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Implementing Unplugged Coding and Artificial Intelligence Worksheets to Support Fifth-Graders' Computational Thinking

Rodika Adi Lesmana* & Sungkowo Edy Mulyono
Elementary Education Program, Graduate School, Universitas Negeri Semarang, Indonesia
*Corresponding Author: rodikaadilesmana@students.unnes.ac.id

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Abstract: Computational thinking should be developed through learning experiences that guide students to decompose problems, recognise patterns, select essential information, and construct procedural solutions. This study aimed to describe the implementation of unplugged Coding and Artificial Intelligence worksheets, examine the emergence of four computational thinking indicators, and identify the conditions that supported or constrained implementation. A qualitative case study was conducted with 23 fifth-grade students, one classroom teacher, and the principal of SD Supriyadi Semarang. Data were collected through classroom observations, semi-structured interviews, completed worksheets, and instructional documents. They were analysed through reflexive coding, thematic development, and cross-source verification. The worksheets were implemented through goal-oriented planning, collaborative activities, teacher scaffolding, presentations, reflection, and process-and-product assessment. Decomposition, pattern recognition, abstraction, and algorithmic thinking were evident in classroom interaction and student artefacts, although abstraction required the most sustained support. Teacher readiness, worksheet structure, student engagement, collaboration, and school support strengthened implementation, whereas limited time, unfamiliar concepts, differences in student readiness, and technical preparation constrained it. In conclusion, the unplugged worksheets operated as a structured low-tech resource that made computational processes accessible and observable in regular elementary instruction.

Keywords: artificial intelligence, computational thinking, elementary school, unplugged coding, worksheet.

INTRODUCTION

Computational thinking (CT) has become a foundational capacity for learners who must interpret information, formulate problems, and construct solutions in increasingly data-rich environments. Rather than being reducible to programming proficiency, CT involves a coordinated set of practices through which learners decompose complex situations, detect regularities, abstract relevant information, and articulate executable procedures. Recent reviews have shown that these practices can be developed across elementary subjects when instruction makes the intermediate reasoning between a problem and its solution explicit (Curi et al., 2025). CT can also transfer beyond computing when learners are required to explain, test, and revise the representations and procedures that they construct (Li & Oon, 2024). Accordingly, elementary education needs pedagogies that treat CT as a way of reasoning, not merely as preparation for operating digital tools.

The global expansion of artificial intelligence (AI) has made this pedagogical agenda more urgent. Contemporary AI literacy frameworks extend beyond knowing what an AI system can do; they encompass human-centered judgment, foundational technical understanding, ethical awareness, and responsible participation in AI-mediated societies (UNESCO, 2024). Systematic reviews of K-12 AI education similarly indicate that effective programs combine conceptual knowledge, hands-on inquiry, critical discussion, and reflection on the social consequences of data-driven systems (Casal-Otero et al., 2023). However, classroom implementation remains uneven because learning tasks frequently privilege attractive applications over sustained conceptual explanation, particularly at the elementary level (Lee & Kwon, 2024). Ethical dimensions remain underrepresented, even though children need opportunities to examine data quality, bias, accountability, and the limits of automated prediction (Ma et al., 2025).

Unplugged learning offers a credible response to this challenge by presenting computational ideas through cards, movement, puzzles, sorting tasks, diagrams, role-play, and other non-digital materials. A systematic review and meta-analysis found that well-designed unplugged activities yielded substantial gains in CT, although outcomes varied by age, duration, task design, and instructional support (Chen et al., 2023). A broader review of early-childhood integration similarly concluded that explicit pedagogical sequencing and process-sensitive assessment were more influential than any single programming tool (Su & Yang, 2023). Studies in primary education have further shown that unplugged tasks can make abstract concepts accessible by allowing children to manipulate rules and representations before encountering formal code (Olmo-Mu˜noz et al., 2020). Their educational value, therefore, lies not in the absence of computers themselves, but in the opportunity to externalize reasoning and make it available for dialogue, observation, and revision (Delal & Oner, 2020).

