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Coding as a Mediating Tool for Early Mathematical Cognition: A Qualitative Case Study of Unplugged and Plugged Programming Activities in an Indonesian Kindergarten

Tsani Muflihatut Daimah
Universitas Islam Negeri Sunan Kudus, Indonesia
Email: muflihatutdaimahtsani@gmail.com

Correspondence: muflihatutdaimahtsani@gmail.com

Abstract: This qualitative case study examines how an eight-week unplugged and plugged coding programme mediates early mathematical cognition and computational thinking among 15 kindergarten children (aged 5–6) in Indonesia. Grounded in computational thinking frameworks, early mathematics learning trajectories, and Vygotskian scaffolding, the study addresses an empirical gap dominated by Western contexts, where early childhood settings differ markedly in infrastructural and curricular constraints. Data were collected through structured observations (1– 4 scale), video recordings, field notes, and teacher interviews, then analysed using thematic analysis triangulated against descriptive score trends. Four themes emerged: mathematics as an embodied practice, computational thinking as an emergent cognitive scaffold, teacher scaffolding as an essential prerequisite, and infrastructural constraints as a pedagogical driver. Notably, pattern initiation scores increased from a mean of 1.8 to 3.2. The study argues that coding's primary pedagogical value lies not in technical programming literacy, but in its capacity to externalise children's tacit sequential and classificatory reasoning during play. Implications for early childhood curriculum design, teacher training, and future empirical research in developing contexts are discussed.

Keywords*:* early childhood education; computational thinking; unplugged coding; early mathematics.

Abstrak: *Studi kasus kualitatif ini mengkaji bagaimana program coding unplugged dan plugged selama delapan minggu memediasi kognisi matematis awal dan berpikir komputasional pada 15 anak TK (usia 5–6 tahun) di Indonesia. Berlandaskan kerangka berpikir komputasional, lintasan belajar matematika awal, dan scaffolding Vygotsky, penelitian ini mengisi kesenjangan literatur yang didominasi konteks Barat, di mana kondisi infrastruktur dan kurikulum PAUD berbeda secara signifikan. Data dikumpulkan melalui observasi terstruktur (skala 1–4), rekaman video, catatan lapangan, dan wawancara guru, lalu dianalisis menggunakan analisis tematik yang ditriangulasi dengan tren skor deskriptif. Empat tema utama menunjukkan bahwa matematika dipahami secara embodied, berpikir komputasional berfungsi sebagai perancah kognitif, scaffolding guru menjadi prasyarat utama, dan keterbatasan infrastruktur membentuk desain pedagogis (misalnya, rerata skor inisiasi pola meningkat dari 1,8 menjadi 3,2). Studi ini berargumen bahwa nilai pedagogis utama coding bukan terletak pada literasi pemrograman teknis, melainkan pada kemampuannya mengeksternalisasi penalaran sekuensial dan klasifikatoris anak yang semula implisit. Implikasi bagi kurikulum PAUD dan pelatihan guru turut didiskusikan.*

Kata kunci: *pendidikan anak usia dini; berpikir komputasional; coding unplugged; matematika awal.*

Introduction

The proposition that children should learn to code before they can read fluently has moved, within roughly a decade, from a Silicon Valley curiosity to a policy commitment across dozens of national curricula. Indonesia's own Ministry of Education has echoed this trajectory: the Vice Minister for Primary and Secondary Education has publicly emphasised that introducing coding and mathematical concepts from early childhood is essential, provided the material is delivered through meaningful play rather than rigid instruction. What is less settled, and considerably less examined in the Southeast Asian literature, is the mechanism by which a set of practices imported from computer-science pedagogy comes to bear on a domain as foundational and as differently theorised as early mathematics. The claim that "coding teaches math" is intuitive enough to have become a slogan; it is precisely that ease of assertion that should make a researcher suspicious. Slogans survive because they are underspecified, and underspecification is where a case study earns its keep.

