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Integration of Coding and Artificial Intelligence Based on Tri-N to Enhance Learning Outcomes in Science and Social Studies for Elementary School Students

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ABSTRACT

Low learning outcomes in the Integrated Science (IPAS) subject at the elementary school level highlight the need for innovative, technology-enhanced learning approaches. This study aims to improve sixth-grade students' IPAS achievement by implementing a learning design that integrates coding and artificial intelligence within the Tri-N approach (niteni, nirokke, nambahi). The novelty of this research lies in the systematic integration of Tri-N—a culturally-rooted pedagogical framework—with modern computational tools (coding and AI), creating a unique bridge between local wisdom and 21st-century digital competencies in elementary education. Conducted at SDN 2 Cikalongwetan, West Bandung Regency, the research involved 40 students and employed Classroom Action Research using Kurt Lewin's two-cycle model. Each cycle consisted of planning the Tri-N–based coding–AI design, implementing learning activities, observing student engagement, and reflecting on outcomes for improvement. Data were collected through observations, interviews, documentation, and learning achievement tests, and analyzed using descriptive quantitative and qualitative techniques. The study found a steady increase in students' average scores from 73.6 (pre-action) to 78.9 (Cycle I) and 84.5 (Cycle II), achieving 100% mastery. Qualitative results also showed enhanced learning activeness, computational thinking, and creativity, particularly during the Nambahi stage. The findings demonstrate that integrating coding and AI supports interactive, adaptive, and meaningful learning experiences while strengthening conceptual understanding and participation. This study suggests that the Tri-N–based coding–AI learning design is a strategic alternative for supporting the Merdeka Curriculum and improving technological literacy in elementary schools.

KEYWORDS *artificial intelligence; coding; learning outcomes; science learning; Tri-N*

INTRODUCTION

The demands of 21st-century competencies encourage education to develop technological literacy, data literacy, and computational thinking skills in students starting in elementary school (Christensen & Lombardi, 2020; Hardianto et al., 2024). The increasingly rapid development of digital technology requires schools to provide learning that is adaptive to change, including the integration of coding and artificial intelligence as part of a learning experience relevant to future needs. The government, through the Independent Curriculum, provides space for teachers to develop innovative, technology-based learning to strengthen the profile of Pancasila students and improve the quality of classroom learning (Asmorojati et al., 2022). Elementary schools need to design learning strategies that combine digital technology with meaningful learning activities to prepare students to face the challenges of the digital era (Shidiq & Nasrudin, 2021).

Natural and Social Sciences (IPAS) learning in elementary schools plays a crucial role in developing students' scientific thinking skills, curiosity, and problem-solving skills. This subject integrates scientific concepts and the surrounding environment so that students can understand natural phenomena contextually and applicably (Afriana et al., 2016). IPAS learning is often considered abstract and unengaging due to the minimal use of innovative learning media and the lack of exploratory activities involving students' direct experiences (Nur et al., 2022; Winarni & Purwandari, 2019). This condition leads to low learning motivation and limited opportunities for students to develop a deeper understanding of concepts (Al Sultan et al., 2018; Syamsi & Tahar, 2021). IPAS learning needs to be designed to be more interactive and contextual to encourage active student involvement and strengthen their understanding of scientific concepts (Amalia & Mukarromah, 2025).

The low achievement of elementary school students in science and natural sciences indicates a problem in the learning process, which is not yet optimal in achieving the Learning Objective Completion Criteria (KKTP). Many students have difficulty understanding science and natural science concepts because learning is still dominated by lecture methods, limited use of media, and a lack of exploratory activities involving direct experience (Fauzi et al., 2023; Huang et al., 2023). This condition causes students to be less active, easily bored, and not have sufficient opportunities to develop independent scientific thinking skills (Holovatenko, 2023; Ramlan et al., 2023). The minimal integration of technology in learning also hinders students from developing more creative and relevant learning methods (Ferro et al., 2021; Hardianto et al., 2023). Learning innovations that can increase student engagement and strengthen conceptual understanding so that science and natural science learning outcomes can achieve the set standards are needed.

The integration of coding and artificial intelligence (AI) in science learning has great potential as a solution to improve the quality of the learning process and outcomes of elementary school students (Hingve et al., 2024; Kabashkin et al., 2023). Coding can help students develop computational thinking, logic, and problem-solving skills through simple, easy-to-understand programming activities (Karlin et al., 2024). Meanwhile, artificial intelligence can provide a more personalized, interactive, and adaptive learning experience through simulations, visualizations, and automated feedback that support deeper conceptual understanding. The collaboration between coding and AI allows students to learn more actively, try various virtual experiments, and understand science concepts through direct, technology-based observation (Liao et al., 2021; Robinson, 2020). The integration of these two aspects can create learning that is more engaging, relevant to digital developments, and effective in addressing low achievement in science learning outcomes.

