

Developing Basic Computational Thinking Skills in Early Childhood Through Interactive Game-Based Learning at PAUD Nurul Ikhlas

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Abstract

This community service program aims to develop basic Computational Thinking (CT) skills in early childhood through interactive game-based learning at PAUD Nurul Ikhlas, Bandung. Computational Thinking is an essential foundational skill that supports problem-solving, logical reasoning, and structured thinking from an early age. However, CT concepts are rarely introduced explicitly in early childhood education settings. Therefore, this program implemented a structured playmat-based learning model integrating sequencing, pattern recognition, abstraction, decision-making, and simple debugging activities. The participants consisted of approximately 30 early childhood students and four teachers. The program was conducted through interactive physical activities involving number sequencing, alphabet paths, decision routes, loops, and challenge zones designed to stimulate active movement and cognitive engagement. The results showed that children demonstrated improved ability to follow step-by-step instructions, recognize patterns, make simple decisions, and complete problem-solving tasks through playful exploration. Teachers also gained practical knowledge and strategies for integrating Computational Thinking concepts into daily classroom activities. The findings suggest that interactive game-based learning provides a feasible and engaging approach for introducing foundational Computational Thinking skills in early childhood education.

Keywords: computational thinking, early childhood education, interactive learning, game-based pedagogy, cognitive development.

1 INTRODUCTION

Early childhood education plays a fundamental role in shaping children's cognitive, social, and emotional development. At this stage, children begin forming foundational thinking structures that influence their future academic readiness and problem-solving abilities. In the context of 21st-century education, Computational Thinking (CT) has emerged as a crucial competency that supports logical reasoning, structured problem-solving, and systematic decision-making processes [1], [2]. Although CT is frequently associated with computer science and programming, its core components decomposition, pattern recognition, abstraction, and algorithmic thinking can be introduced through developmentally appropriate and non-digital activities [3], [4].

Research has shown that early exposure to structured thinking activities contributes significantly to

children's executive functions, cognitive flexibility, and logical reasoning skills [5]. In Indonesia, studies published in SINTA-accredited journals indicate that play-based learning effectively enhances logical thinking, pattern recognition, and early problem-solving skills among young learners [6], [7]. However, despite the increasing global discourse on CT integration in education, computational thinking has not yet been systematically embedded in most early childhood curricula in Indonesia [8].

Game-based learning is widely recognized as an effective pedagogical strategy in early childhood settings. Through play, children actively explore, experiment, and construct knowledge in meaningful contexts [9], [10]. Interactive physical activities, especially those involving sequencing, spatial navigation, and rule-based movement, provide natural opportunities to introduce CT principles. Unplugged computational thinking activities have been shown to



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support algorithmic reasoning and debugging skills without relying on digital devices [4], [11]. Furthermore, activity-based learning models have demonstrated positive impacts on children's early problem-solving competence [12].

PAUD Nurul Ikhlas, located in Bandung, serves approximately 30 early childhood students supported by four teachers [13]. Although the institution promotes joyful learning approaches, structured computational thinking activities have not yet been explicitly integrated into classroom practices. Therefore, this community service program aimed to strengthen five observable components of foundational Computational Thinking sequencing, pattern recognition, decision-making, loop understanding, and debugging behavior among approximately 30 children aged 4–6 years at PAUD Nurul Ikhlas, Bandung. These competencies were introduced through an unplugged interactive playmat model that combined structured movement, sequential pathways, pattern-based tasks, branching decisions, repetition activities, and problem-solving challenges. Program outcomes were assessed descriptively by comparing the proportion of children demonstrating each targeted CT behavior during the initial and final observations, complemented by teacher feedback regarding the practicality and applicability of the learning model.

2 METHODS

2.1 Program Design

This community service program employed a participatory, activity-based implementation approach in which teachers were involved as learning facilitators and children participated directly in structured unplugged Computational Thinking activities. This approach was selected because the program was intended not only to introduce CT-related activities to children but also to transfer practical implementation knowledge to teachers so that the activities could be continued after the community service program ended.

