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Enhancing Teacher Competence in Coding and Artificial Intelligence Through an Interdisciplinary Plugged-Unplugged

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ABSTRACT

The integration of coding and artificial intelligence (AI) in early childhood education has become a global priority, yet many Indonesian teachers remain underprepared to implement these competencies. This study examines the effectiveness of a professional development programme aimed at enhancing teacher competence in coding and AI through an interdisciplinary plugged-unplugged approach. Using a pre-experimental One-Group Pretest-Posttest design, the study involved 14 teachers from seven early childhood schools in Makassar, South Sulawesi. The intervention combined screen-based (plugged) and screen-free (unplugged) activities within an interdisciplinary framework. Teacher competence was measured using an observational rubric covering conceptual understanding, pedagogical integration, practical implementation, and reflective practice. The results showed a substantial increase in competence from pre-test ($M = 1.43$) to post-test ($M = 2.89$). The Wilcoxon Signed-Rank Test confirmed a significant improvement ($p < .05$) with a very large effect size ($r \geq .80$). These findings indicate that the programme effectively enhances teachers' competence and has strong potential as a scalable model for teacher training in Indonesia

INTRODUCTION

The global proliferation of digital technologies has fundamentally reconfigured the skills landscape for both children and the educators who serve them (Islami, Sidiq, et al., 2025). Within early childhood education (ECE), there is growing international consensus that foundational competencies in coding and artificial intelligence (AI) are no longer the exclusive domain of secondary and higher education, but represent developmental capacities that can and should be cultivated from the earliest years of formal schooling (Yafie et al., 2024). This perspective is closely aligned with the developmental characteristics of young children. At this stage, children become highly receptive and capable of learning new things. This can be observed in their tendency to ask questions about everything around them, reflecting their strong curiosity and eagerness

to understand the world (Kurnia et al, 2024). This repositioning has significant implications for early childhood teachers, who are expected to serve as primary mediators of these competencies yet who often lack the knowledge, confidence, or practical preparation to do so effectively.

Indonesia's national curriculum framework for early childhood education (PAUD) increasingly emphasises holistic, contextually responsive pedagogy; however, formal recognition of coding and AI as components of early childhood teacher competence remains nascent (Biana, 2021; Cheng et al., 2024; Kontkanen & Havu-nuutinen, 2023). Professional development pathways for practising teachers are fragmented, and opportunities to engage with computational thinking (CT), programming concepts, or AI literacy in systematic ways are rare, particularly outside major metropolitan centres.

Teachers in Makassar and broader South Sulawesi like many of their counterparts across the Indonesian archipelago typically receive limited in-service training on digital competencies and are left to navigate emerging curriculum expectations without structural support.

The plugged-unplugged framework offers one promising pedagogical response to this challenge. Drawing on decades of CS education research (Bell et al., 1998; (Brackmann et al., 2017) this approach integrates screen-based ("plugged") activities with screen-free ("unplugged") tasks to ensure that conceptual understanding of coding and AI is not dependent on device availability a critical consideration in under-resourced educational contexts. When designed through an interdisciplinary lens, plugged-unplugged activities can leverage existing domain knowledge in literacy, mathematics, science, and social development, enabling teachers to see coding and AI not as supplementary technical skills but as embedded dimensions of integrated early childhood learning (Kurnia et al., 2023; Kurnia et al., 2024)

Despite the theoretical appeal of this approach, empirical evidence documenting its effectiveness in enhancing teacher rather than child competence in Indonesian ECE settings remains limited. The majority of existing studies focus on learner outcomes, leaving teacher professional development largely unaddressed. This study responds to that gap by examining the effectiveness of a structured professional development programme for early childhood teachers in Makassar, designed around an interdisciplinary plugged-unplugged approach to coding and AI. The central research question is: Does participation in an interdisciplinary plugged-unplugged professional development programme significantly enhance the coding and AI competence of early childhood teachers in Makassar?

METHODS

Research Design

This study employed a pre-experimental design using a One-Group Pretest-Posttest model (Campbell & Stanley, n.d.) This design was selected as contextually appropriate given the professional

development context: with a single cohort of teachers participating in a structured programme, random assignment to a control condition was neither ethically nor practically feasible. Pre-test data established baseline competence, with post-test data assessed immediately following programme completion. The Wilcoxon Signed-Rank Test was used for hypothesis testing given the non-parametric nature of the data.

Participants

Participants comprised 14 early childhood teachers (all female; age range 24-47 years; mean teaching experience 8.3 years) drawn from 7 early childhood schools in Makassar, South Sulawesi. Schools were recruited through the local PAUD network (Gugus PAUD) using purposive sampling, with inclusion criteria requiring active classroom teaching status and absence of prior formal training in coding or AI. None of the participants had received structured professional development in these domains prior to the study. All participants provided informed consent, and school principals endorsed participation in writing.