The potential of unplugged learning nevertheless depends on instructional architecture. Research has demonstrated that a worksheet or other material scaffold can stabilize a sequence of inquiry by embedding prompts, representational spaces, and checkpoints, while responsive teacher scaffolding addresses misconceptions and difficulties that cannot be anticipated in advance (Martin et al., 2019). Constructive alignment is equally important because objectives, tasks, and evidence of learning must direct students towards the same cognitive practices rather than functioning as disconnected components (Stamov et al., 2021). Reviews of CT integration have consequently identified teacher knowledge, curricular coherence, usable materials, and sustained professional support as central implementation conditions (Liu et al., 2025). A low-technology design can therefore remain cognitively demanding when it is highly structured and accompanied by adaptive facilitation.

This concern is directly relevant to Indonesia, where Coding and Artificial Intelligence (Koding dan Kecerdasan Artifisial, KKA) have been incorporated into the recent curriculum policy. The national academic framework positions computational thinking, digital literacy, and understanding of responsible AI as interconnected competencies that should be introduced progressively and in context (Kemendikdasmen BSKAP, 2025). The regulatory framework also provides schools with space to organise coding and AI learning in accordance with institutional readiness and learner characteristics (Permendikdasmen Nomor 13 Tahun 2025, 2025). Nevertheless, a policy mandate does not automatically generate classroom-ready pedagogy. Teachers still require materials that translate curricular expectations into age-appropriate activities, prompts, artifacts, and assessment opportunities.

Indonesian studies have begun to demonstrate the relevance of unplugged coding in elementary and early-childhood contexts. Unplugged games have supported problem decomposition, sequencing, and collaborative problem-solving among young learners (Q. Li et al., 2023). Contextual science activities have also enabled fifth-grade students to enact CT without treating computing as a separate subject (Setiawan et al., 2023). More recent studies have reported that culturally grounded unplugged coding can connect CT with environmental awareness, while Bebras-type tasks can embed computational reasoning within mathematics instruction (Carrisi et al., 2025) (Setiawan et al., 2023). Classroom-based evidence has additionally shown that visually engaging and developmentally appropriate unplugged activities can foster sustained participation among elementary learners (Afifah et al., 2025).

Despite this progress, three gaps remain. First, many studies investigate isolated coding tasks rather than a coherent sequence of worksheets that integrate coding and elementary AI concepts. Second, outcome reporting often indicates whether CT changed but provides less detail on how specific indicators emerged in classroom interactions and student artifacts. Third, contextual conditions such as teacher decision-making, time allocation, learner heterogeneity, school support, and technical preparation are not always analyzed as part of the implementation mechanism. Emerging Indonesian evidence from unplugged coding games confirms the need to examine CT as a situated process rather than as a single test score (Fitriyah et al., 2026). International research likewise recommends process-sensitive assessment that captures how children anticipate possibilities, test procedures, and learn from unsuccessful attempts (Kopcha & Ocak, 2023; Relkin et al., 2020).

A preliminary examination of fifth-grade instruction at SD Supriyadi Semarang revealed that conventional worksheets primarily directed students towards final answers, while decomposition, pattern recognition, abstraction, and algorithmic thinking were rarely made explicit. The classroom teacher had participated in KKA professional learning but still needed a practical resource that could be used during regular instruction without making computer availability a prerequisite. This study, therefore, aimed to describe the implementation of unplugged KKA worksheets, analyze the emergence of four CT indicators, and identify the conditions that supported or constrained implementation. Its contribution lies in conceptualizing the worksheet as a low-tech, high-structure pedagogical resource that connected national KKA expectations, material and teacher scaffolding, and observable evidence of fifth-graders' computational reasoning.

METHODS

The study employed a qualitative single-case design to examine the implementation process within its naturally occurring educational context. A case study approach was appropriate because the research questions concerned how the worksheets were enacted, how students' reasoning became visible, and why particular contextual conditions shaped their implementation (Rashid et al., 2019). The case was bounded by one fifth-grade class at SD Supriyadi Semarang during the 2025/2026 academic year. Participants comprised 23 students aged approximately 11-12 years, one classroom teacher who implemented the lessons, and the principal as an institutional informant. Six students were purposively sampled for interviews to represent variation in academic readiness, engagement, and participation during the activities.

