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The Effectiveness Of *Unplugged Coding And Artificial Intelligence (Kka) Learning* In Improving The Computational Thinking Ability Of Primary School Students

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Abstract

The Indonesian Ministry of Education has formally introduced Coding and Artificial Intelligence (Koding dan Kecerdasan Artifisial, KKA) as a learning content area for primary and secondary education, yet many primary schools remain constrained by limited digital infrastructure and low teacher technological readiness. This study evaluates the effectiveness of an unplugged-based KKA instructional model in improving the computational thinking ability of fifth-grade primary school students. The model integrates two phases, namely unplugged coding activities that build conceptual foundations through concrete manipulation and an artificial intelligence phase combining age-appropriate AI literacy with AI-assisted tutoring support. A quasi-experimental design using a non-equivalent pretest-posttest control group was applied to 64 students from two state primary schools in Bojonegoro Regency, divided into an experimental group (n = 32) receiving the KKA model and a control group (n = 32) receiving conventional expository instruction. Computational thinking was measured through a validated Bebras-based test covering decomposition, pattern recognition, abstraction, and algorithmic thinking. Data were analysed using normality and homogeneity tests, an independent sample t-test, the normalised gain score, and Cohen's effect size. The experimental group achieved a mean posttest score of 82.19 against 68.44 in the control group, with a normalised gain of 0.66 (moderate-to-high) compared to 0.35 (moderate). The t-test confirmed a statistically significant difference ($t = 6.473$; $p < 0.001$), and the effect size of $d = 1.62$ indicated a large practical impact. The KKA model proved most influential on algorithmic thinking and decomposition while also strengthening engagement and collaborative problem solving. The study contributes a structured, low-cost, and policy-aligned

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instructional model that addresses the equity gap in computational thinking education for resource-limited primary schools.

Keywords: unplugged coding; artificial intelligence; computational thinking; primary education; quasi-experiment

INTRODUCTION

The transformation of twenty-first century education places computational thinking as one of the core competencies that must be mastered from the primary education level onward. Wing (2006) introduced the term computational thinking as a way of formulating problems and devising solutions so that they can be carried out by a human or a machine, a notion later expanded into a fundamental literacy comparable to reading, writing, and arithmetic. Shute, Sun, and Asbell-Clarke (2017) emphasise that computational thinking is not merely a technical programming skill but a cognitive construct that underpins problem solving across disciplines. The recent work of Montuori, Gambarota, Altoè, and Arfè (2024), through a systematic meta-analysis, demonstrates that computational thinking interventions produce consistent cognitive effects on students' transfer skills, so that its relevance to primary education can no longer be postponed.

This need is now reinforced by the presence of artificial intelligence, which is reshaping the landscape of work and life in fundamental ways. Yeter, Tan, and Le (2024) explain that introducing artificial intelligence literacy from the primary level serves as a scaffold to stimulate critical thinking while preparing children for an increasingly technology-integrated world. Lin, Dai, and Ng (2025) add that artificial intelligence education for children is most effective when grounded in constructionist pedagogy that emphasises the direct creation of artefacts. Memari (2025), through a systematic review, finds that computational thinking and artificial intelligence literacy are two intertwined competencies, so that ideally the learning of both should be designed in an integrated manner from primary school.

Indonesia responds to this dual demand through the national policy on Coding and Artificial Intelligence learning, abbreviated as KKA. The Education Standards, Curriculum, and Assessment Agency (2025) issued the Academic Manuscript on Coding and Artificial Intelligence Learning for Primary and Secondary Education, which serves as the official basis for integrating this content into the curriculum. Suharyo and colleagues (2024) explain that the coding and artificial intelligence policy within the context of the Merdeka Curriculum is positioned as part of efforts to build skills toward the vision of a Golden Indonesia 2045. However, Fitri and

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Iswatiningsih (2025) find that the implementation of artificial intelligence learning in primary schools still faces real opportunities and challenges for teachers, particularly regarding competency readiness and the availability of concrete learning models.

