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Development of an Unplugged Coding Learning Guide to Stimulate Early Childhood Cognitive Development

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Abstract

Although computational thinking has received increasing attention in early childhood education, research translating this concept into a systematic, teacher-ready unplugged coding guide for Indonesian kindergarten contexts remains limited. This study aimed to identify instructional needs and to develop and evaluate the validity, practicality, and effectiveness of an unplugged coding learning guide designed to stimulate the cognitive development of children aged 4–6 years. Using a research and development approach based on the ADDIE model—Analysis, Design, Development, Implementation, and Evaluation—the study involved two expert validators, one principal, one teacher, and 12 children aged 4–6 years at PAUD Aurora, Ambon, selected through purposive sampling. Data were collected through interviews, expert validation sheets, a teacher-response questionnaire, and cognitive development observation sheets and were analyzed using descriptive statistics and a paired-samples t test. The guide achieved a validity score of 3.35, categorized as very valid; a practicality score of 98.44%, categorized as very practical; and an effectiveness score of 80.65%, categorized as very effective. Children's observed cognitive development scores increased from 45.14% at the first meeting to 97.22% at the seventh meeting, while the paired-samples t test demonstrated a statistically significant difference between pretest and posttest scores, $t(11) = 47.87$, $p < .001$. These findings demonstrate that a systematically structured, indicator-based unplugged coding guide can transform informal cognitive stimulation activities into effective classroom practices. The study contributes to the literature on computational thinking and early cognitive development by extending understanding of technology-free instructional strategies for young learners. Practically, the guide provides teachers and early childhood education institutions with a low-cost approach to strengthening children's logical reasoning, while further research should employ larger samples, control-group designs, and broader developmental outcomes.

Keywords: ADDIE Model; Cognitive Development; Computational Thinking; Early Childhood Education; Unplugged Coding

INTRODUCTION

Early childhood education (ECE) is designed to facilitate children's holistic growth, with particular emphasis on the cognitive foundations formed during the "golden age" of brain development (Fadhillah, 2017). Cognitive development in this period involves progressively maturing processes of attention, memory, and logical reasoning that depend heavily on the quality of stimulation children receive (Zega & Suprihati, 2021). One competency increasingly recognized as central to this process is computational thinking (CT), a logical, systematic, and efficient approach to identifying and solving problems (Wing, 2006) that has become a cross-disciplinary skill relevant well beyond computer science (Masarwa et al., 2024). Introducing CT to young children does not require digital devices; unplugged coding activities rely instead on concrete media, such as patterns, symbols, and sequencing games, to cultivate the same reasoning processes (Bers, 2018). Indonesia's education authorities have likewise encouraged the introduction of coding-related concepts at the early-childhood level in accordance with children's developmental characteristics (Kementerian Pendidikan dan Kebudayaan, 2025). Despite this policy direction, everyday practice in many Indonesian kindergartens, including PAUD Aurora in Ambon, continues to privilege early literacy and numeracy over structured cognitive-stimulation activities such as pattern recognition, sequencing, and problem-solving.

This gap is conceptually significant. Piaget's (1952) account of the preoperational stage holds that children aged roughly two to seven construct understanding primarily through concrete, hands-on experience, so any pedagogical strategy intended to build logical reasoning must be experiential rather than abstract. Vygotsky's (1978) sociocultural theory adds that cognitive growth is accelerated through guided interaction within the Zone of Proximal Development, meaning that teacher scaffolding and peer collaboration function as an integral mechanism of development rather than an incidental classroom feature (Wulandari & Rahmawati, 2022). Unplugged coding activities, built from tangible objects, structured instructions, and playful challenges, directly instantiate both principles: they are concrete, and they are naturally scaffolded through teacher-guided play. It follows that a well-designed, systematically structured unplugged coding guide should be an effective and developmentally appropriate strategy for stimulating logical thinking and problem-solving in the early years, provided it is delivered as a planned program rather than sporadic activity.