This article reports a qualitative case study of an eight-week coding intervention at TK Nawa Kartika, a kindergarten in Indonesia, involving fifteen children in the five-to-six-year-old cohort (Kelompok B). The intervention combined unplugged activities, in which children sequenced blocks, cards, and puzzles to represent algorithmic logic without any screen, and plugged activities, in which children used simple digital applications under teacher supervision. The empirical question is narrower than the policy slogan: not whether coding improves mathematics in the abstract, but what specific cognitive and social behaviours emerge when Indonesian kindergarten children are given a structured, teacher-scaffolded programming task, and how those behaviours relate to the mathematical competencies that early-childhood curricula are already committed to developing, namely pattern recognition, classification, sequencing, and elementary quantity concepts.

Three bodies of literature converge on this question without fully answering it for the Indonesian context. The first is the computational-thinking literature associated with Bers and colleagues, which has repeatedly demonstrated, largely in North American and Western European robotics laboratories, that programming activity can be decomposed into teachable sub-skills such as sequencing, debugging, and modularity (Bers, 2020; Bers et al., 2014; Relkin et al., 2020). The second is the early-mathematics literature associated with Clements and Sarama (2009), whose learning-trajectories framework treats mathematical development as a sequence of empirically documented cognitive levels rather than an undifferentiated maturation curve, and which has rarely been put into direct conversation with computational-thinking research despite the evident overlap between sequencing, pattern recognition, and the pre-numerical competencies both frameworks describe. The third is a smaller but growing body of quasi-experimental studies, mostly from Turkey and Greece, that have measured coding's effect on preschool mathematical reasoning under controlled conditions and reported small-to-moderate positive effects (Fessakis et al., 2013; Palmér, 2017; Somuncu & Aslan, 2022; Zurnacı & Turan, 2024). These three literatures rarely cite one another, which is itself a symptom of a field still assembling its own foundations: computer scientists study computational thinking, mathematics educators study learning trajectories, and educational psychologists run the intervention trials, with comparatively little cross-pollination.

Before turning to that complication, it is worth being precise about what "the Indonesian context" is being asked to do analytically in this study, because appeals to national context can easily become a rhetorical placeholder rather than a substantive variable. The claim here is narrower than "Indonesia is different," which is true of every country and therefore explains nothing on its own. The specific, testable claim is that Indonesian PAUD institutions of the kind represented by TK Nawa Kartika combine three conditions rarely co-present in the settings that generated the existing coding-and-mathematics evidence base: a device-to-child ratio well below one, an early-childhood teaching workforce whose pre-service training rarely included computational-thinking pedagogy (Prasetyo et al., 2023), and a curricular culture in which thematic integration across subjects, rather than discrete subject blocks, is already the dominant instructional norm. Each of these conditions independently shapes what a coding intervention can look like; together, they generate a configuration of constraints and affordances that neither the Turkish quasi-experimental literature nor the Scandinavian robotics literature was designed to anticipate. Indonesia complicates all three literatures at once. Unlike the well-resourced Turkish and Scandinavian kindergartens in which most quasi-experimental coding studies have been conducted, Indonesian PAUD institutions, particularly those outside major urban centres, operate under chronic device scarcity, inconsistent internet access, and wide variation in teacher preparedness for technology-integrated pedagogy (Prasetyo et al., 2023; Rahmawati & Agustin, 2024). A pedagogy imported wholesale from a one-device-per-child Scandinavian classroom does not survive contact with a kindergarten where eighteen children share fifteen ageing laptops. The present study treats this constraint not as a limitation to be apologised for but as a substantive research condition: it asks what a coding-based mathematics pedagogy looks like when plugged activity is structurally rationed and unplugged activity must therefore carry a proportionally larger pedagogical load. This is a different question from the one Nordic robotics labs have been answering, and it deserves a different kind of evidence.

The case for taking unplugged coding seriously as a mathematical pedagogy, rather than as a screen-time-reduction compromise, rests on a specific theoretical claim. Sequencing a row of coloured blocks according to a repeating rule is not a simulation of programming; it is, structurally, the same cognitive operation as identifying and extending a numerical pattern, which is one of the eight learning trajectories Clements and Sarama (2009) document as foundational to later arithmetic competence. Fessakis et al. (2013) reached a structurally similar conclusion in their Logo-based case study of Greek kindergartners, finding that programming problems elicited higher-order problem-solving behaviours, hypothesis testing, error correction, peer negotiation, that are difficult to observe in less open-ended mathematical tasks. If that claim generalises, then the pedagogical value of coding for early mathematics does not depend on children acquiring programming literacy as an end in itself; it depends on coding tasks functioning as an unusually transparent window onto reasoning processes that are otherwise submerged in the ordinary flow of play.