The gap between the acceleration of policy and the readiness of schools constitutes a genuine phenomenon that urgently needs to be addressed. Nur Marifah, Abdul Mu'ti, and Rijal Wahid (2022), through a systematic literature review, found that the integration of computational thinking in Indonesian primary schools remains hindered by limited teacher understanding and a scarcity of contextual learning tools. Han, Kim, and Lee (2024) assert that the greatest barrier to teaching computer science in primary schools lies not in the curriculum but in the availability of resources and teacher capacity. In many Indonesian primary schools, the lack of computer laboratories, unstable internet connectivity, and a low device-to-student ratio make screen-based coding and artificial intelligence learning difficult to implement equitably, so that the KKA policy risks widening the educational equity gap if it is not accompanied by an inclusive approach (Suttrisno, et al 2025.

Teaching coding and artificial intelligence at the primary level faces a twofold challenge. The first challenge stems from the cognitive developmental characteristics of children. Primary school students aged seven to twelve are at the concrete operational stage, so abstract concepts such as loops, branching, and the idea of how a machine learns are difficult to grasp without the mediation of concrete objects. The second challenge stems from the structural aspect of device limitations. Sigayret, Tricot, and Blanc (2022), through a comparative experimental study, found that screen-based coding instruction for novice learners actually increases extraneous cognitive load because students must manage a technological interface and computational concepts simultaneously. del Olmo-Muñoz, Cózar-Gutiérrez, and González-Calero (2020) show that introducing computational concepts through non-digital media is better aligned with the learning readiness of primary-age children.

The unplugged coding approach emerges as an answer to this challenge. Bell, Witten, and Fellows, widely cited in the literature, introduced Computer Science Unplugged as a series of learning activities that teach computer science concepts through games, cards, and the manipulation of physical objects without using a computer. Mladenović, Krpan, Dragičević, and Zaharija (2026) assert that the unplugged approach allows students to touch the essence of computational thinking through concrete interaction suited to their developmental stage. Huang and Looi (2021), through a systematic review, found that unplugged activities effectively lower students' affective barriers toward computer science while building a robust conceptual

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foundation. Hu and Wang (2024) add that unplugged activities in primary classrooms not only improve computational thinking but also enhance students' creativity simultaneously.

Recent developments show that artificial intelligence can serve as a learning partner that strengthens students' cognitive achievement. Seung, Cukurova, and Lee (2025), through a scoping review, found that chatbots and intelligent tutoring systems are the most frequently used forms of artificial intelligence in primary and secondary education because of their capacity to provide immediate feedback. Wang and colleagues (2025) explain that artificial intelligence based tutoring systems contribute to improvements in students' problem-solving and logical-reasoning skills through adaptive feedback. However, Lin, Dai, and Ng (2025) caution that the use of artificial intelligence with children demands a clear pedagogical framework so as not to foster dependency and to keep students positioned as active constructors of knowledge.

Although evidence on the effectiveness of unplugged coding and the use of artificial intelligence has been documented separately, the integration of both within a single coherent learning model still leaves theoretical debate unresolved. Relkin, de Ruiter, and Bers (2021) argue that without connection to authentic practice, unplugged activities risk remaining at the level of play and failing to transfer computational thinking skills. Fagerlund, Häkkinen, Vesisenaho, and Viiri (2021) add that the effectiveness of the unplugged approach depends heavily on the didactic quality of the activities, not merely on the absence of a computer. Wang, Luo, Liu, and Yang (2023), through a meta-analysis of 49 studies, found a large effect size for unplugged activities, yet with high heterogeneity arising from the diversity of designs. This debate shows that the research question has shifted from whether unplugged is effective toward how to design unplugged instruction that is structured and connected to intelligent technology.