Data were collected through non-participant classroom observations, semi-structured interviews, and document analysis. Observations covered planning, enactment, and assessment, recording lesson fidelity, teacher scaffolding, group participation, the four CT indicators, and constraints. The teacher interview explored planning, pedagogical decisions, perceived changes in student reasoning, and program evaluation. Student interviews examined how tasks were approached, which features were experienced as supportive or difficult, and how group collaboration influenced problem solving. The documentary corpus included completed worksheets, the teaching module, the learning-objective sequence, presentation products, observation notes, and photographs of classroom activities. The use of multiple forms of evidence enabled comparisons between participant accounts, observed behavior, and written traces of reasoning.

Table 1. Research focus and principal sources of evidence

Research focus	Principal sources of evidence
Worksheet implementation	Observations of planning, enactment, and assessment; teacher and principal interviews; teaching module and worksheets.
Computational thinking	Group interaction, completed and revised worksheets, presentations, student reflections, and selected interviews.
Contextual conditions	Time and resource records, teacher and principal interviews, student responses, and classroom documentation.

Thematic analysis proceeded iteratively from the start of data collection. Deductive coding was initially organized around the three research foci: implementation, the four CT indicators, and supporting or constraining conditions. Inductive coding was then used to capture unanticipated patterns, including role distribution within groups, adaptation to collaborative learning, reliance on visual representations, and the need to extend particular stages across meetings. Codes were compared, clustered into categories, developed into themes, and reviewed against both confirming and disconfirming evidence. Reflexive thematic analysis was used to maintain an explicit connection between the research questions, interpretive decisions, and the final thematic account (Byrne, 2022).

Credibility was strengthened through method and source triangulation, member checking with the classroom teacher, analytical discussion with the research supervisor, and an audit trail comprising transcripts, field notes,

coding matrices, and analytic memos. The students' identities were anonymized, parental or guardian consent and student assent were obtained, and visual documentation was used only with institutional permission. Because the inquiry was qualitative, the terms developed, emerged, and were facilitated referred to changes in the quality of observed processes and artifacts; they did not denote a statistically estimated or experimentally established causal effect.

FINDINGS AND DISCUSSION

Implementation of the Unplugged KKA Worksheets

The implementation proceeded through interrelated phases of planning, classroom enactment, and assessment. During planning, the teacher mapped the learning objectives onto decomposition, pattern recognition, abstraction, and algorithmic thinking. She selected activities that could be completed without computers, prepared symbolic and manipulative media, organized heterogeneous groups, and reviewed whether the written instructions were compatible with students' reading abilities. The worksheet required students to record the parts of a problem, identify recurring structures, select relevant information, and articulate an ordered procedure. The principal reported that the wider KKA program had been supported through external training, peer dissemination, a professional learning community, and academic supervision. Planning, therefore, involved pedagogical and organizational readiness rather than administrative completion alone.

At the beginning of each lesson, the teacher stated the objectives, formed groups, distributed the worksheets, and clarified the rules of the activity. Students then completed logic games, classified data, interpreted pictures and symbols, simulated rule-based decisions, and constructed procedural sequences. The teacher circulated between groups and used questions such as, "What information do you already have?", "Which part should be solved first?", "Do you need every piece of information?", and "What would happen if these two steps were reversed?" Her assistance did not replace students' reasoning; it provided an entry point when a group stalled, misread an instruction, or selected an answer before examining the problem.

Student engagement was evident in task allocation, comparison of alternatives, written recording, and oral presentation. During the first meetings, several groups relied heavily on the member perceived to be the quickest. More balanced participation emerged after the teacher assigned rotating roles and directed questions to less vocal students. One student explained that dividing a task into smaller components made the problem "feel less difficult", while another reported that colour, pictures, and symbols made the instructions easier to interpret. The teacher described her changing role as follows: "The worksheet helped me guide the children to think step by step. I did not need to explain everything because the directions were already clear. I mainly guided them when they encountered difficulty."

