.

Numerous studies have shown that young children are able to develop basic computational thinking concepts such as sequencing, pattern recognition, decomposition, and algorithmic thinking through various learning activities. Some studies emphasize the use of technological devices such as educational robots, visual programming applications, and interactive digital devices to facilitate CT development in children (Bers, 2020; Strawhacker & Bers, 2015; Sullivan & Bers, 2016). Other research also shows that the use of robots or digital media can increase children's engagement and help them understand algorithmic concepts more systematically (Avcı & Deniz, 2022). However, this technology-based approach cannot always be applied equally across all educational contexts. Several studies have shown that CT development can also be achieved through unplugged activities, namely learning activities without digital devices that utilize games, gestures, manipulation of concrete objects, and story-based activities (Brackmann et al., 2017; del Olmo-Muñoz et al., 2020). This approach is considered more appropriate for the developmental characteristics of early childhood, who learn through direct experience and play.

Although research on computational thinking in early childhood continues to grow, most studies still focus on the use of digital devices as the primary learning medium. A literature review shows that many CT studies in early childhood examine the use of educational robots or visual programming applications in learning environments with adequate technology access (Martins et al., 2023; Silva et al., 2023). This situation suggests that educational contexts with limited technological resources have received relatively little attention in CT research. Furthermore, most previous research has used experimental designs or technology-based interventions, focusing on measuring learning outcomes after the implementation of specific programs. These approaches provide insight into the effectiveness of technology media, but are limited in describing how CT skills can develop naturally through everyday classroom learning practices.

In the context of early childhood education, the unplugged coding approach has the potential to be a more contextual and inclusive alternative for developing computational thinking. Through play activities, manipulating concrete objects, and solving problems in real-world situations, children can understand algorithmic and logical concepts without relying on digital devices. However, empirical studies exploring how unplugged coding activities are implemented in everyday learning practices in early childhood education are still relatively limited, particularly in educational contexts in developing countries or the Global South. Furthermore, there is little research analyzing how variations in pedagogical approaches in early childhood education units influence the development of computational thinking skills through play activities. Yet, differences in pedagogical approaches can influence learning strategies, the types of activities teachers design, and the opportunities children provide to explore computational thinking processes.

Based on this gap, this study aims to analyze how computational thinking skills develop through unplugged coding play in the context of early childhood education. This study uses a multiple case study design in three early childhood education units in Surakarta, Indonesia, which have different pedagogical approaches. By exploring naturally occurring classroom learning practices, this study is expected to provide empirical contributions regarding how computational thinking can be developed through unplugged play-based activities in the context of early childhood education. Furthermore, this study also provides perspectives from the Global South, which is still relatively underrepresented in the research literature on computational thinking in early childhood.

## 2. Methods

### *2.1. Research Design*

This research employed a qualitative approach with a multiple case study design. This design was chosen to gain a deeper understanding of how CT skills develop in early childhood learning practices through unplugged coding activities in various pedagogical contexts. This research followed the multiple-case study design framework proposed by Yin (2012), where each case was studied separately (within-case analysis) before conducting a cross-case comparative analysis. The multiple case study design was chosen based on the research objective of exploring variations in the implementation of unplugged coding learning in early childhood education contexts with different pedagogical approaches. By using more than one case, this study allows researchers to identify patterns of similarities and differences in CT skill development across various learning contexts. In this study, each early childhood education unit was treated as a case unit representing a distinct pedagogical approach to learning practices. Analysis was conducted at two levels: within-case analysis to understand the characteristics of each learning context, and cross-case analysis to identify common patterns in the implementation of unplugged coding and CT skill development.

### *2.2. Research Context and Site Selection*

This research was conducted at three early childhood education units in Surakarta, Indonesia. The research sites were selected purposively, considering two main criteria: (1) the variety of pedagogical approaches in early childhood learning practices, and (2) the institutions' readiness and willingness to participate in the research. These three ECE (Early Childhood Education) units represent distinct learning approaches. ECE site X reflects a more structured learning approach dominated by teacher direction. ECE site Y has a specific development focus aligned with the institution's curriculum orientation. Meanwhile, ECE site Z implements a more flexible, play-based, and child-centered learning approach. This diversity of pedagogical contexts is considered crucial to understanding how the unplugged coding approach can be implemented in various early childhood learning practices.