The current state of the art reveals two streams that have not yet converged. The first stream focuses on unplugged coding for computational thinking, as conducted by Hu and Wang (2024) and Yılmaz and İzmirli (2023), who compared the unplugged approach with the plugged one. The second stream focuses on artificial intelligence literacy and its use in schools, as reviewed by Seung, Cukurova, and Lee (2025) and Lin, Dai, and Ng (2025). Erümit (2024) notes that most unplugged studies still use one-group designs without a control class, so that their causal claims are weak. Meanwhile, studies that deliberately combine unplugged coding with artificial intelligence in the context of Indonesian primary schools with genuine resource constraints remain very scarce and generally stop at the descriptive or community-service level.

The identified research gap can be formulated in three layers. The first is an integrative gap, namely the absence of a learning model that combines unplugged coding and artificial

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intelligence within a single coherent framework. The second is a methodological gap, namely the scarcity of control-group quasi-experimental studies testing KKA content with Indonesian primary school students. The third is a contextual gap, namely the scarcity of KKA models designed specifically for schools with limited digital infrastructure. These three layers underscore the urgency of developing and testing a learning model that is at once integrative, structured, contextual, and empirically tested.

This study offers novelty through the development and testing of the Unplugged Coding and Artificial Intelligence learning model. The KKA model is designed as a two-phase form of learning in which the phases mutually reinforce each other. The first phase is unplugged coding based on movement, instruction cards, and role play that concretises the concepts of instruction, looping, branching, and the idea of an algorithm. The second phase is artificial intelligence, which introduces the basic concept of how a machine learns through concrete activities while also using an artificial-intelligence-assisted tutor as a provider of feedback on students' reasoning. The KKA syntax follows the flow of problem decomposition, unplugged algorithm construction, simulation, artificial intelligence introduction, and artificial-intelligence-assisted reflection, so that activities do not stop at play but lead to a measurable mastery of computational thinking skills aligned with national policy.

Based on this discussion, this study aims to test the effectiveness of the KKA learning model in improving the computational thinking ability of primary school students and to analyse which computational thinking indicators are most affected by the implementation of the model. Theoretically, this study enriches the body of computational thinking pedagogy by offering a framework that combines unplugged learning and artificial intelligence grounded in constructivist and constructionist learning theory. Practically, this study provides a model that can be adopted by primary schools with limited resources, thereby contributing to the equalisation of the quality of KKA education. The hypothesis proposed states that there is a significant difference in computational thinking ability between students who learn with the KKA model and students who learn with conventional instruction.

RESEARCH METHOD

Approach and Research Design

This study employed a quantitative approach with a quasi-experimental method. The choice of the quasi-experimental method was based on the consideration that the grouping of students in primary schools has been naturally formed within intact classes, so that full

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randomisation of individuals was not feasible without disrupting the learning ecosystem. Creswell and Creswell (2018) explain that a quasi-experiment is an appropriate choice when researchers use already-formed groups and still wish to draw defensible causal conclusions. The specific design used was a non-equivalent pretest-posttest control group design, which allowed the researchers to compare changes in computational thinking ability between the experimental and control groups while controlling for threats to internal validity through an initial measurement.

The experimental group received treatment in the form of learning with the Unplugged Coding and Artificial Intelligence model, while the control group received conventional expository instruction commonly used by teachers. Both groups received material with equivalent scope, time allocation, and basic competencies in order to ensure fair comparison. The difference lay only in the learning strategy and media, so that the difference in achievement could be attributed to the treatment.

Participants and Research Site

The research participants were 64 fifth-grade students from two state primary schools in Bojonegoro Regency, East Java, selected through a purposive sampling technique. The criteria for selecting schools included equivalence of accreditation, comparable student socio-economic profiles, and the digital-infrastructure limitations relevant to the research context. The experimental group consisted of 32 students and the control group consisted of 32 students. The equivalence of the two groups' initial ability was verified through a difference test of pretest scores before the treatment was administered, and the results showed no significant difference, so that the two groups were comparable.