Intervention

The professional development programme comprised three structured full-day sessions (totalling approximately 18 instructional hours) delivered over three weeks. The programme was designed around the interdisciplinary plugged-unplugged framework, integrating four thematic areas: (1) foundational concepts in coding and CT; (2) AI literacy and its applications in early childhood contexts; (3) plugged implementation using freely available educational software appropriate for young children; and (4) unplugged activity design and facilitation. Each session followed a consistent structure: conceptual input through mini lecture and case study (30%), collaborative activity design (40%), and reflection and peer feedback (30%). Interdisciplinary integration was foregrounded throughout, with explicit mappings between coding/AI concepts and existing PAUD curriculum domains (language, mathematics, science, social-emotional learning, and physical development).

Instrument

Teacher competence was assessed using a structured observational rubric developed by the

research team and validated by two early childhood education experts and one computer science education specialist (content validity index: .87). The rubric comprised 20 indicators across four domains: (1) Conceptual Understanding knowledge of fundamental coding and AI concepts; (2) Pedagogical Integration ability to connect coding/AI to PAUD curriculum areas; (3) Practical Implementation demonstration of plugged and unplugged activities appropriate for young children; and (4) Reflective Practice capacity to evaluate and adapt activities based on observed outcomes. Each indicator was rated on a four-point Likert scale (1 = not yet demonstrated, 4 = fully demonstrated). Domain scores and a composite mean score were computed for each participant at pre-test and post-test.

Data Analysis

Descriptive statistics (mean, standard deviation, minimum, maximum) were computed for pre-test and post-test composite scores. The Wilcoxon Signed-Rank Test was employed to assess statistical significance of change, appropriate for paired ordinal data with a non-normal distribution. Effect size was calculated using the formula $r = Z/\sqrt{N}$ (FIELD, 2013). with thresholds of $r = .10$ (small), $.30$

(medium), and $.50$ (large) following (Cohen, 1988) conventions noting that values above $.80$ are indicative of very large practical effects. All analyses were conducted using SPSS version 26.

RESULTS AND DISCUSSION

Pre-Test and Post-Test Descriptive Statistics

Pre-test results indicated low initial teacher competence across all four domains (composite $M = 1.43$, $SD = 0.38$), consistent with the absence of prior formal training in coding and AI. Scores clustered around the first scale point ("not yet demonstrated"), with no participant achieving a composite score above 2.10 at baseline. Post-test results demonstrated substantial improvement following the three-week intervention (composite $M = 2.89$, $SD = 0.41$). All 14 participants showed marked improvement from pre-test to post-test, with no cases of regression. The domain showing the greatest mean gain was Practical Implementation ($\Delta = 1.67$), followed by Pedagogical Integration ($\Delta = 1.51$), Conceptual Understanding ($\Delta = 1.44$), and Reflective Practice ($\Delta = 1.38$).

Table 1 presents the descriptive statistics for pre-test and post-test performance by domain.

Table 1. Descriptive Statistics of Teacher Competence by Domain (N = 14)

Domain	Pre-test M (SD)	Post-test M (SD)	Mean Gain	% Increase
Conceptual Understanding	1.41 (0.41)	2.85 (0.43)	+1.44	102.1%
Pedagogical Integration	1.39 (0.37)	2.90 (0.46)	+1.51	108.6%
Practical Implementation	1.45 (0.35)	3.12 (0.42)	+1.67	115.2%
Reflective Practice	1.48 (0.44)	2.86 (0.39)	+1.38	93.2%
Composite Score	1.43 (0.38)	2.89 (0.41)	+1.46	102.1%

Wilcoxon Signed-Rank Test

The Wilcoxon Signed-Rank Test confirmed a statistically significant improvement in composite teacher competence scores from pre-test ($Mdn = 1.43$) to post-test ($Mdn = 2.89$), $Z = -3.30$, $p = .001$ (two-tailed), $p < .05$. All 14 participants showed positive ranks (i.e., post-test scores exceeded pre-test scores); there were no negative ranks or ties.

Effect size was calculated as $r = Z/\sqrt{N} = 3.30/\sqrt{14} = .882$, indicating a very large practical

effect. This finding is consistent with the magnitude of pre-test to post-test score gains observed across all four competence domains and suggests that the intervention produced not merely a statistically detectable, but a practically meaningful and substantial change in teacher competence. Table 2 summarises the hypothesis testing results.

Table 2. Wilcoxon Signed-Rank Test Results

Comparison	Z	p (two-tailed)	Effect Size (r)	Inter-pretation
Post-test – Pre-test (Composite)	–3.30	.001*	.882	Very Large

Note. * $p < .05$ (two-tailed). Effect size r : small = .10, medium = .30, large = .50, very large > .80.