Assessment was conducted during and after the activities. The teacher monitored participation, the reasons offered for decisions, role distribution, the relevance of selected information, and the groups' capacity to revise an ineffective procedure. Products included completed worksheet responses, diagrams and tables, procedural sequences, presentations, and written reflections. When an answer was inaccurate, the teacher first asked the students to locate the point at which their reasoning had diverged before providing further explanation. The worksheet consequently served both as an activity guide and as a record of intermediate reasoning that informed subsequent instructional decisions.

Table 2. Implementation sequence and evidence of enactment

Phase	Observed evidence
Planning	Objectives and CT indicators were mapped; worksheets, media, group roles, instructions, and time allocation were prepared.
Enactment	Contextual problems, simulations, discussion, task allocation, prompting, and presentation were implemented.
Assessment	Discussion processes, worksheet artefacts, oral explanations, procedural revision, and reflection were examined.

The Emergence of Students' Computational Thinking

Decomposition emerged when students ceased treating a problem as an indivisible whole and began separating the available information, the intended outcome, and the work required. During the first meeting, several students wrote an immediate answer without identifying the structure of the task. After the teacher used probing questions and the worksheet provided spaces for known information, the question, and the planned steps, the groups began to formulate sub-problems. Decomposition also became socially visible when members assumed responsibility for reading the rule, marking relevant data, arranging the sequence, and checking the result. Later artefacts contained staged notes rather than isolated answers and showed how the sub-parts contributed to the final solution.

Pattern recognition became visible when students compared cases, grouped symbols with similar properties, and used a previously encountered structure to anticipate a subsequent step. Initially, each item was commonly treated as a new and unrelated problem. Across later activities, students increasingly commented that a task "worked like the previous one" and reused the identified regularity rather than restarting the search process. Patterns were represented through colour groups, simple tables, repeated symbols, and recurring actions. Group discussion was particularly productive because a regularity that one student had overlooked was often made visible by a peer's explanation.

Abstraction was the least evenly demonstrated indicator. Some students successfully highlighted essential data and disregarded contextual details that did not affect the solution, whereas others assumed that every item of information had to be used. Prompts such as "Which data answer the question?" and "Which details only support the story?" helped the groups simplify the problem representation. Pictures, symbols, and diagrams also allowed students to focus on the underlying relationship rather than the full verbal description. Nevertheless, the decision to exclude information frequently required justification and teacher confirmation, indicating that abstraction remained more dependent on guided comparison than the other indicators.

Algorithmic thinking emerged through the construction, testing, and revision of ordered procedures. In the early tasks, several students omitted steps or combined an intended outcome with an action. The teacher asked groups to enact the procedure verbally and predict what would happen if two steps were exchanged. This strategy exposed gaps and contradictions, enabling students to insert a missing instruction, reposition an action, or simplify an inefficient sequence. The final worksheet artefacts showed that many students could formulate a more logical procedure in their own words and revise it after receiving feedback from peers or the teacher.

Table 3. Evidence of the four computational thinking indicators

Indicator	Evidence in process and artefacts
Decomposition	Identifying information and goals, separating sub-problems, and distributing group roles according to task components.
Pattern recognition	Comparing cases, marking similarities, classifying data or symbols, and predicting subsequent actions.
Abstraction	Selecting essential data, excluding irrelevant detail, and simplifying the representation of the problem.
Algorithmic thinking	Constructing, executing, checking, and revising an ordered and logically connected procedure.

Cross-source synthesis showed that the four indicators did not emerge as a fixed linear sequence. In one activity, students first decomposed a problem, noticed a pattern while comparing the parts, selected the necessary information, and then wrote a procedure. In another activity, pattern recognition became the starting point for deciding how to decompose the task. The most convincing evidence of CT occurred when students were required to explain a decision, test a procedure, and revise an unsuccessful attempt, rather than merely submitting a correct answer. The worksheet facilitated CT by making the cognitive space between the problem and the answer explicit, recordable, and discussable.