This reframing matters for how the present study reports its findings. Rather than asking whether TK Nawa Kartika's children "improved in mathematics" as a global outcome, a claim that would require inferential statistical machinery this case study does not have the sample size or design to support, the analysis asks a more tractable question: which specific mathematical and computational behaviours became observable, and under what pedagogical conditions, over eight weeks of structured coding activity. The answer, developed across four themes in the Results and Discussion sections, is that mathematical reasoning surfaced most visibly not during moments of successful task completion but during moments of productive failure, when children encountered a sequencing error, attempted to diagnose it, and revised their approach, often through peer discussion rather than teacher correction. That pattern, if it holds beyond this single case, has implications for how PAUD institutions in resource-constrained settings might sequence unplugged and plugged activity, and for what teacher training in this domain should actually prioritise.

Further complication concerns which faction within computational-thinking research this study's findings actually support, because the field is not theoretically unified in the way policy documents tend to imply. One camp, tracing its lineage to Papert's (1980) constructionism, treats programming as valuable primarily because constructing an artefact, a sequence, a small program, a robot's route, forces a child to make implicit reasoning explicit and debuggable; on this view, the pedagogical work is done by the act of construction itself, and adult instruction should stay minimal so as not to short-circuit the child's own discovery process. A second, more instructionist camp, closer to the curriculum-design tradition from which Bers's (2020) seven powerful ideas emerged, treats computational thinking as a set of discrete, teachable sub-skills that benefit from explicit sequencing, modelling, and teacher-led scaffolding, closer in spirit to Clements and Sarama's (2009) learning-trajectories approach to mathematics instruction, which likewise assumes that developmental progression benefits from deliberately sequenced adult guidance rather than unstructured discovery. These two camps are not merely stylistic variants; they generate different predictions about what should happen when scaffolding is withdrawn or degraded, a distinction this study's data can actually speak to, because TK Nawa Kartika's device shortage functioned as an unplanned natural experiment in exactly that kind of withdrawal. The theme-three findings, developed below, side more with the instructionist camp than the constructionist one: children's progress tracked the quality and continuity of teacher mediation closely enough that unmediated construction alone, in this setting, does not appear to have been sufficient.

The remainder of the article proceeds as follows. The theoretical framework section develops the three-strand synthesis, computational thinking, learning trajectories, and scaffolding, that organises the analysis. The method section details the observational and interview instruments, the thematic-analysis procedure, and the ethical safeguards observed given the involvement of young children as research subjects. The results present the four themes generated from triangulated observation, video, field-note, and interview data. The discussion situates these findings against the Turkish, Greek, and Swedish literature, addresses the study's methodological limitations directly rather than deferring them to a closing paragraph, and derives implications for curriculum design and teacher preparation in the Indonesian PAUD context.

Method

Research Design

This study employed a qualitative case design, appropriate for an exploratory investigation of a bounded, naturally occurring instructional intervention (a single classroom, a single eight-week programme) in which the research interest lies in process and mechanism rather than in generalisable effect size. A case study design, rather than a quasi-experimental one, was selected deliberately: the absence of a comparison group and the small purposive sample make this study unsuited to causal inference, and it does not claim to provide any. What it offers instead is a fine-grained account of how coding activity was enacted, negotiated, and occasionally resisted by a specific group of Indonesian kindergarten children and their teachers, evidence of a kind that quasi-experimental designs, by virtue of their reliance on pre-specified outcome measures, are structurally poor at capturing.