KKA Learning Model Syntax

The KKA learning model was implemented through five stages that combine the unplugged coding phase and the artificial intelligence phase. The first stage is problem orientation and decomposition, in which students break a contextual problem into simpler sub-tasks. The second stage is unplugged algorithm construction using instruction cards and body movement. The third stage is algorithm simulation and testing to identify step errors. The fourth stage is the introduction of artificial intelligence, in which students understand the basic concept of how a machine recognises patterns through concrete activities. The fifth stage is artificial-intelligence-assisted reflection, in which students use a teacher-guided artificial-intelligence-based tutor to obtain feedback on their reasoning. A summary of the syntax is presented in Table 1.

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Table 1. Syntax of the KKA Learning Model

Stage	Phase	Learning Activity
1	Unplugged Coding	Contextual problem orientation and decomposition of the problem into sub-tasks
2	Unplugged Coding	Algorithm construction using instruction cards and body movement
3	Unplugged Coding	Algorithm simulation and testing to identify step errors
4	Artificial Intelligence	Introduction to the basic concept of how a machine recognises patterns, presented concretely
5	Artificial Intelligence	Teacher-guided reflection and revision assisted by an artificial intelligence tutor

Source: Constructed by the researchers, 2026.

Instrument, Validity, and Reliability

The main research instrument was a Computational Thinking Ability Test developed based on the Bebras task model and the computational thinking indicator framework. The test consisted of 20 items representing four indicators, namely decomposition, pattern recognition, abstraction, and algorithmic thinking. Each indicator was measured through five contextual items adapted to the everyday world of primary school students so as not to impose an excessive linguistic burden. In addition to the test, the study used a student engagement observation sheet to record aspects of participation, collaboration, and persistence during the learning process.

The content validity of the instrument was tested through the judgement of three experts consisting of a primary education lecturer, an educational informatics lecturer, and a certified practising teacher. The results of the expert judgement were analysed using Aiken's V formula, and all items obtained a V value above 0.80, so that they were declared content-valid. Empirical validity was obtained through a limited trial with 30 students at another equivalent school, with an item-total correlation analysis showing that all items were valid at the 0.05 significance level. The reliability of the instrument was tested using Cronbach's Alpha coefficient and yielded a value of 0.88, which is categorised as high reliability, so that the instrument was suitable for measurement.

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Procedure and Data Analysis Technique

The study was conducted over eight meetings, consisting of one pretest meeting, six treatment meetings, and one posttest meeting. In the experimental group, each treatment meeting followed the five-stage KKA model syntax. In the control group, learning was conducted through lecturing, the provision of examples, and individual assignments. Quantitative data were collected through the pretest and posttest, while engagement data were collected through observation at each treatment meeting by two observers to maintain consistency of assessment.

Data analysis was carried out through several stages. The first stage was descriptive statistical analysis to obtain a picture of the mean, standard deviation, and score distribution. The second stage was the assumption tests, which included the Shapiro-Wilk normality test and Levene's homogeneity test. The third stage was hypothesis testing with an independent sample t-test to compare the posttest scores of the two groups. The fourth stage was the calculation of the normalised gain score or N-Gain to measure the magnitude of the improvement. The fifth stage was the calculation of the effect size using Cohen's d to assess the practical magnitude of the treatment's impact. All tests were conducted at the 0.05 significance level with the aid of statistical software.

RESULTS

Description of Computational Thinking Achievement

The descriptive statistical analysis showed a clear difference in achievement between the experimental and control groups. Before the treatment, the mean pretest scores of the two groups were relatively equivalent, namely 48.13 in the experimental group and 48.75 in the control group, which confirmed the equivalence of initial ability. After the treatment, the mean posttest score of the experimental group rose sharply to 82.19, while the control group reached only 68.44. The difference of 13.75 points in final achievement indicates that the KKA model treatment made a real contribution to improving students' computational thinking ability. A summary of the descriptive statistics is presented in Table 2.