The participatory approach emphasizes the involvement of relevant participants in practical activities, reflection, and the development of contextually appropriate solutions [14]. Such an approach was considered suitable for PAUD Nurul Ikhlas because the learning activities required continuous interaction among the community service team, teachers, and children. For young learners, CT concepts were translated into concrete physical activities rather than abstract programming tasks. Accordingly, the program emphasized learning by doing through movement, visual cues, repetition, route selection, and guided problem-solving. Teacher participation was incorporated to ensure that the playmat activities

remained developmentally appropriate and could subsequently be adapted to routine classroom learning.

The program therefore combined direct implementation with observation and reflection rather than employing an experimental research design. Changes in children's observable CT-related behaviors were interpreted descriptively within the participating group and were not intended to establish causal effects or population-level generalizations.

2.2 Scope and Participants

The program was conducted at PAUD Nurul Ikhlas, Bandung. Participants consisted of approximately 30 early childhood students aged 4–6 years and four teachers. The children served as primary participants, while teachers were involved as facilitators to ensure sustainability of the learning model after program completion.

2.3 Materials and Tools

The main instructional media was a large-format interactive playmat (2 m × 1.5 m) designed with structured pathways including:

- Sequential number tracks (algorithm practice)
- Pattern recognition zones
- Decision points with branching routes
- Loop paths (repetition concept)
- Mini-maze areas (problem-solving & debugging)
- Final challenge zone leading to “Finish – CT Hero”

Supporting materials included alphabet cards, color markers, instruction cue cards, and observation sheets for assessment purposes.

2.4 Implementation Procedure

The program was conducted in four main stages:

- 1) Preparation Stage
 - Coordination with school management and teachers
 - Introduction to Computational Thinking concepts
 - Training teachers on playmat usage
- 2) Implementation Stage
 - Guided interactive play sessions
 - Sequencing and pattern recognition activities
 - Decision-making and looping exercises
 - Problem-solving challenges
- 3) Observation and Documentation Stage
 - Behavioral observation using structured indicators

- Documentation of children's responses and participation
- 4) Evaluation and Reflection Stage
 - Discussion with teachers
 - Identification of improvements in children's CT-related skills

2.5 Data Collection Techniques

Data were collected using three complementary techniques: structured observation, semi-structured teacher interviews, and activity documentation.

Structured observation was conducted using an observation sheet containing five observable CT-related behaviors derived from the learning objectives and the activities embedded in the playmat. The indicators consisted of: (1) sequencing, indicated by the child's ability to follow step-by-step movement instructions; (2) pattern recognition, indicated by the ability to identify and continue a simple visual pattern; (3) decision-making, indicated by selecting an appropriate route at a branching point; (4) loop understanding, indicated by correctly repeating an instructed sequence; and (5) debugging behavior, indicated by retrying or changing a route after encountering an incorrect choice.

Each indicator was operationalized as an observable behavior so that it could be consistently identified during the activity. The same indicator definitions were used during the initial and final observations. The observation instrument was designed specifically for the community service evaluation and was aligned with the CT components embedded in the playmat activities. Because the instrument was intended as a practical program-evaluation tool rather than a standardized psychometric instrument, the resulting scores are interpreted descriptively.

Teacher feedback was collected using a semi-structured interview guide focusing on three aspects: children's engagement during the activities, ease of implementing the playmat, and the feasibility of integrating similar CT activities into routine classroom learning. Activity documentation consisted of field notes and photographs used to contextualize the observation and interview findings.

Observations were conducted using predefined behavioral criteria. Where observations involved more than one facilitator, the criteria were discussed prior to implementation to establish a common interpretation of each indicator. Formal inter-rater reliability coefficients were not calculated; this is acknowledged as a methodological limitation of the program evaluation.

2.6 Data Analysis

Quantitative observational data were analyzed descriptively using frequencies and percentages. For each CT indicator, the percentage was calculated by dividing the number of children who demonstrated the predefined behavior by the total number of children observed and multiplying the result by 100. Initial and final observation percentages were compared descriptively to identify the direction and magnitude of observable changes. No inferential statistical test was performed; therefore, differences were not interpreted as statistically significant effects.