Participants and Setting

Participants were fifteen children (eight girls, seven boys) enrolled in Kelompok B (the five-to-six-year-old cohort) at TK Nawa Kartika, Indonesia. Children were selected through purposive sampling on a single criterion: demonstrated readiness to participate in structured group activities, as judged by the classroom teacher, in order to exclude children for whom participation would have been developmentally inappropriate rather than to bias the sample toward higher performers. Two class teachers, referred to hereafter as Teacher 1 and Teacher 2 to protect their identities, were interviewed as key informants; Teacher 1 was responsible for thematic integration between the coding sessions and the regular classroom curriculum, and Teacher 2 was responsible for the plugged, digital-media component of the sessions.

Data Collection Instruments

Four instruments were used, triangulated against one another during analysis. First, a structured behavioural observation sheet recorded three computational-thinking indicators, pattern initiation, sequence execution, and reflection, on a 1–4 ordinal scale, completed weekly across the eight-week intervention. Second, classroom video recordings captured each session in full for subsequent review and thematic coding. Third, daily field notes recorded contextual and interactional detail not visible on video, including children's verbal reasoning and teacher-child exchanges. Fourth, semi-structured interviews were conducted with both class teachers at the conclusion of the intervention, covering their perception of children's mathematical and computational development, the pedagogical rationale behind session design, and the infrastructural constraints they navigated.

Procedure

Over eight weeks, children participated in one coding session per week, alternating and combining unplugged activities (block sequencing, pattern cards, physical puzzles) with plugged activities (guided use of simple educational applications on shared laptops). Session content was aligned, where feasible, with the thematic unit already being taught in the regular classroom curriculum, a coordination decision made by Teacher 1 specifically to avoid treating coding as a decontextualised add-on. Two consecutive weeks at the start of the plugged component were dedicated exclusively to basic digital literacy, mouse clicking and drag-and-drop manipulation, before any coding content properly was introduced, reflecting the teachers' judgement that computational-thinking tasks presuppose a baseline of device fluency this cohort did not yet reliably possess.

Data Analysis

Data were analysed using Braun and Clarke's (2006) six-phase thematic analysis: familiarisation with the video and field-note corpus; generation of initial codes grounded in the theoretical framework (sequencing, debugging, pattern extension, scaffolding instances) as well as in vivo codes drawn from children's own language; searching for candidate themes across codes; reviewing themes against the full data corpus for internal coherence and external distinctiveness; defining and naming the four final themes reported below; and producing the analytic narrative that constitutes the Results and Discussion sections. Observation-sheet scores were analysed descriptively, means and ranges by week, and are reported as indicative trends rather than as inferential statistics, given that no comparison group, randomisation, or pre-registered hypothesis test was part of the design. This is a deliberate departure from the original field report on which this article draws, which described the score increase as statistically significant without specifying a test; that claim could not be substantiated and has been removed rather than repeated.

Ethical Considerations

Because participants were young children, consent was obtained from parents or guardians and from the kindergarten's administration prior to observation and video recording. Children's assents were sought verbally at the start of each session, consistent with the understanding that assent from young children is an ongoing, revocable process rather than a single signed form. All children's names reported in this article are pseudonyms; the two teacher-informants are identified only by role (Teacher 1, Teacher 2) rather than by name, in keeping with standard confidentiality practice for qualitative classroom research.

Researcher Positionality

Qualitative case studies of classroom practice are shaped, unavoidably, by the researcher's prior relationship to the site. The researcher had an existing professional connection to TK Nawa Kartika's teaching staff prior to data collection, which afforded the sustained classroom access a study of this depth requires, but which also warrants an explicit note on the risk of over-rapport, a tendency to read ambiguous classroom moments charitably because the researcher already trusted the teachers' pedagogical judgement. This risk was addressed procedurally rather than merely acknowledged: video and field-note coding were conducted against the pre-specified theoretical categories derived from Bers (2020) and Clements and Sarama (2009) before the four themes were allowed to take their final shape, so that the analytic categories were not free to drift toward whatever reading made the intervention look most successful. This is a partial safeguard, not a complete one, and it is offered to the reader as a basis for judging the interpretive claims that follow, not as a claim that the risk has been eliminated.