### *2.3. Participants*

The research participants consisted of three classroom teachers and children aged 5–6 years who participated in learning activities at each early childhood education unit. The three teachers involved were the classroom teachers responsible for designing and implementing daily learning activities. All teachers held academic qualifications in early childhood education and had experience teaching young children. Observations were conducted in three class groups, each consisting of approximately 15–18 children, resulting in a total of approximately 48 children participating in the observed activities. The children came from diverse social and cultural backgrounds, reflecting the general characteristics of students in early childhood education units in the region.

### *2.4. Data Collection Procedures*

Research data was collected through two main techniques, namely non-participatory classroom observation and semi-structured interviews with teachers. Observations were conducted over six weeks, with a duration of approximately two weeks for each ECE unit. In each class, observations were conducted for four learning sessions, for a total of 12 observation sessions. Each observation session lasted approximately 60–90 minutes, reflecting the duration of classroom learning activities. During the observations, the researcher acted as a non-participant observer, observing the learning activities without directly participating in the classroom activities. The researcher remained at the back or side of the class to minimize disruption to the ongoing learning process.

The observation instrument was developed based on a computational thinking skills framework that includes indicators such as pattern recognition, decomposition, algorithmic thinking, and abstraction. Children's activities were recorded using descriptive field notes, focusing on (1) types of play activities, (2) teacher-child interactions, (3) emerging problem-solving strategies, (4) forms of representation of children's thinking during play activities. Observation notes were then coded to identify the emergence of CT skills in learning activities.

In addition to observations, this study also used semi-structured interviews to gain a deeper understanding of teachers' perspectives on the development of computational thinking in learning. Interviews were conducted after the observations as short follow-up reflective interviews aimed at clarifying observed learning practices. Each interview lasted approximately 15–20 minutes and was conducted individually with each teacher. The interview questions focused on (1) teachers' understanding of computational thinking, (2) strategies used in designing learning activities, (3) pedagogical rationale behind the activities, (4) factors that support or hinder the implementation of unplugged coding activities.

### *2.5. Data Analysis*

Data were analyzed using thematic analysis following the procedures proposed by Braun & Clarke (2006) combining deductive and inductive coding strategies. The deductive coding was guided by an established CT framework, while inductive coding allowed themes to emerge from teachers' interview data. The coding process was conducted in several stages. First, all observation field notes and interview transcripts were read repeatedly to obtain a comprehensive understanding of the data. Second, initial codes were generated based on the computational thinking framework commonly used in the literature, including decomposition, pattern recognition, abstraction, and algorithmic thinking. These codes were used as deductive analytical categories to identify the presence of CT skills in classroom activities.

Third, additional inductive codes were developed from interview data to capture contextual factors influencing the implementation of unplugged coding activities. These emerging codes were grouped into broader themes representing enabling factors and inhibiting factors affecting computational thinking integration in early childhood classrooms. All coding procedures were managed using ATLAS.ti qualitative data analysis software. The software was used to organize observation notes and interview transcripts, develop code networks, group related categories into themes, and visualize relationships among CT skills and concepts through analytical diagrams. Data analysis was conducted at two analytical levels. The first stage involved within-case analysis, where observation and interview data from each ECE site were analyzed independently to understand the characteristics of unplugged computational thinking practices within each learning context. The second stage involved cross-case analysis, which compared findings across the three cases to identify similarities, differences, and recurring patterns in the development of CT skills through play-based learning activities.

Table 1. Coding Scheme

| Deductive Codes from Classroom Observations (±15 codes) | Inductive Codes from Teacher Interviews (±6 codes) |
|---|---|
| Computational Thinking Skills (4) | Enabling Factors |
| Pattern Recognition | Age-appropriate learning activities |
| Decomposition | Play-based methods aligned with developmental stages |
| Algorithmic Thinking | Institutional support for the learning approach |
| Abstraction | Availability of concrete materials and simple games |
| Computational Thinking Concepts (11) | Inhibiting Factors |
| Problem Solving | Activities not aligned with children's developmental levels |
| Iteration | Limited teacher understanding of CT |
| Debugging | |
| Modelling | |

Based on Table 1, the qualitative data analysis framework in this study combines deductive codes derived from classroom observations and inductive codes obtained from teacher interviews within a multiple-case study design. The deductive codes were developed based on the established CT theoretical framework in the literature and were used to analyze authentic learning practices in ECE classrooms. These codes encompass two main dimensions: CT skills such as abstraction, logical thinking, algorithmic thinking, decomposition, pattern recognition, and simple evaluation and CT concepts emerging in children's play activities, such as sequencing, repetition, problem-solving, visualization, simulation through role-playing, the use of non-digital artifacts, and simple reflection.