Table 2. Descriptive Statistics of Computational Thinking Scores

Group	N	Pretest Mean	Posttest Mean	SD Pre	SD Post
Experimental (KKA)	32	48.13	82.19	9.04	6.98
Control	32	48.75	68.44	8.86	8.52

Source: Research data processing results, 2026.

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The indicator-level analysis revealed an uneven pattern of improvement. The algorithmic thinking and decomposition indicators experienced the largest improvement in the experimental group, while the abstraction indicator showed a more moderate improvement. This pattern indicates that the activities of unplugged algorithm construction and artificial-intelligence-assisted reflection provided the most intensive practice in the ability to arrange steps and break down problems. The details of the achievement per indicator are presented in Table 3.

Table 3. Posttest Achievement and N-Gain per Indicator in the Experimental Group

Indicator	Pretest	Posttest	N-Gain	Category
Decomposition	49.38	84.38	0.69	Moderate
Pattern Recognition	48.75	82.50	0.66	Moderate
Abstraction	46.88	78.13	0.59	Moderate
Algorithmic Thinking	47.50	85.63	0.73	High

Source: Research data processing results, 2026.

Results of the Assumption Tests

Before hypothesis testing, normality and homogeneity tests were conducted as prerequisites for parametric statistics. The Shapiro-Wilk normality test showed that all pretest and posttest data in both groups had a significance value above 0.05, so that the data were declared to be normally distributed. Levene's homogeneity test yielded a significance value of 0.187 for the posttest data, meaning that the variances of the two groups were homogeneous. The fulfilment of both prerequisites ensured that the independent sample t-test could be applied validly. A summary of the assumption tests is presented in Table 4.

Table 4. Results of the Normality and Homogeneity Tests

Type of Test	Data	Sig. Value	Decision
Normality (Shapiro-Wilk)	Posttest Experimental	0.153	Normal
Normality (Shapiro-Wilk)	Posttest Control	0.219	Normal
Homogeneity (Levene)	Combined Posttest	0.187	Homogeneous

Source: Research data processing results, 2026.

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Results of Hypothesis Testing and Effect Size

Hypothesis testing was conducted with an independent sample t-test on the posttest scores of the two groups. The test results showed a calculated t value of 6.473 with a significance value of less than 0.001. This significance value, well below 0.05, confirms that there is a significant difference in computational thinking ability between students who learned with the KKA model and students who learned with conventional instruction, so that the research hypothesis is accepted. The N-Gain calculation reinforced this finding, with the experimental group obtaining a normalised gain of 0.66, categorised as moderate-to-high, while the control group obtained only 0.35, categorised as moderate.

To assess the practical magnitude of the treatment's impact, the effect size was calculated using Cohen's d. The calculation yielded a d value of 1.62, which according to conventional categories is classified as a large impact. This effect size value shows that the superiority of the KKA model is not only statistically significant but also practically meaningful in the context of real classroom learning. A summary of the hypothesis test and effect size results is presented in Table 5.

Table 5. Results of the t-test, N-Gain, and Effect Size

Parameter	t value	Sig. (p)	N-Gain	Cohen's d
Posttest Experimental vs Control	6.473	< 0.001	0.66 / 0.35	1.62

Source: Research data processing results, 2026.

The results of the student engagement observation over the six treatment meetings showed an upward trend in participation in the experimental group. The mean engagement score rose from 2.9 at the first meeting to 3.8 at the sixth meeting on a four-point scale. The most visible improvement was in the aspect of collaboration, when students actively discussed the arrangement of algorithms and interpreted the feedback from the artificial intelligence tutor. Narratively, the graph of engagement development formed a consistent upward pattern, in line with the improvement in cognitive achievement. Together, these quantitative and observational findings indicate that the KKA model affects both the cognitive and the affective dimensions of computational thinking learning.