Results and Discussion

Descriptive Trends in Computational-Thinking Indicators

Across the eight-week intervention, mean scores on the three observation-sheet indicators showed a consistent upward trend on the 1–4 ordinal scale. Pattern initiation, operationalised as a child's capacity to begin constructing a sequence or pattern independently, rose from a week-one mean of approximately 1.8 to a week-eight mean of approximately 3.2. Sequence execution, the capacity to carry an instructed or self-initiated sequence through to completion, showed a comparable trajectory, as did reflection, operationalised as a child's capacity to evaluate whether a completed sequence matched its intended rule and to correct it if not. These trends are reported descriptively; the absence of a comparison group means they cannot be attributed to the coding intervention with statistical confidence, and an equally plausible partial explanation is ordinary maturation and familiarisation with the observation procedure itself over eight weeks. What the trends do establish, at minimum, is that the observation instrument was sensitive enough to detect within-child change over the intervention period, which is a precondition for, though not proof of intervention effect.

Theme One: Mathematics as an Embodied and Contextual Activity

The clearest pattern across field notes and video was that children's mathematical engagement was strongest when quantitative concepts were anchored to a physical, manipulable referent rather than presented abstractly. In sessions using coloured blocks and geometric-shape cards, several children began consistently generating repeating patterns and predicting the next element in a sequence, a behaviour Teacher 1 described directly: "there was a coding activity applying geometric shapes matched with colours ... to strengthen the children's cognitive ability" (Teacher 1, interview). This is consistent with Clements and Sarama's (2009) account of the patterning trajectory, in which children's earliest pattern competence is tied to concrete, perceptually salient materials before it generalises to abstract or numerical representations. Teacher 1 also described embedding number recognition into adjacent activities, such as threading beads by colour sequence, noting that this simultaneously reinforced counting and fine-motor coordination. The mathematical content here was rarely presented as an isolated lesson; it was distributed across activities that were, from the children's perspective, primarily about play, colour, and object manipulation.

A second illustration of embodied mathematics appeared in a counting task in which children viewed an image containing a fixed number of stars, for example seven, counted them aloud, and then selected the matching numeral from a set of alternatives. Teacher 2 described this as a deliberately layered task: children were simultaneously practising cardinal counting and numeral recognition, two competencies that Clements and Sarama (2009) treat as developmentally distinct trajectories that only later converge. Once a child demonstrated consistent success at this level, the task escalated to simple addition, first with small quantities and eventually into the low teens, at which point several children began to falter when totals crossed into the tens, a threshold Teacher 2 identified without prompting as a natural difficulty boundary for this cohort. This unprompted identification of a difficulty threshold is itself a modest piece of evidence for the learning-trajectories claim that mathematical development proceeds through identifiable, teacher-observable stages rather than as smooth, continuous growth.

The embodied character of these tasks was not uniformly welcomed by all children; a point the data make it important not to smooth over. Field notes and both interviews converged on a consistent finding that children showed a marked preference for image-rich, narrative-style tasks, such as guiding a car to a parking space or moving a ball through a maze, over tasks requiring letter sequencing or alphabetic ordering, which several children found tedious and disengaging within a matter of minutes. Boredom, when it occurred, had a recognisable behavioural signature: a child would leave their seat, wander toward a peer's screen, and either return to the task if re-engaged by what they observed or continue wandering until redirected by a teacher, who would, according to both informants, eventually restrict further computer access if the wandering became a repeated pattern within a session. This finding complicates any simple claim that coding activity is uniformly motivating for young children; motivation here was contingent on the specific representational format of the task, image-based and narrative tasks sustaining engagement considerably longer than symbol-sequencing tasks stripped of narrative context.

Theme Two: Computational Thinking as an Emergent Cognitive Scaffold

The second theme concerns the specific behaviours that emerged around task failure and revision, the moments the theoretical framework predicted would be analytically richest. Field notes documented children encountering sequencing tasks with irregular or repeating patterns, attempting an initial solution, recognising a mismatch, and revising, frequently through peer consultation rather than teacher correction: children were observed proposing alternative orderings, reversing a sequence to test an alternative rule, and verbally narrating their own errors ("wrong colour," "I forgot the order") before proposing a repair strategy ("let's try again from the start," "let's ask a friend"). This pattern of self-initiated error detection and peer-mediated repair is precisely the debugging component of Bers's (2020) seven powerful ideas, observed here in a screen-free, block-based context rather than in the software-debugging context for which the construct was originally developed. Its presence in unplugged activity is notable because it suggests the underlying cognitive operation, detecting a mismatch between an intended and an actual outcome, is not contingent on the digital medium, a finding that has direct implications for how much pedagogical weight unplugged activity can bear in infrastructure-constrained settings, discussed further below.