Several empirical studies support this position. A study on daily-life-based unplugged coding reported consistent gains in children's ability to follow instructions logically, self-correct errors, and decompose tasks into smaller steps (Fitriyah & Aljawad, 2023). Similarly, unplugged coding activities have been shown to improve logical-thinking scores among Indonesian kindergartners (Hasanah, 2022), while structured, worksheet-based coding media has been found to strengthen young children's problem-solving skills (Maulidya & Saputra, 2023). At the international level, a systematic review and meta-analysis of unplugged computational-thinking interventions confirmed statistically significant effects on children's computational-thinking outcomes across a wide range of studies (Chen et al., 2023), and an embodied-cognition analysis demonstrated that unplugged tasks engage algorithmic reasoning and debugging even when performed through physical movement rather than screen-based coding (Hu et al., 2024). However, these studies converge mainly on outcomes rather than instructional tools: most examine the effect of isolated unplugged activities on computational thinking or problem-solving, and few provide teachers with a complete, procedurally validated guide, covering learning objectives, developmental indicators, step-by-step activities, media, and assessment rubrics, that can be directly implemented in daily kindergarten practice. In the Indonesian context specifically, preliminary interviews at PAUD Aurora revealed that although some cognitive-stimulation activities such as puzzles were already present, they were carried out informally and were not systematically linked to specific cognitive-development indicators.

This study addresses that gap by developing a structured unplugged coding learning guide grounded in Piagetian constructivism, Vygotskian scaffolding, and Wing's (2006) computational-thinking framework, and by empirically testing its validity, practicality, and effectiveness using the ADDIE development model. The novelty of this study lies in three areas: first, it produces a complete, teacher-ready instructional guide rather than a single activity or worksheet; second, it integrates cognitive-development indicators, namely pattern recognition, sequencing, classification, causal reasoning, and problem-solving, directly into daily lesson plans and observation rubrics; and third, it provides layered empirical evidence of product quality through expert validation, teacher practicality response, and a pretest-posttest comparison across seven meetings, extending prior unplugged-coding research that has largely relied on single-outcome measures (Montuori et al., 2024; Relkin et al., 2020).

Accordingly, this study aims to analyze the need for an unplugged coding learning guide to stimulate the cognitive development of children aged 4-6 years at PAUD Aurora, to describe the procedure used to develop such a guide, and to examine its validity, practicality, and effectiveness once implemented in classroom practice.

METHODS

1. Type of Research

This study used a Research and Development (R&D) approach, defined as a systematic method for designing, producing, and testing the validity of an educational product (Rahayu, 2025). This approach was selected because the study's objective was not merely to describe an existing condition but to produce a concrete, testable instructional product, namely an unplugged coding learning guide, following established R&D procedures (Sugiyono, 2019).

2. Research Design.

The study adopted the ADDIE model (Analysis, Design, Development, Implementation, Evaluation), chosen for its systematic and cyclical structure that allows continuous evaluation and refinement at every stage of product development (Cahyadi, 2019; Rohaeni, 2020). In the Analysis stage, the researcher identified the actual instructional needs of teachers and children through interviews and a needs questionnaire. In the Design stage, the guide's structure, comprising objectives, developmental indicators, materials, activity steps, media, daily lesson plans (RPPH), and assessment rubrics, was drafted. In the Development stage, the draft guide was validated by content and media experts and revised accordingly. In the Implementation stage, the revised guide was applied across seven learning sessions with the target children. In the Evaluation stage, formative feedback from experts and summative outcomes from implementation were used to judge the guide's overall quality.

3. Participants and Sampling Technique

Participants were selected purposively according to their role in the development process. Two validators, lecturers in the undergraduate and graduate Early Childhood Education programs at Universitas Negeri Makassar, assessed the content and media feasibility of the guide. One school principal and one teacher at PAUD Aurora provided needs-analysis data and practicality responses as the guide's direct users. Twelve children aged 4-6 years at PAUD Aurora, Latta Village, Baguala Sub-district, Ambon City, participated in the implementation stage to determine the guide's effectiveness in stimulating cognitive development.