### *2.6. Trustworthiness and Ethical Considerations*

To enhance the credibility of the research, several strategies were employed, including triangulation of data sources, combining observational and interview data, and cross-case comparison to ensure consistency of findings across cases. Furthermore, detailed observation notes and a systematic coding process were used to enhance the transparency of data analysis. This study also addressed ethical aspects of research. Prior to data collection, the researcher obtained permission from the head of the early childhood education institution and approval from the teachers involved in the study. Information regarding the research objectives and procedures was also provided to parents to ensure transparency. The identities of the institutions and participants were anonymized using pseudonyms to maintain data confidentiality.

## 3. Result

### *3.1. Case Findings*

The analysis of the research results was conducted by interpreting children's play activities as indicators of the emergence of Computational Thinking (CT) skills. The analysis process involved several stages. First, researchers documented children's learning activities and behaviors observed during play. Second, these behaviors were analyzed using a CT framework encompassing decomposition, pattern recognition, abstraction, and algorithmic thinking. Third, specific activities that emerged during play were then interpreted as CT practices or concepts such as sequencing, iteration, debugging, modeling, and problem solving. Through this analysis, children's play activities were understood not only as ordinary learning activities but also as manifestations of computational thinking processes that develop naturally in the context of play-based learning. Observations showed that various play activities designed by teachers enabled the emergence of various CT skills in children, although teachers were not always explicitly aware of them as part of computational thinking.

For example, in the natural materials exploration activity at ECE Site X, children were asked to group leaves and rocks based on size and shape. In this activity, children first observed the characteristics of the objects, then determined the grouping criteria before arranging the objects into specific groups. This process demonstrated the emergence of pattern recognition, as children were able to recognize similarities and differences between objects, and decomposition, as they broke down the grouping task into several simple steps before making a decision. Another activity demonstrating CT development was the activity of arranging arrow cards at ECE Site Z to help a puppet reach a specific goal. In this game, children arranged instruction cards such as forward, turn, and stop to determine the puppet's movement path. This activity reflected algorithmic thinking, as children systematically arranged a sequence of steps to achieve a specific goal. When the path they had arranged didn't work, they revised the sequence of cards. This process demonstrated debugging and iteration, namely the ability to correct errors and try new strategies to solve problems.

Furthermore, during art activities at various learning centres, children demonstrate abstraction skills when they design works based on their ideas, select appropriate materials, and determine the steps for creating them. This process demonstrates that children are able to construct mental representations of the ideas they wish to realize through creative activities.

In general, observations indicate that CT skills can emerge through various play activities such as environmental exploration, construction games, art activities, and role-playing. These activities provide opportunities for children to explore, test strategies, and reflect on the results of their actions during play.

### *3.2. Cross-case Analysis*

A comparative analysis between cases shows that computational thinking skills emerged in the three early childhood education institutions studied, but with varying characteristics and intensity. These differences were primarily influenced by the pedagogical approach used by each institution. At ECE Site X, learning tended to be more structured, with clear teacher direction. Play activities were typically structured into specific steps that children had to follow. In this context, computational thinking skills primarily emerged through activities that required children to follow a sequence of steps, such as composing a picture story or sequencing certain activities. This environment supported the development of algorithmic thinking and decomposition, as children became accustomed to breaking down tasks into systematic steps.

Table 2. Field Notes

| Play Activity | Observable Child Behavior | CT Skill | CT Practice |
|---|---|---|---|
| Grouping leaves and stones by size | Children compare object characteristics and decide grouping criteria | Pattern recognition | Classification |
| Arranging arrow cards to guide a puppet | Children arrange step-by-step instructions to reach a goal | Algorithmic thinking | Sequencing |
| Rebuilding a collapsed block tower | Children revise strategies after failure | Decomposition | Iteration / Debugging |

Based on Table 2 at ECE Site Y, learning activities focused more on achieving specific academic objectives, such as counting or symbol recognition. In this context, CT skills still emerged, particularly in the form of decomposition and abstraction, but the variety of children's thinking experiences was relatively limited because play activities often took the form of predetermined tasks. In contrast, at ECE Site Z, learning was more flexible and exploration-based. Children were given greater freedom to determine game rules, select materials, and develop game ideas independently. In this context, children frequently engaged in the process of trying, evaluating, and refining strategies. This process fostered skills such as iteration, debugging, and modeling, indicating a more reflective level of thinking during play activities.