Theme Three: The Teacher's Scaffolding Role as a Precondition, Not a Supplement

Both teachers described their role in terms that positioned scaffolding as structurally necessary rather than optional or supplementary. Teacher 1 reported adapting instruction to wide within-cohort variation, noting that despite all children being nominally in Kelompok B, "there are still children who do not yet understand some numbers, for instance still confusing the digits 6 and 9," which required individualised remediation, sometimes returning a child to basic number-recitation tasks, sometimes coordinating directly with the child's regular classroom teacher. Teacher 2, responsible for the plugged component, described a staged introduction to digital tools: two weeks devoted exclusively to click-based colouring activities before any drag-and-drop task was introduced, on the reasoning that computational tasks presuppose device fluency that could not be assumed. This staging decision is a direct, practitioner-generated instance of scaffolding within the zone of proximal development, introduced not because a theoretical framework demanded it but because the teachers' working knowledge of their own students made the unscaffolded alternative visibly unworkable. The theoretical prediction that coding-task performance would be unusually sensitive to mediation quality, because the task is unfamiliar enough that children cannot rely on rote procedure, is corroborated by the teachers' own account of why this staging was necessary in the first place.

Theme Four: Infrastructural Constraint as a Structuring Force on Pedagogical Design

The fourth theme departs from the cognitive focus of the first three to document a structural condition that shaped what pedagogy was possible at all. Teacher 2 described recurring technical failures, slow or malfunctioning computers, application files corrupted by malware requiring reinstallation, and a persistent device-to-child ratio shortfall: approximately eighteen children per class against fifteen available laptops, requiring device-sharing arrangements that some children accepted readily and others resisted. This constraint was not peripheral to the pedagogy; it actively shaped session design, biasing activity toward unplugged formats not purely on pedagogical grounds but because plugged sessions could not be reliably delivered at the frequency the curriculum nominally called for. This finding complicates any straightforward reading of the observation-score trends: to the extent gains are attributable to the intervention at all, they appear to be gains substantially driven by the unplugged component, which was pedagogically deliberate in the block-and-card sessions but was also, in practice, the more infrastructurally reliable half of the programme.

Device-sharing itself generated a secondary, unanticipated social finding. Where two children were assigned to a single laptop, some pairs negotiated turn-taking spontaneously and appeared to benefit from the arrangement, narrating their reasoning to one another in a manner consistent with the peer-mediated debugging documented in theme two; other pairs showed visible discomfort, with one child dominating the keyboard and the other disengaging, a pattern both teachers described as more likely when the paired children had no prior friendship. This suggests that device scarcity, while unambiguously a constraint on the frequency and consistency of plugged instruction, does not translate into a uniform social cost; its effect is moderated by pre-existing peer relationships in ways that a purely technical account of infrastructural limitation would not predict, and that future studies with a larger sample could examine as a distinct research question in its own right.

The four themes reported above converge on a claim that is narrower, and for that reason more defensible, than the one implicit in the original field report from which this study draws: coding activity in this setting appears to function as an unusually transparent occasion for children to externalise sequential and classificatory reasoning, rather than as a distinct skill domain that separately and additively improves mathematics. This distinction matters because it changes what should count as evidence of success. If coding were understood as an independent skill domain, the relevant evidence would be a mathematics-achievement gain attributable specifically to programming instruction, the kind of evidence quasi-experimental designs such as Somuncu and Aslan's (2022), which found a significant experimental-group advantage in early mathematical reasoning using a pre-test/post-test control-group design, are built to produce. If instead coding functions as a window onto reasoning that is otherwise submerged in ordinary play, as the present case study's theme-two findings suggest, the relevant evidence is closer to what Fessakis et al. (2013) documented in their Greek Logo-based case study: richer, more visible instances of hypothesis testing, error correction, and peer negotiation than less open-ended mathematical tasks typically elicit. The present findings sit closer to the second reading, and the theoretical framework developed here, linking Bers's (2020) debugging construct to Clements and Sarama's (2009) patterning trajectory, was built specifically to make that reading legible rather than to force the data toward a causal claim the design cannot support.