4. Instruments and Data Collection

Data were collected using five instruments: (1) semi-structured interview guidelines administered to the principal and teacher during the needs-analysis stage; (2) expert validation sheets assessing content quality, presentation, language, instructional feasibility, appearance, and product benefit on a four-point Likert scale; (3) a teacher-response questionnaire assessing ease of use, activity appropriateness, attractiveness, and product benefit; (4) a cognitive-development observation sheet covering pattern recognition, instruction-following, classification, causal reasoning, and problem-solving, scored across seven meetings; and (5) field notes and visual documentation to capture children's spontaneous reactions and classroom dynamics. Data credibility was strengthened through source-and-method triangulation, comparing findings from interviews, observation, and documentation.

5. Data Analysis Technique

Qualitative data from interviews, observation, and documentation were analyzed descriptively through data reduction, data display, and conclusion drawing. Quantitative data were analyzed descriptively to determine three product qualities. Validity was calculated as the mean expert score ($RTV = \Sigma Ai/n \times 100\%$), converted into four categories ranging from very valid (3.26-4.00) to invalid (1.00-1.75). Practicality was calculated as the ratio of the obtained score to the maximum possible score ($P = \text{score obtained}/\text{maximum score} \times 100\%$), categorized from very practical (76-100%) to impractical (0-25%). Effectiveness was calculated using the same percentage formula applied to children's cognitive-development observation scores across the seven meetings, using the same four-tier interpretation scale. To confirm whether the pretest-posttest improvement was statistically significant, a paired-sample t-test was additionally conducted comparing the first- and seventh-meeting scores of all 12 children, following prior hypothesis testing ($\alpha = 0.05$).

RESULTS

1. Needs Analysis for the Development of the Unplugged Coding Learning Guide

Needs-analysis data were collected through interviews with the principal and teacher and through a needs questionnaire distributed to teachers at PAUD Aurora. As shown in Table 1, only 25% of teachers reported familiarity with the concept of unplugged coding, whereas 75% already possessed some form of supporting instructional media. All teachers (100%) reported difficulty stimulating children's logical thinking, required a structured learning guide, needed clear step-by-step activity examples, and requested greater variety in cognitive-stimulation activities.

Table 1. Summary of Teachers' Needs Analysis Results

Indicator	Percentage	Category
Teachers familiar with the concept of unplugged coding	25%	Low
Teachers already possessing supporting instructional media	75%	High
Teachers experiencing difficulty stimulating logical thinking	100%	High
Teachers requiring a structured learning guide	100%	High
Teachers requiring clear step-by-step activity examples	100%	High
Teachers requiring new activity variations	100%	High

Source: needs-analysis questionnaire and interview results, 2026.

As indicated in Table 1, interviews confirmed that existing activities such as puzzles were carried out informally when children arrived early or were waiting to be picked up, rather than as part of a planned, indicator-based program connected to specific cognitive-development goals.

2. Development Steps of the Unplugged Coding Learning Guide

The guide was developed through the five stages of the ADDIE model. The Analysis stage identified teachers' need for a structured, ready-to-use instructional reference. The Design stage produced a prototype comprising a cover, foreword, usage instructions, learning objectives, developmental indicators, media and tools, activity procedures, observation sheets, and evaluation instruments, together with seven graded activities sequenced from simple to more complex tasks. In the Development stage, the prototype was validated by two experts and revised based on their input regarding content accuracy, language clarity, layout, and the feasibility of the activity steps. In the Implementation stage, the revised guide was applied across seven meetings with the 12 participating children, with teachers using the accompanying daily lesson plans (RPPH) as their primary instructional reference. In the Evaluation stage, both formative feedback (obtained during development) and summative outcomes (obtained after implementation) were used to determine the final quality of the product.

3. Validity of the Unplugged Coding Learning Guide

Validation was conducted by two expert validators from the Early Childhood Education programs at Universitas Negeri Makassar, assessing six aspects of the guide. As shown in Table 2, the overall mean validity score reached 3.35, placing the guide in the very valid category and confirming its feasibility for classroom implementation.

Table 2. Recapitulation of Expert Validation Results

Aspect Assessed	Mean Score	Category
Content quality	3.50	Very valid
Presentation quality	3.25	Valid
Language	3.33	Very valid
Instructional feasibility	3.50	Very valid
Product appearance	3.00	Valid
Product benefit	3.50	Very valid
Overall mean	3.35	Very valid

Source: expert validation sheets, 2026.