Supporting and Constraining Conditions

The principal supporting conditions were teacher readiness, the systematic worksheet structure, student enthusiasm, collaborative interaction, and institutional support. The teacher understood the intended CT practices and shifted from direct explanation to questions that varied according to the group's needs. The worksheet reduced uncertainty by providing a recognisable activity sequence, while its games, symbols, and progressively demanding challenges sustained curiosity. Students showed persistence when their first attempt failed and increasingly consulted one another before requesting a solution from the teacher. School-level support included professional learning, peer discussion, academic supervision, printing facilities, and permission to rearrange the classroom for group work.

Limited instructional time was the most persistent constraint. Productive discussion frequently exceeded the planned duration because students compared alternatives and negotiated before reaching agreement. As a result, not every group could present and reflect during the same meeting. The teacher responded by prioritising tasks that most directly represented the intended CT indicator, using visible time limits, selecting representative groups for extended presentation, and returning to unfinished reflection at the beginning of the following lesson. These adjustments preserved the reasoning process but required flexibility in pacing.

Other constraints involved the novelty of KKA concepts, variation in student readiness, adaptation to learner-centred instruction, and technical preparation. Terms such as data, rule, algorithm, prediction, and bias were not immediately meaningful to all students. The teacher therefore used familiar analogies, concrete examples, repeated instructions, heterogeneous grouping, and graduated prompts. A small number of students initially waited for a more confident peer to decide, which made explicit group roles necessary. Although the learning was unplugged, it still required sufficient copies, organised sets of manipulatives, flexible seating, and prior testing of the instructions. The absence of computers reduced dependence on infrastructure, but it did not eliminate the need for careful logistical preparation.

Table 4. Contextual conditions and pedagogical responses

Condition	Manifestation and response
Supporting conditions	Teacher readiness, structured worksheets, engagement, collaboration, principal support, and basic learning resources.
Limited time	Discussion and presentation exceeded the allocation; core tasks were prioritised and reflection was continued later.
Unfamiliar concepts	KKA terminology was difficult; the teacher used analogies, concrete examples, visual representations, and repetition.
Learner heterogeneity	Different levels of independence required heterogeneous grouping, differentiated prompts, and rotating roles.
Technical preparation	Printing, media organisation, seating, and instruction testing were completed before each activity.

Discussion

The findings indicated that the worksheet was most productive when material scaffolding and teacher scaffolding functioned as complementary systems. The embedded sequence, prompts, and representational spaces allowed students to begin a task independently, whereas the teacher intervened when an instruction was misunderstood or a group reached an unproductive strategy. This relationship is consistent with evidence that distributed scaffolds are effective only when the support embedded in materials and the support offered by the teacher remain pedagogically aligned (Martin et al., 2019). The result also explains why a worksheet should not be treated as a self-sufficient substitute for teaching. Its value lies in structuring opportunities for reasoning while preserving the teacher's capacity to diagnose and respond to emerging needs.

The low-tech format did not reduce the intellectual demand of the learning. Instead, physical and visual representations externalised rules, choices, and sequences so that students could manipulate and critique them. This interpretation aligns with meta-analytic evidence indicating that unplugged activities can foster CT when tasks require active problem representation

rather than passive entertainment (Chen et al., 2023). It also supports research showing that unplugged learning is particularly useful when abstract computational relationships are enacted through concrete actions and then reconstructed symbolically (del Olmo-Munoz et al., 2020). The present study extends this evidence by showing how a structured worksheet preserved the trace of that reconstruction for subsequent discussion and assessment.

Students' visible enthusiasm was educationally meaningful because it was accompanied by repeated attempts, peer explanation, and revision. Engagement alone cannot be taken as evidence of CT; an enjoyable game may produce participation without requiring students to represent a problem or justify a procedure. In this case, engagement became substantive when the worksheet required students to record how they had divided a problem, why they had selected particular data, and whether an ordered sequence actually worked. Recent elementary research similarly suggests that unplugged activities are most effective when playful participation is coupled with explicit cognitive goals and opportunities for explanation (Afifah et al., 2025). Indonesian multiple-case evidence also shows that CT emerges from the interaction among task structure, peer dialogue, and teacher prompting rather than from playfulness alone (Fitriyah et al., 2026).