This reframing has a direct methodological consequence that the original field report obscured: describing the observation-score increase as statistically significant, without a specified test, comparison group, or sample-size justification, was not a minor reporting omission but a category error, treating case-study observational data as though it had the inferential structure of a controlled trial. Removing that claim, as this revision does, is not a weakening of the study's contribution; a case study that honestly reports "we do not know whether this generalises, but here is what we saw happen and why it plausibly happened" is more useful to the field than one that borrows the rhetoric of significance testing without its machinery. Zurnacı and Turan (2024), in the one study in this literature that directly compared robotics-based and unplugged coding conditions using a genuine quasi-experimental design, found no statistically significant difference in overall computational-thinking gains between the two conditions, a result that is directly relevant to theme four here: if unplugged and plugged coding produce comparable cognitive gains under controlled conditions, then TK Nawa Kartika's infrastructurally forced tilt toward unplugged activity may be less of a compromise than it appears to the teachers delivering it, and considerably less of one than the original field report's framing implied.

A further point of comparison concerns the specific mathematical sub-domain each strand of literature has found coding to affect most strongly, because the present study's emphasis on patterning and classification is not the only plausible candidate. Palmér's (2017) Swedish preschool study, using small programmable floor robots, reported that programming activity was associated most clearly with gains in spatial thinking, children's capacity to visualise and relate movement in physical space to symbolic or map-based representations, rather than with patterning or classification as such. TK Nawa Kartika's programme did not include robotics, and the present data accordingly offer no direct evidence on spatial reasoning, a gap worth flagging rather than glossing over, since it means the present findings should be read as complementary to, rather than a replication of, the Swedish evidence. Read together, the two studies suggest that "coding" is not a single pedagogical intervention with a single characteristic cognitive signature; a block-sequencing task, a floor-robot navigation task, and a screen-based drag-and-drop task plausibly draw on overlapping but distinct sub-components of early mathematical and spatial cognition, which argues against treating coding as a unitary construct in future intervention design and evaluation, and in favour of studies that report which specific coding modality produced which specific cognitive gain, rather than aggregating heterogeneous activities under a single outcome label.

The teacher-scaffolding theme also bears directly on a tension in the computational-thinking literature between activity-centred and teacher-centred accounts of how coding produces its effects. Bers's (2020) framework, developed substantially through structured robotics curricula with trained facilitators, has sometimes been read, perhaps uncharitably, as implying that the activity itself, given the right materials, does most of the cognitive work. The present data do not support that reading. Teacher 2's staged, two-week digital-literacy scaffold before any coding task proper was introduced, and Teacher 1's continual individualised remediation for children still confusing basic digit forms, both indicate that the activity was pedagogically inert, or worse, frustrating, without substantial adult mediation calibrated to a specific child's zone of proximal development. This is consistent with the broader early-childhood technology literature's caution that digital tools scaffold learning only when embedded in a responsive pedagogical relationship, and it suggests that teacher-training investment, not device procurement, may be the binding constraint on this pedagogy's effectiveness in under-resourced Indonesian PAUD settings, a point with direct policy relevance given the Ministry's stated ambition to expand early coding exposure nationally.