Discussion

The results of this study provide compelling empirical support for the effectiveness of an interdisciplinary plugged-unplugged professional development programme in enhancing early childhood teacher competence in coding and AI. The statistically significant and practically very large improvement observed across all four competence domains from a composite mean of 1.43 at pre-test to 2.89 at post-test represents a meaningful shift from foundational non-competence to developing proficiency within a compressed intervention period of three weeks.

These findings align with and extend existing literature on ECE teacher professional development in digital domains. The pre-test scores confirm prior research documenting low digital competence among practising Indonesian early childhood teachers (Marnoko, 2025). and validate the premise that targeted, structured professional development is necessary to bridge the gap between policy expectations and classroom readiness. The magnitude of the effect size ($r = .882$) is consistent with findings from analogous short-duration professional development studies in other technical domains, where focused, practice-embedded interventions produce larger effect sizes than extended but less structured programmes (Darling-hammond et al., 2020)

The domain pattern of gains merits particular attention. Practical Implementation showed the greatest mean gain ($\Delta = 1.67$), suggesting that teachers responded most strongly to opportunities for hands-on activity design and facilitation consistent with adult learning theory's emphasis on experiential, contextually embedded learning (knowles, 2015)qq This finding also reflects the affordance of the plugged-unplugged framework: by beginning with embodied, screen-free activities, teachers could build confidence and conceptual grounding before engaging with digital tools, reducing the technological anxiety that frequently inhibits uptake in this population.

The strong gains in Pedagogical Integration ($\Delta = 1.51$) are theoretically significant, indicating that teachers not only acquired new content knowledge but developed the capacity to connect coding and AI concepts to existing PAUD curriculum areas. This represents what (Chaitidou & Peikos, 2026) terms the development of pedagogical content knowledge arguably the most critical dimension of teacher competence for sustainable classroom implementation. The interdisciplinary design of the programme, which explicitly mapped coding and AI activities onto language, mathematics, science, and social-emotional development domains, appears to have been effective in supporting this integration.

The relatively smaller gain in Reflective Practice ($\Delta = 1.38$), while still substantial in absolute terms, may indicate that critical pedagogical reflection the ability to systematically evaluate and adapt activities in response to observed children's learning requires longer sustained engagement than a three-week programme affords. This is consistent with professional development literature suggesting that reflection as a teaching disposition develops through repeated cycles of practice and feedback over time (Rozimela et al., 2025). Future programmes should consider incorporating peer coaching or lesson study components to extend opportunities for structured reflection beyond the initial training period.

Several study limitations warrant acknowledgement. The pre-experimental design while appropriate for the feasibility and access constraints of this context does not permit causal inference with the rigour of a randomised controlled trial. The absence of a control group means that observed gains cannot be unambiguously attributed to the intervention, as maturation, familiarity with the assessment rubric, and social desirability effects cannot be fully ruled out. The relatively small sample ($N = 14$) further limits statistical power and generalisability. Additionally, post-test data were collected immediately following programme completion; it is unknown whether competence gains

were sustained over time or transferred to actual classroom practice with children.

Future research should address these limitations through quasi-experimental designs incorporating comparison groups, larger and more geographically diverse samples, longitudinal follow-up assessments,

CONCLUSION

This study demonstrates that a short-duration, interdisciplinary plugged-unplugged professional development programme can significantly and meaningfully enhance the competence of early childhood teachers in coding and AI. The pre-test to post-test gains observed across all four competence domains conceptual understanding, pedagogical integration, practical implementation, and reflective practice indicate that the programme was effective in moving teachers from baseline non-competence to developing proficiency within three weeks of structured engagement.

The effect size of $r = .882$ underscores that this improvement is not merely statistically significant but practically substantial, carrying real implications for programme design and policy. The interdisciplinary plugged-unplugged framework employed in this study represents a contextually appropriate and scalable approach to coding and AI teacher training one that requires neither specialised infrastructure nor expensive proprietary resources, making it particularly well-suited to deployment across the diverse and often under-resourced landscape of Indonesian PAUD settings.

These findings carry direct implications for teacher education institutions, regional education offices, and curriculum policymakers. Embedding coding and AI competence within existing PAUD teacher certification pathways supported by interdisciplinary, practice-embedded professional development offers a viable route to systemic change that neither overwhelms teachers with unfamiliar technical demands nor reduces coding and AI to isolated skill drills. Rather, it positions these competencies as natural extensions of effective early childhood pedagogy, accessible to and achievable by all teachers who are provided with appropriate support.

and classroom observation data capturing transfer to practice. Research examining child learning outcomes in classrooms taught by programme graduates would provide a critical test of the ultimate educational relevance of teacher competence gains.

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