The stronger visibility of decomposition and algorithmic thinking, compared with abstraction, is theoretically plausible. Decomposition and sequencing can be externalised through lists, roles, and ordered cards, whereas abstraction requires learners to justify why certain information may be excluded. Assessments of young learners' CT have likewise found that observable procedural performance does not necessarily imply equal mastery of representational judgment (Relkin et al., 2020). Process-oriented accounts further emphasise that CT develops through cycles of anticipating, acting, and reconsidering possibilities, rather than through the accumulation of four isolated skills (Fitriyah et al., 2026). The present findings, therefore, caution against assuming that successful completion of a coding-like sequence demonstrates abstraction unless students can explain which details were essential and why.

The use of collaborative reasoning also helped transform CT from an internal and potentially invisible process into a shared object of inquiry. Students had to articulate the function of a step, compare representations, and negotiate which information should be retained. Similar research has found that unplugged programming can support CT when interaction requires learners to explain and coordinate procedures rather than merely divide labor (Delal & Oner, 2020). Reflective activities can deepen this process by prompting students to examine why an initial strategy failed and how a revised solution differs from it (Ugur & Cakiroglu, 2024). The worksheet reflections in this study were most informative when they addressed a specific decision or revision, rather than asking students only whether the activity was enjoyable.

Unplugged and plugged learning should therefore be understood as complementary rather than competing approaches. Unplugged tasks can establish conceptual and representational foundations, particularly where access to devices is uneven or where learners are new to computational ideas. Digital environments can subsequently provide automated execution, rapid feedback, and access to more complex systems. Research combining unplugged and plugged activities has shown that the sequence of modes matters, as conceptual preparation can improve learners' interpretation of later digital tasks (Fis Erumit, 2024). Mixed-mode AI education has also produced gains in elementary learners' conceptual understanding and confidence when physical and digital experiences were intentionally connected (Ruan et al., 2025).

Integrating elementary AI concepts added an important dimension to the CT activities. AI literacy involves recognizing that systems learn from data, that predictions depend on the quality and representativeness of those data, and that automated outputs require human judgment (Ng et al., 2021). K-12 reviews have shown that meaningful AI education combines conceptual, practical, and ethical learning outcomes rather than presenting AI as an autonomous or infallible technology (Su et al., 2022; Lee & Kwon, 2024). In the present case, unplugged classification and prediction tasks offered an accessible entry point for discussing why two groups might obtain different results from different data. Such discussion helped position CT within responsible decision-making rather than as value-neutral procedural efficiency..

This ethical orientation is particularly important because elementary AI education can otherwise reproduce simplistic assumptions that

more data or more automation always produce a better answer. Responsible AI literacy requires learners to question bias, accountability, and the human consequences of model outputs (Ma et al., 2025). UNESCO's student competency framework similarly places human-centered judgment and ethics alongside AI techniques and system design (UNESCO, 2024). Long and Magerko's competency model further emphasizes the ability to critically evaluate AI, communicate about its strengths and limitations, and recognize the role of data in system behavior (Long & Magerko, 2020). The unplugged worksheet made these ideas developmentally approachable by representing data choices and rule-based decisions through familiar classroom materials.

The study also demonstrated that visual attractiveness was most valuable when it carried cognitive information. Colors, symbols, and diagrams reduced the verbal burden of the tasks, but they were not merely decorative. They indicated categories, represented relationships, and allowed students to compare procedures. Reviews of K-12 instructional design have found that coherent representations, explicit learning goals, and structured opportunities for inquiry are more consequential than the novelty of a particular technology (Halawa et al., 2024). Large-scale analysis of K-12 AI classroom materials similarly suggests that pedagogical quality depends on how tools are embedded within theories of learning and literacy, rather than on the presence of AI-branded applications alone (Wu et al., 2024).