Qualitative data obtained from semi-structured teacher interviews and field notes were analyzed using descriptive content analysis. Responses were grouped into recurring categories related to children's engagement, implementation challenges, ease of playmat use, and potential classroom sustainability. The qualitative findings were used to complement and contextualize the observational results.

Because the observation instrument was developed specifically for program evaluation and no standardized psychometric validation or inferential testing was conducted, the percentage comparisons should be interpreted as descriptive indicators of change within this participant group rather than precise estimates of intervention effectiveness.



Figure 1. Program Implementation Stages

Figure 1 illustrates the systematic stages of the community service program implementation aimed at

developing basic Computational Thinking skills in early childhood learners at PAUD Nurul Ikhlas. The program began with a needs analysis to identify the educational context and learning gaps. This was followed by the design of the interactive playmat model integrating core CT components such as sequencing, decision branching, looping, and problem-solving challenges. The next stage involved teacher training to ensure understanding and sustainability of the learning model. Implementation with children was conducted through structured interactive play sessions. Observations and documentation were carried out to monitor children's engagement and skill development. Finally, the program concluded with an evaluation and reflection stage to assess effectiveness and identify improvements for future implementation.

3 RESULTS AND DISCUSSION

This section presents the findings obtained from the implementation of the interactive playmat-based learning model and discusses their implications in relation to computational thinking development in early childhood education. The results are organized based on observed Computational Thinking (CT) components, including sequencing, pattern recognition, decision-making, looping understanding, and debugging behavior. Quantitative observations are presented in tabular and graphical forms to provide a clearer illustration of skill improvement. The discussion further interprets these findings by connecting them with relevant theoretical and empirical studies.

3.1 Results

The implementation of the interactive playmat-based learning model demonstrated positive responses from both students and teachers at PAUD Nurul Ikhlas. The activities were conducted in structured sessions where children engaged in sequencing tasks, pattern recognition exercises, decision-based routing, looping paths, and multi-step problem-solving challenges.

During the initial sessions, several children required guidance in following sequential instructions, particularly in activities involving multi-step movements. However, after repeated exposure to structured play scenarios, children showed noticeable improvement in their ability to follow ordered steps without direct assistance. Most participants were able to complete number sequencing tracks and correctly navigate decision branches within the playmat structure.

In the pattern recognition zone, children demonstrated increasing accuracy in identifying and continuing simple color and shape patterns. Additionally, at decision points where children were required to choose between two or more routes,

participants showed improved confidence and reasoning ability when explaining their choices.

The looping and mini-maze sections were particularly effective in stimulating debugging behavior. When encountering incorrect paths, children were observed retracing their steps and attempting alternative routes without frustration. This indicates emerging problem-solving resilience and adaptive thinking.

Teachers reported that the playmat model was easy to implement and adaptable to daily classroom activities. They also noted increased student engagement, active participation, and collaborative interaction among peers during the sessions.

Table 1. Observation Results of CT Skill Indicators

CT Component	Indicator Observed	Initial Observation n (%)	Final Observation n (%)
Sequencing (Algorithm)	Following step-by-step movement instructions	14/30 (46.7%)	25/30 (83.3%)
Pattern Recognition	Identifying and continuing simple patterns	16/30 (53.3%)	26/30 (86.7%)
Decision-Making	Choosing correct route at branching points	14/30 (46.7%)	24/30 (80.0%)
Loop Understanding	Repeating steps correctly when instructed	12/30 (40.0%)	23/30 (76.7%)
Debugging Behavior	Retrying after making mistakes	11/30 (36.7%)	25/30 (83.3%)

Table 1 presents the descriptive observation results for five CT-related behaviors during the initial and final observations. Across the five indicators, the proportion of children demonstrating the expected behaviors increased after participating in the interactive playmat activities. Pattern recognition increased from 16 of 30 children (53.3%) to 26 of 30 (86.7%), while sequencing increased from 14 (46.7%) to 25 (83.3%). Improvements were also observed in decision-making, loop understanding, and debugging behavior. The largest proportional change was observed in debugging behavior, increasing from 11 children (36.7%) to 25 children (83.3%). These findings are interpreted descriptively and indicate changes within the participating group rather than statistically significant intervention effects.