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DISCUSSION

The main finding of this study confirms that the Unplugged Coding and Artificial Intelligence model effectively improves the computational thinking ability of primary school students significantly. The superiority of the experimental group with an effect size of 1.62 places the KKA model in the large-impact category that is rarely achieved by educational interventions in general. Wang, Luo, Liu, and Yang (2023), through a meta-analysis of dozens of unplugged studies, reported an aggregate effect size of Hedges's g of 1.028, so that the achievement of this study lies at the upper range of the distribution of effectiveness reported to date. Montuori, Gambarota, Altoè, and Arfè (2024) explain that structured computational thinking interventions do tend to produce strong cognitive effects, and the integration of the two phases in the KKA syntax appears to be the primary explanatory factor for the magnitude of the effect found in this study.

The effectiveness of the KKA model can be explained through the framework of constructivist and constructionist learning theory. KKA learning positions students as active constructors of knowledge who manipulate instruction cards and interpret artificial intelligence feedback to build an understanding of computational concepts. Mladenović, Krpan, Dragičević, and Zaharija (2026) assert that the unplugged approach rests on constructivist principles because it allows students to touch the essence of a concept through concrete interaction. Lin, Dai, and Ng (2025) add that artificial intelligence education for children is most effective when grounded in constructionist pedagogy that emphasises the creation of artefacts. del Olmo-Muñoz, Cózar-Gutiérrez, and González-Calero (2020) reinforce this explanation with their finding that non-digital activities are highly suited to the concrete operational stage of primary school children.

The indicator-level analysis provides sharper insight into the working mechanism of the KKA model. The algorithmic thinking indicator obtained the highest N-Gain of 0.73, followed by decomposition at 0.69. This pattern is logical because the core of the unplugged phase of KKA is to arrange, run, and revise algorithm sequences. Fagerlund, Häkkinen, Vesisenaho, and Viiri (2021) explain that repeatedly practising the arrangement of instruction sequences is the most direct path toward mastering algorithmic thinking. Erümit (2024) found a similar pattern that programming activities involving the arrangement of concrete steps provide the greatest impact on students' algorithmic and decomposition abilities. Sun, Hu, and Zhou (2021) add that unplugged activities requiring students to break problems into sub-tasks explicitly train decomposition as a transferable skill.

The abstraction indicator obtained a more moderate improvement with an N-Gain of 0.59, and this finding is worth examining critically. Abstraction is the most complex computational

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thinking skill because it requires students to generalise patterns and discard irrelevant detail. Shute, Sun, and Asbell-Clarke (2017) place abstraction as a peak skill requiring greater cognitive maturity. Wang and Kale (2025) report that abstraction does consistently become the most slowly developing indicator across various computational thinking interventions. The implication is that the artificial intelligence phase in the KKA model needs to be enriched with activities that specifically train pattern generalisation, for example through the exploration of how simple classification works in subsequent development.

The superiority of the experimental group over the control group can also be explained through cognitive load theory. Conventional instruction in the control group required students to understand computational concepts verbally and abstractly without concrete mediation, so that intrinsic cognitive load was not well managed. Sigayret, Tricot, and Blanc (2022) demonstrated that screen-based coding instruction for novice learners actually increases extraneous cognitive load due to the management of the technological interface. The unplugged phase in the KKA model lowers this load by providing a visual representation in the form of cards that externalise the thinking process. Hu and Wang (2024) assert that manipulative media in unplugged activities serve as a cognitive scaffold that frees students' working-memory capacity to focus on computational reasoning.

The role of artificial intelligence as a learning partner in the second phase of the KKA model makes its own contribution to students' achievement. The teacher-guided artificial-intelligence-based tutor enabled students to obtain feedback on their reasoning more responsively than in conventional instruction. Wang and colleagues (2025) explain that intelligent tutoring systems contribute to improving problem-solving skills because they provide adaptive feedback that encourages students to correct errors independently. Seung, Cukurova, and Lee (2025) found that chatbots and intelligent tutors are the most effective forms of artificial intelligence in supporting learning because of their capacity to interact directly. This explanation reinforces the argument that the integration of unplugged and artificial intelligence in the KKA model is not merely a combination of two activities but a mutually reinforcing synergy.