4. Practicality of the Unplugged Coding Learning Guide

Practicality was assessed through a teacher-response questionnaire covering four indicators. As shown in Table 3, the overall practicality score reached 98.44%, categorized as very practical, indicating that teachers found the guide easy to use, appropriately sequenced, attractive, and beneficial for classroom instruction.

Table 3. Teachers' Response to the Practicality of the Guide

Indicator	Percentage	Category
Ease of use	100%	Very practical
Activity appropriateness	96.88%	Very practical
Attractiveness	96.88%	Very practical

Indicator	Percentage	Category
Product benefit	100%	Very practical
Overall	98.44%	Very practical

Source: teacher-response questionnaire, 2026.

5. Effectiveness of the Unplugged Coding Learning Guide

Effectiveness was determined from children's cognitive-development observation scores across seven meetings. As presented in Table 4, the class mean percentage increased steadily from 45.14% at the first meeting (pretest) to 97.22% at the seventh meeting (posttest), yielding an overall effectiveness score of 80.65%, categorized as very effective. Individually, 8 of the 12 children (66.67%) reached the "Developing Very Well" (BSB) category by the final meeting, while the remaining 4 children (33.33%) reached the "Developing as Expected" (BSH) category; no child remained in the "Undeveloped" or "Emerging" categories.

Table 4. Children's Cognitive Development Across Seven Meetings

Meeting	Total Score	Maximum Score	Mean	Percentage
P1 (Pretest)	65	144	5.42	45.14%
P2	98	144	8.17	68.06%
P3	124	144	10.33	86.11%
P4	126	144	10.50	87.50%
P5	124	144	10.33	86.11%
P6	136	144	11.33	94.44%
P7 (Posttest)	140	144	11.67	97.22%
Total	813	1008	-	80.65%

Source: cognitive-development observation sheets, 2026.

6. Negative and Divergent Data

Although the overall trend across seven meetings was strongly positive, two children (coded ERJ and AMCN) recorded the lowest final percentages (71.4%) and remained in the BSH rather than the BSB category, and a small class-wide decline was observed between the fourth meeting (87.50%) and the fifth meeting (86.11%). This divergence is reported transparently in accordance with objectivity requirements for research and development reporting; possible explanations for this pattern are addressed in the Discussion section.

7. Statistical Testing of Pretest-Posttest Differences

To confirm whether the improvement in children's cognitive scores was statistically significant, descriptive statistics and a paired-sample t-test were computed comparing the first meeting (pretest) and the seventh meeting (posttest), as presented in Table 5.

Table 5. Descriptive Statistics and Paired-Sample t-Test Results

Variable	N	Min	Max	Mean	SD
Meeting 1 (Pretest)	12	5	6	5.42	0.51
Meeting 7 (Posttest)	12	11	12	11.67	0.49

Source: statistical test results (paired-sample t-test), 2026.

The correlation between pretest and posttest scores was statistically significant, $r = .598$, $p = .040$, indicating a meaningful positive relationship between children's initial and final cognitive scores. The paired-sample t-test further confirmed a statistically significant improvement from pretest to posttest, with a mean difference of 6.25, $t(11) = 47.87$, $p < .001$, providing quantitative confirmation of the guide's effectiveness beyond the descriptive percentage analysis.

DISCUSSION

1. Analysis and Interpretation of Findings

The finding that only 25% of teachers understood the concept of unplugged coding, despite 100% reporting difficulty stimulating children's logical thinking, indicates that the central obstacle at PAUD Aurora was not an absence of cognitive-stimulation activity in the classroom, but the absence of a conceptual and procedural framework connecting existing informal activities to specific developmental indicators. This finding directly addresses the study's first objective by showing that a structured, indicator-based guide, rather than additional unplanned activities, was the intervention teachers actually required to stimulate children's cognitive development in a systematic way.