These findings suggest that pedagogical approaches do not determine whether CT skills emerge, but rather influence the manner and depth of children's thinking processes in developing these skills. More flexible and exploratory learning environments tend to provide greater opportunities for children to engage in more complex and reflective thinking processes.

## 4. Discussion

The results of this study indicate that integrating unplugged coding-based play activities can facilitate the development of various components of CT in early childhood. This finding is evident in the emergence of thinking patterns such as sequencing, pattern recognition, problem solving, and symbolic representation during play activities. These findings align with previous studies showing that computational thinking concepts can be effectively introduced to young children through non-digital, or unplugged, activities. This approach allows children to understand algorithmic concepts, logic, and problem-solving without relying on digital technology devices (Bell & Vahrenhold, 2018; Korte et al., 2025; Relkin et al., 2021). Research also shows that unplugged activities can increase learning engagement and support the development of logical and executive thinking skills in young children. Several studies also show that young children are able to understand basic computational concepts through manipulative and exploratory activities involving play, movement, and simple problem solving (Faizatul Fitriyah et al., 2023; Kopcha & Ocak, 2023).

In addition to the relationship between CT skills and CT concepts, this study also found that teachers' pedagogical strategies play a crucial role in facilitating children's computational thinking development. Teachers not only function as facilitators of play activities but also as mediators who help children understand problem-solving steps, provide scaffolding, and facilitate reflection on their thinking processes. This aligns with the concept of pedagogical content knowledge in teaching computational thinking (Maharani et al., 2024), which emphasizes that the successful implementation of CT in early childhood education is heavily influenced by teachers' ability to integrate pedagogical strategies with learning content (Ocak et al., 2025). This study also found differences in learning characteristics between the research locations. These variations were evident in the way teachers facilitated play activities, the level of children's involvement in problem exploration, and the forms of interaction that emerged during the activities. These differences indicate that the implementation of computational thinking in early childhood education is strongly influenced by the learning context, including school culture, teachers' pedagogical approaches, and the availability of learning resources. Therefore, CT integration cannot be viewed as a universal approach but needs to be adapted to the characteristics of each educational context. In addition, this approach has also been proven to increase children's learning engagement because the activities carried out are playful and exploratory, which is in accordance with the characteristics of learning in early childhood (Avcı & Deniz, 2022; Murcia et al., 2025; Pollak & Ebner, 2019; Sharma et al., 2019; Sung, 2022).

Another important finding is the varying levels of teacher awareness of the concept of computational thinking. Some teachers have intuitively implemented strategies that support CT development through play activities, such as encouraging children to organize steps, make predictions, or correct mistakes. However, some teachers have not explicitly recognized these practices as part of computational thinking learning. This finding suggests that developing teacher competency in understanding CT concepts remains a critical need in the context of early childhood education. Teachers play a role in providing scaffolding, asking provocative questions, and helping children reflect on their problem-solving processes. This aligns with research that emphasizes the importance of teacher pedagogical competence in integrating computational thinking into learning (Georgiou & Angeli, 2019; Weintrop et al., 2016).

The findings of this study also indicate differences in learning characteristics across the study sites, particularly in terms of how teachers facilitate play activities and the level of child engagement during them. This variation suggests that the implementation of computational thinking is strongly influenced by the educational context, including school culture, teacher experience, and the pedagogical approach used. This aligns with previous research showing that the application of CT in education is highly contextual and influenced by the learning environment and existing teaching practices (Fitriyah et al., 2023).

Furthermore, this study found that teachers' awareness of the concept of computational thinking varied. Some teachers intuitively implemented practices that support CT development, such as encouraging children to develop problem-solving steps, identify patterns, and correct errors during play. However, some teachers did not explicitly recognize these practices as part of computational thinking learning. This finding aligns with research showing that many teachers in elementary and early childhood education lack an adequate understanding of the concept of CT and how to integrate it into their learning (Avcı & Deniz, 2022; Pressley & Ha, 2021; Šindić & Vodopivec, 2025; Sosa-Alonso et al., 2025).