The dimension of student engagement is a supporting finding that enriches the understanding of the KKA model's effectiveness. The increase in the engagement score from 2.9 to 3.8 over six meetings shows that this model has not only a cognitive but also an affective impact. Hu and Wang (2024) explain that unplugged activities based on object manipulation consistently increase engagement because they involve a play dimension suited to the world of children. Yeter, Tan, and Le (2024) found that introducing artificial intelligence through age-appropriate activities

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increases students' curiosity and enthusiasm. Relkin, de Ruiter, and Bers (2021) add that affective engagement is an important prerequisite for the successful transfer of computational thinking skills. The high engagement in this study shows that the KKA model succeeded in changing students' perception of coding and artificial intelligence into an enjoyable and accessible activity.

The problem-solving aspect received particular reinforcement through the syntax of the KKA model. The problem decomposition stage in the KKA syntax explicitly trains students to break a complex problem into simpler sub-tasks before devising a solution. Han, Kim, and Lee (2024) explain that the ability to break down problems is the most transferable foundation of computational thinking to real-life contexts. Wang, Luo, Liu, and Yang (2023) report that unplugged interventions that structure decomposition as an explicit stage produce a greater impact than interventions that allow decomposition to occur implicitly. Fagerlund, Häkkinen, Vesisenaho, and Viiri (2021) add that problem-solving skills develop optimally when students are given repeated opportunities to design, run, and evaluate their own solutions, which is precisely the core of the simulation and reflection stages in the KKA model.

The dimension of collaborative learning is another strength that emerged from the implementation of the KKA model. The observation showed that the collaboration aspect experienced the most visible improvement, when students actively discussed the arrangement of algorithms and interpreted the artificial intelligence tutor's feedback together. Huang and Looi (2021) explain that unplugged activities naturally encourage social interaction because completing the task requires negotiation and coordination among group members. Sun, Hu, and Zhou (2021) found that computational learning in a collaborative setting produces higher computational thinking achievement because students externalise their reasoning to one another. Yılmaz and İzmirli (2023) add that group discussion in coding activities allows students to access a diversity of problem-solving strategies, thereby enriching their repertoire of thinking.

The aspects of logical thinking and creativity were also affected by the implementation of the KKA model. The unplugged construction of algorithms required students to think sequentially, consider cause and effect, and anticipate the consequence of each instruction, while the artificial intelligence phase opened space for exploring alternative solutions. Günaltay, Balcı, and Orhan Özen (2025), through a meta-analysis, found that computational thinking interventions provide a positive impact on students' creativity. Hu and Wang (2024) demonstrated that unplugged activities in primary classrooms improve creativity simultaneously with computational thinking. Aytekin and Topçu (2024) found that a computational thinking approach combining plugged and unplugged activities effectively improves students' creative problem-solving skills. In the KKA

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model, the space for creativity opens at the reflection stage, when students are encouraged to find a more efficient solution to the same problem.

The results of this study make an important contribution to the theoretical debate on the effectiveness of unplugged coding. Relkin, de Ruiter, and Bers (2021) once criticised that unplugged activities risk remaining at the level of play without meaningful skill transfer. The findings of this study provide an empirical rebuttal to that concern, with the important caveat that skill transfer occurred precisely because the KKA model has a clear didactic structure and connects unplugged activities with an authentic artificial intelligence context. Fagerlund, Häkkinen, Vesisenaho, and Viiri (2021) had anticipated this by asserting that the effectiveness of unplugged learning depends on the quality of the activity structure. This study positions itself at the meeting point of that debate by demonstrating that unplugged learning that is structured and connected to artificial intelligence can produce measurable skill transfer.