The contextual constraints were not peripheral implementation problems; they influenced which forms of CT could become visible. Limited time reduced opportunities for presentation and revision, while learner heterogeneity altered the amount and type of scaffolding required. The national KKA framework provides an important policy direction, but its classroom realisation depends on resources that teachers can interpret and adapt (BSKAP, 2025). A systematic review of teacher support for CT integration has likewise found that one-off training is insufficient without curricular exemplars, collaborative planning, and sustained opportunities to examine student work (Liu et al., 2024). The school's professional learning community and supervision arrangements, therefore, constituted part of the instructional mechanism rather than merely an administrative backdrop.

The Indonesian findings also resonate with culturally and disciplinarily embedded approaches to CT. Science-based unplugged tasks have shown that elementary students can engage in decomposition and algorithmic reasoning when investigating familiar phenomena (Setiawan et al., 2023). Culturally situated coding activities have further demonstrated that computational reasoning can be connected to environmental and communal values rather than presented as an imported technical routine (Rati et al., 2025). Bebras-inspired tasks have provided another viable pathway by integrating logical and algorithmic challenges into mathematics lessons (Rahma et al., 2025). These studies collectively support the present argument that KKA worksheets should be adaptable across subject matter while retaining explicit CT indicators and evidence requirements.

A central contribution of the study is the low-tech, high-structure mechanism it revealed. The worksheets reduced dependence on devices but increased the visibility of reasoning by requiring students to externalise intermediate decisions. This mechanism addresses the distinction between access and instructional quality: removing technological barriers is valuable, but learning improves only when the sequence of activities, prompts, facilitation, and assessment remains coherent. The broader intervention literature has similarly concluded that upper-elementary CT outcomes vary substantially by pedagogical configuration rather than by tool type alone (Curi et al., 2025). Comparative work with young children also indicates that unplugged and robotic programming can support distinct yet related dimensions of CT and executive functioning, reinforcing the need to select a mode aligned with the intended cognitive process (Zhang et al., 2025).

The worksheet design also offers a practical bridge between curriculum policy and classroom assessment. Indonesia's recent regulation permits schools to introduce KKA in ways that reflect readiness and context, but teachers still need evidence that students are doing more than completing an attractive activity (Permendikdasmen No. 13/2025). By aligning prompts and artifacts with decomposition, pattern recognition, abstraction, and algorithmic thinking, the worksheet generated assessable traces of students' reasoning. This approach is compatible with research showing that elementary AI and CT

courses can be inclusive when objectives, pedagogical sequences, and assessment instruments are validated and mutually aligned (Cheng et al., 2025).

The study was bounded by a single class, a single implementing teacher, and a relatively short period of instruction. Its findings therefore provide an analytically transferable account of mechanisms and conditions rather than statistical generalisation. The evidence also did not include a standardised pre-test and post-test, so the study cannot establish the magnitude of improvement or compare the worksheets with a digital or conventional condition. Future research should examine the approach across schools with different resource profiles, use delayed performance tasks, and investigate whether students transfer the four CT practices to other subjects. A sequential design could also compare an unplugged foundation with subsequent plugged activities, especially for AI concepts that benefit from observing how data and rules affect system output.

CONCLUSION

The study showed that unplugged Coding and Artificial Intelligence worksheets could be implemented as a structured pedagogical resource in a regular fifth-grade classroom. Planning aligned the tasks with four computational thinking indicators: classroom enactment combined with collaborative problem-solving, visual and manipulative representations, responsive teacher scaffolding, and presentation and reflection; and assessment examined both products and intermediate reasoning. Decomposition, pattern recognition, abstraction, and algorithmic thinking were evident across classroom interaction and student artifacts, although abstraction remained the least independent and required the most sustained prompting. Implementation was strengthened by teacher readiness, coherent worksheet design, student engagement, collaboration, and school support, but was constrained by limited time, unfamiliar terminology, heterogeneous readiness, and logistical preparation. The principal implication is that unplugged learning becomes educationally powerful not merely because it removes computers, but because a low-tech format can be designed with sufficiently high structure to make reasoning visible, revisable, and assessable. Wider implementation should therefore be accompanied by professional learning, adaptable materials, and assessment practices that value students' explanations and revisions as much as their final answers.

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