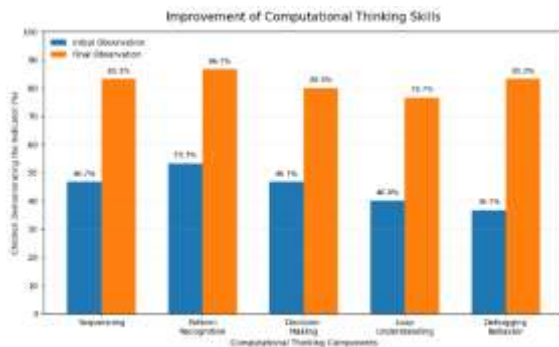


Figure 2. Comparison of Computational Thinking Skill Indicators Between Initial and Final Observations

Figure 2 illustrates the descriptive comparison of children's Computational Thinking (CT) skill indicators between the initial and final observations. An increase was observed across all five components. Pattern recognition showed the highest final observation percentage, increasing from 53.3% to 86.7%, followed by sequencing from 46.7% to 83.3%. Decision-making increased from 46.7% to 80.0%, while loop understanding rose from 40.0% to 76.7%. Debugging behavior showed the largest proportional change, increasing from 36.7% to 83.3%. These results indicate a positive descriptive trend in children's observable CT-related behaviors after participating in the interactive playmat activities. However, the differences should be interpreted as changes within the participating group and not as evidence of statistically significant intervention effects.

3.1 Discussion

Despite the overall positive trend, not all children responded to the activities at the same pace. Some participants continued to require verbal or visual prompts when completing multi-step sequences, particularly in the loop and branching-route activities. The debugging task was also more demanding for children who tended to immediately seek teacher assistance after selecting an incorrect route rather than independently attempting an alternative.

Several practical challenges were observed during implementation. Because the playmat encouraged physical movement, children occasionally entered the activity area simultaneously, requiring teachers to regulate turns and maintain children's attention. Differences in age, concentration span, and familiarity with rule-based games may also have contributed to variation in task completion. These observations indicate that movement-based CT activities for early childhood learners require flexible facilitation, shorter instructions, repeated demonstrations, and adjustment of task complexity according to children's developmental readiness.

These findings also suggest that improvement should not be interpreted as uniform mastery of CT concepts. Rather, the activities provided an introductory environment in which children could practice observable behaviors related to sequencing, pattern recognition, decision-making, repetition, and error correction. Longer-term implementation is needed to determine whether these behaviors are retained and transferable to other learning situations.

4 CONCLUSION

The implementation of the interactive playmat-based learning model at PAUD Nurul Ikhlas showed positive descriptive changes in foundational Computational Thinking (CT)-related behaviors among participating children. Increases were observed in sequencing, pattern recognition, decision-making, loop understanding, and debugging behavior between the initial and final observations. By translating abstract computational concepts into concrete physical activities, the program provided children with opportunities to practice structured thinking and problem-solving in an engaging and developmentally appropriate learning environment.

The program also highlighted the importance of teacher involvement in supporting the sustainability of CT activities beyond the community service period. Through participatory training and guided implementation, teachers gained practical experience in integrating CT principles into classroom activities. The model is relatively easy to replicate because it does not require computers, programming devices, or complex technological infrastructure. Implementation primarily requires a reusable playmat or similar floor-based learning medium, simple instruction cards, and teachers who understand the basic CT activity sequence. This makes the approach particularly relevant for PAUD institutions with limited access to digital learning technologies.

At the policy level, the findings may provide practical input for regional education offices and early childhood curriculum developers when considering the integration of foundational Computational Thinking activities into PAUD enrichment programs. Rather than requiring technology-intensive instruction, policymakers could support the development of age-appropriate unplugged CT activities, teacher capacity-building, and reusable low-cost learning media as complementary strategies for strengthening problem-solving and structured thinking in early childhood education.

For future studies, the most urgent priority is to evaluate the model over a longer implementation period with repeated observations. This is necessary to determine whether the observed CT-related behaviors

are retained over time and transferable to different learning activities, rather than reflecting only short-term responses to the playmat sessions. Once such longitudinal evidence is established, subsequent studies may extend the program to multiple PAUD institutions and examine the complementary use of digital learning tools.

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