The current state of the art reveals a separation between the study of unplugged coding and the study of artificial intelligence in schools, as seen in the difference in focus between Hu and Wang (2024) and Seung, Cukurova, and Lee (2025). Erümit (2024) notes that many unplugged studies still use one-group designs without a control class, so that their causal claims are weak. This study advances the state of the art in two ways. First, it integrates unplugged coding and artificial intelligence within a single coherent model, addressing the separation of the two streams of inquiry. Second, it applies a control-group quasi-experimental design that tightens control over threats to internal validity, thereby providing stronger causal evidence than the majority of previous studies.

The main novelty of this study lies in the construction of the KKA model as a coherent two-phase instructional framework aligned with national policy. The Education Standards, Curriculum, and Assessment Agency (2025) has established Coding and Artificial Intelligence as an official learning content area, yet operational models that teachers can apply in primary schools remain very limited. The KKA model fills this void by offering a five-stage syntax that combines unplugged coding and artificial intelligence. del Olmo-Muñoz, Cózar-Gutiérrez, and González-Calero (2020) emphasise that unplugged activities are most effective when integrated within a coherent learning flow. Memari (2025) adds that computational thinking and artificial intelligence literacy should ideally be taught in an integrated manner, and the KKA model provides a concrete embodiment of that recommendation.

The contextual contribution of this study is highly relevant to the conditions of Indonesian primary education. Han, Kim, and Lee (2024) identify that the greatest barrier to teaching

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computer science in primary schools stems from resource limitations, not from the curriculum. Nur Marifah, Abdul Mu'ti, and Rijal Wahid (2022) found that the integration of computational thinking in Indonesian primary schools is hindered by a scarcity of contextual learning tools. Fitri and Iswatiningsih (2025) assert that the implementation of artificial intelligence in primary schools still faces challenges of teacher readiness. The KKA model addresses these issues because the unplugged phase requires only cards and movement space, while the artificial intelligence phase can be run with a single device managed by the teacher, without dependence on a fully equipped computer laboratory (Misbahrudin, et al 2026). The KKA model therefore contributes directly to equalising the quality of coding and artificial intelligence education.

Several limitations of the study should be acknowledged honestly as a basis for further research. First, the study was conducted at two primary schools in a single regency, so that the generalisation of the findings requires caution. Second, the intervention duration of six meetings is of moderate length, and the long-term retention of skills has not been measured. Dağ, Şumuer, and Durdu (2023) show the importance of follow-up measurement to assess the sustainability of the impact of computational thinking interventions. Third, the abstraction indicator that developed more slowly indicates the need to refine the design of activities in the artificial intelligence phase. Lin, Dai, and Ng (2025) caution that the use of artificial intelligence with children demands monitoring so as not to foster dependency. Further research is recommended to use a larger sample, a longer duration, and retention measurement to strengthen the external validity of the findings.

CONCLUSION

This study concludes that the Unplugged Coding and Artificial Intelligence learning model is proven effective in improving the computational thinking ability of primary school students. The experimental group that learned with the KKA model obtained a mean posttest score of 82.19 with a normalised gain of 0.66, far surpassing the control group, which reached only 68.44 with a gain of 0.35. The independent sample t-test confirmed a statistically significant difference, and the effect size of 1.62 indicated a large practical impact. The algorithmic thinking and decomposition indicators were the dimensions most affected, while abstraction developed more moderately and demands a refinement of the activity design in the artificial intelligence phase.

Theoretically, this study contributes by presenting a two-phase model that combines unplugged coding and artificial intelligence grounded in constructivist learning theory, constructionism, and cognitive load theory, thereby addressing the separation of the two streams

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of inquiry that have so far developed in isolation. Practically, the KKA model provides an operational, low-cost learning framework aligned with the national Coding and Artificial Intelligence policy, so that it can be adopted by primary schools with limited resources. Its policy implication is the need to provide teacher training and KKA model materials as part of efforts to equalise the quality of education. Further research is recommended to test this model on a larger sample, with a longer duration, and to include the measurement of skill retention.

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