In this study, the concept of deep learning refers to a learning approach that encourages children to build deeper conceptual understanding through exploration, reflection, and active engagement in the learning process (Adorni et al., 2024; Lin et al., 2024; Moreno-León et al., 2025; Zurnacı & Turan, 2024). In the context of unplugged coding activities, deep learning occurs when children not only mechanically follow instructions but also understand the rationale behind their actions, evaluate the results of their actions, and develop new strategies to solve problems. Overall, the results of this study indicate that unplugged coding-based play activities can be an effective pedagogical approach for introducing computational

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thinking to early childhood. This approach allows for the integration of computational concepts into meaningful and contextual play activities, thus supporting the development of logical, creative, and reflective thinking skills in children.

The findings of this study strengthen the argument that computational thinking can be effectively integrated into early childhood education through a playful approach that does not rely on digital technology. This approach provides opportunities for children to develop logical, creative, and systematic thinking skills from an early developmental stage (Sullivan & Bers, 2016). Therefore, integrating unplugged coding activities into early childhood learning can be a potential pedagogical strategy for introducing computational thinking concepts in a more inclusive and contextualized manner.

### *4.1. Research Contribution*

This research makes several important contributions to the growing literature on computational thinking in early childhood education. *First*, it provides empirical evidence that computational thinking skills can be developed through non-digital play activities without the need for technological devices or computer programming. *Second*, it demonstrates how unplugged coding activities can be integrated into everyday learning practices in early childhood education, particularly through games that involve exploration, problem-solving, and collaboration. Third, it enriches the literature on computational thinking by presenting perspectives from educational contexts in the Global South, particularly in resource-constrained educational settings that do not always have access to digital technology.

### *4.2. Limitations*

This study has several limitations. First, it was conducted in three early childhood education institutions in one region, so the findings should be interpreted with caution when applied to different educational contexts. Second, although the study involved six weeks of classroom observations and teacher interviews, the relatively limited observation period may not fully capture the long-term dynamics of computational thinking development in everyday learning practices.

### *4.3. Suggestions*

Further research can expand the study of computational thinking in early childhood education using various approaches. Future research could explore the relationship between teachers' pedagogical strategies and the development of children's computational thinking skills in greater depth. Furthermore, developing a structured unplugged coding learning model for early childhood education is also an important area of research. Future research could also examine the impact of computational thinking development on problem-solving abilities, logical reasoning, and higher-order thinking skills in early childhood.

## 5. Conclusion

This study demonstrates that computational thinking (CT) in early childhood education can be effectively fostered through unplugged coding games embedded in play-based learning environments. The findings show that core CT skills—including sequencing, pattern recognition, abstraction, and problem-solving—emerge through embodied, collaborative, and contextually meaningful play activities. Importantly, the study reveals that teachers often facilitate these processes implicitly, without explicitly framing them as CT practices, which may limit pedagogical intentionality and conceptual clarity.

These findings suggest that the development of CT in early childhood is not inherently dependent on digital technologies, but rather on the design of pedagogically meaningful play experiences that enable children to engage in iterative and socially mediated problem-solving. This challenges dominant technology-centric perspectives in the CT literature and extends current understandings by positioning CT as a play-based and contextually grounded learning process. While the study is limited to three early childhood settings within a specific regional context, it provides empirical evidence from the Global South that broadens the geographical and theoretical representation of CT research. Practically, the study highlights the need to strengthen teachers' pedagogical competencies in recognizing and intentionally integrating CT concepts within unplugged, play-based activities. Future research is encouraged to explore longitudinal implementations and diverse educational contexts to further validate and extend these findings.

# Declarations

## Author contribution statement

Qonitah Faizatul Fitriyah: Conceptualization and Writing - Original Draft.
Tri Asmawulan: Investigation and Data Curation.
Atika Tsania Faza: Validation, Resources, Supervision, and Writing - Review & Editing.
Khadijah Wafa: Methodology, Data Curation, and Writing - Review & Editing.
Taufik Eko Susilo: Formal Analysis, and Writing - Review & Editing.

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## Data availability statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to ethical considerations involving young children, the data are not publicly available.

## Declaration of interests statement

All authors declare that they have no financial or personal interests that could influence the work presented in this manuscript.

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