2. Comparison with Theories and Previous Literature

The very valid, very practical, and very effective ratings obtained in this study align with Piaget's (1952) contention that concrete, activity-based instruction is developmentally appropriate for children in the preoperational stage, and with Vygotsky's (1978) emphasis on teacher-guided scaffolding within the Zone of Proximal Development. The 80.65% effectiveness score and the significant paired-sample t-test result, $t(11) = 47.87$, $p < .001$, are consistent with a systematic review and meta-analysis reporting that unplugged computational-thinking interventions produce meaningful gains in children's computational and logical-thinking outcomes across a wide range of contexts (Chen et al., 2023). They also corroborate findings that unplugged, embodied activities involving physical materials rather than screens support algorithmic reasoning, sequencing, and debugging in young children (Hu et al., 2024), and evidence that computational-thinking interventions more broadly yield measurable cognitive benefits, including improvements in reasoning and problem-solving (Montuori et al., 2024). The steady week-on-week increase in scores, from 45.14% to 97.22%, mirrors earlier Indonesian findings that daily-life-based unplugged coding builds children's capacity to follow instructions logically and self-correct errors through repeated practice (Fitriyah & Aljawad, 2023), and is consistent with evidence that structured, worksheet-based unplugged coding activities strengthen young children's problem-solving skills when applied consistently over time (Maulidya & Saputra, 2023). The slight dip observed between meetings four and five, together with the two children who plateaued at the BSH category, reflects a common pattern in developmental-skill acquisition curves rather than a failure of the intervention; such individual variation in pacing is precisely what play-based, unplugged computational-thinking assessment tools are designed to detect (Relkin et al., 2020).

3. Research Implications

Theoretically, these findings extend the application of Piagetian and Vygotskian developmental theory and Wing's (2006) computational-thinking framework to a concrete Indonesian early-childhood setting, reinforcing that computational thinking can be cultivated without digital devices when activities are systematically sequenced and scaffolded. Practically, the validated guide equips PAUD teachers with a ready-to-use, low-cost instructional tool that does not require technological infrastructure, addressing a resource constraint common in many Indonesian kindergartens. For institutions, the guide offers a concrete model for translating national policy encouraging the introduction of coding at the PAUD level (Kementerian Pendidikan dan Kebudayaan, 2025) into classroom-ready practice. Methodologically, the study demonstrates how the ADDIE model can be paired with a paired-sample t-test to strengthen the evidentiary basis of research and development studies in early-childhood education beyond descriptive percentages alone.

4. Research Limitations and Directions for Future Research

This study is limited by its small sample size of 12 children and its single-site design at PAUD Aurora, which restricts the generalizability of the effectiveness findings. The absence of a control or comparison group also means that causal claims about the guide's superiority over alternative instructional approaches cannot be firmly established. Future studies are encouraged to replicate this design with larger and more diverse samples, incorporate a control-group or quasi-experimental comparison, extend the implementation period beyond seven meetings, and examine the guide's contribution to other developmental domains such as language, social-emotional skills, and fine-motor coordination, in line with recommendations for more rigorous unplugged-coding research designs (Chen et al., 2023; Montuori et al., 2024).

CONCLUSION

This study found that PAUD Aurora required a structured unplugged coding guide because, despite existing informal cognitive-stimulation activities, teachers lacked conceptual understanding and procedural direction for embedding computational-thinking practices into daily instruction. Using the ADDIE model, the researcher developed a complete guide encompassing learning objectives, developmental indicators, seven graded activities, daily lesson plans, instructional media, and assessment instruments. The guide achieved a validity score of 3.35 (very valid), a practicality score of 98.44% (very practical), and an effectiveness score of 80.65% (very effective), with a statistically significant improvement from pretest to posttest, $t(11) = 47.87$, $p < .001$.

This study contributes theoretically by demonstrating the applicability of Piagetian, Vygotskian, and computational-thinking frameworks to a concrete, unplugged instructional design, and practically by providing PAUD teachers with a validated, technology-free tool for stimulating pattern recognition, sequencing, classification, causal reasoning, and problem-solving in children aged 4-6 years.

Future research should test the guide across larger and more diverse samples, employ control-group designs to strengthen causal inference, extend the implementation period, and explore its integration with other developmental domains beyond cognition, such as language, social-emotional development, and fine-motor skills.

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