Several limitations bear directly on how these findings should be read. First, the absence of a comparison group means the study cannot distinguish intervention effects from maturation or observation-familiarity effects; the descriptive score trends should be read as motivating, not confirming, the qualitative themes. Second, the purposive sampling criterion, teacher-judged readiness, likely selected for children already somewhat disposed toward structured group participation, which may inflate the apparent smoothness of engagement documented in theme one relative to a full, unselected cohort. Third, the study's single-site, single-cohort design limits transferability; TK Nawa Kartika's specific combination of curricular thematic integration and device scarcity is illustrative of, but not necessarily representative of, the broader diversity of Indonesian PAUD institutions. Fourth, video and field-note coding, while conducted according to Braun and Clarke's (2006) procedure, was carried out by a single researcher without an independent second coder, which limits the study's ability to report inter-coder reliability; this is a methodological gap future replications in this setting should address directly. These limitations argue not for discounting the findings but for the kind of quasi-experimental follow-up, ideally multi-site, with a comparison group and pre-registered outcome measures, that could test whether the mechanisms proposed here (coding as an externalisation device for otherwise-tacit sequential reasoning) generalise beyond this single, infrastructurally constrained case.

A related implication concerns curricular sequencing rather than teacher training as such. Teacher 1's practice of aligning coding sessions to the classroom's existing thematic unit, rather than treating coding as a stand-alone weekly add-on, appears from the data to be a substantive design decision rather than a mere administrative convenience: it is the mechanism by which the mathematical content of the coding session acquires meaning within a broader instructional narrative the child is already tracking, consistent with the constructivist premise, shared by both Papert (1980) and Clements and Sarama (2009) despite their disagreement over the degree of adult direction required, that children build mathematical understanding by connecting new material to an existing, meaningful context rather than by absorbing decontextualised procedures. Where thematic alignment was not possible, Teacher 1 reported defaulting to colouring activities, described as the easiest fallback, a decision that, on the framework developed here, likely sacrifices some of the sequencing and classification demands that make coding tasks analytically useful in the first place. This suggests that curriculum designers extending this pedagogy to other Indonesian PAUD institutions should treat thematic integration as a core design requirement rather than as an optional refinement to be attempted once basic device logistics are solved, since the data here suggest the two problems, infrastructural and curricular, are not sequential but simultaneous constraints on the same intervention.

Conclusion

This study set out to examine a narrower and more tractable question than the policy slogan that motivated it: not whether coding improves early mathematics in general, but what specific reasoning behaviours become visible when Indonesian kindergarten children engage in structured, teacher-scaffolded coding activity under real infrastructural constraints. The answer, developed through four themes grounded in triangulated observation, video, field-note, and interview data, is that coding activity functioned primarily as a device for externalising sequential and classificatory reasoning that is difficult to observe directly in less structured play, and that this function depended heavily on continuous teacher scaffolding rather than on the coding materials or devices themselves. This conclusion sits deliberately closer to the constructionist-versus-instructionist debate identified in the introduction than to either pole: the data show children's own construction and revision of sequences doing real cognitive work, consistent with Papert's (1980) intuition, but only within scaffolding boundaries set continuously by teachers, consistent with the instructionist reading of Bers's (2020) framework, which suggests the two camps may be describing complementary rather than competing mechanisms once the specific developmental stage and infrastructural setting are held fixed.

Two implications follow for practice. Institutions operating under conditions similar to TK Nawa Kartika's, device scarcity, unreliable connectivity, wide within-cohort developmental variation, should not treat unplugged coding as a fallback pending better infrastructure; the present findings, read alongside Zurnacı and Turan's (2024) quasi-experimental comparison of robotics and unplugged conditions, suggest unplugged activity can carry substantial pedagogical weight in its own right. Teacher-training investment, specifically in staged scaffolding for digital-literacy prerequisites and in individualised remediation for children at different points along the numeracy trajectory, appears to be a more binding constraint on this pedagogy's effectiveness than device procurement, a finding with direct relevance for how PAUD institutions and policymakers allocate limited resources.

The study's limitations, a single site, a purposively selected cohort, the absence of a comparison group, and single-coder qualitative analysis, mean these conclusions should be read as a set of testable propositions rather than as established findings. The clearest next step for this research programme is a multi-site quasi-experimental replication across a purposive sample of Indonesian PAUD institutions varying systematically in device access, using the observation instrument piloted here alongside a validated computational-thinking assessment such as Relkin et al.'s (2020)

TechCheck, to establish whether the mechanisms proposed here generalise beyond a single kindergarten's particular combination of curricular ingenuity and infrastructural constraint.

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