The Tri-N (niteni, nirokke, nambahi) teachings are local wisdom-based learning strategies that are highly relevant for integration with technology in elementary school science learning (Hayati et al., 2024). The niteni stage encourages students to observe, recognize, and understand concepts through real-life examples or phenomena; the nirokke stage trains students to imitate, practice, or apply learned concepts in a focused manner; while the nambahi stage encourages students to develop creativity by modifying, refining, or creating new solutions based on their understanding. These three stages align with the principles of active and independent learning in the Independent Curriculum, thereby strengthening the internalization of science concepts. When the Tri-N approach is combined with coding and artificial intelligence, students gain not only conceptual understanding but also opportunities to create and experiment with the support of modern technology. Thus, Tri-N can be an effective bridge in connecting culture-based learning with the needs of 21st-century digital competencies.

The urgency of this study is underscored by the persistent gap between traditional teaching methods and the digital competencies required in contemporary education. While previous research has explored coding in isolation (Hingve et al., 2024) or AI applications separately (Kabashkin et al., 2023), few studies have systematically integrated both technologies within a culturally-grounded pedagogical framework like Tri-N, particularly at the elementary level.

The development of Tri-N-based coding and artificial intelligence learning is highly urgent for implementation in elementary school science learning due to the limited learning innovations that directly integrate digital technology with local cultural approaches (Hidayati et al., 2020). The novelty of this research lies in three key aspects: (1) the systematic integration of coding and AI as complementary tools rather than separate interventions; (2) the embedding of these technologies within the Tri-N framework, which provides cultural relevance and pedagogical structure; and (3) the application to elementary-level IPAS subjects, an area underexplored in existing literature.

Many previous studies have emphasized the use of digital media in general, but have not yet addressed the integration of coding and AI as a means to deepen understanding of science concepts through the stages of niteni, nirokke, and nambahi. The combination of these three components can provide a more creative, systematic, and contextual learning experience for students. This learning design enables students not only to understand science concepts but also to develop computational thinking skills and creativity through technological activities relevant to current developments. Therefore, Tri-N-based coding-AI integration is a strategic alternative to address low learning outcomes and simultaneously prepare students to face the challenges of the digital era.

This study aims to improve elementary school students’ science learning outcomes through the implementation of a learning design that integrates coding and artificial intelligence based on the Tri-N approach. Specifically, this study seeks to determine the effectiveness of the niteni, nirokke, and nambahi stages in strengthening the understanding of science concepts when combined with digital technology-based activities. Additionally, this study aims to identify changes in the learning process from each action research cycle and evaluate the increase in student activeness and engagement during the learning process. This research is expected to provide practical contributions to teacher professional development and become a reference for technology-based learning innovations in elementary education.

METHOD

Research Type

This study employed Classroom Action Research (CAR) with the aim of improving the process and outcomes of science learning through the application of a Tri-N-based coding and artificial intelligence learning design to elementary school students. A mixed methods approach was employed, combining qualitative and quantitative analysis to describe changes in learning behavior, the learning process, and improvements in student learning outcomes (Leedy & Ormrod, 2015).

Research Subjects

This study was conducted at SDN 2 Cikalongwetan as the primary location because the school experienced low science learning outcomes that needed to be improved through learning innovation. The study subjects were 40 sixth-grade students, consisting of 19 boys and 21 girls, so the data obtained could reflect the overall classroom conditions. This study took place over two learning cycles, each cycle consisting of 2–3 meetings, depending on the material requirements and action stages.

Research Procedure

This research procedure follows the Kurt Lewin Classroom Action Research model which consists of four main stages, namely planning, implementation, observation, and reflection, and is carried out in two cycles. In the planning stage, the researcher compiled learning tools, including Tri-N-based lesson plans, coding media, artificial intelligence applications, and test and observation instruments in accordance with the research objectives. The implementation stage is carried out by applying coding and AI learning designs to IPAS materials through the stages of niteni, nirokke, and adding to increase student engagement and understanding. Furthermore, the observation stage is carried out to monitor the activities of teachers and students, record the activeness, interaction, and use of technology during learning. In the reflection stage, the researcher analyzes the results of observations and cycle tests, identifies weaknesses that arise, and formulates improvements to be applied in the next cycle. Through this procedure, research can run systematically and provide an overview of the increase that occurs from cycle I to cycle II.

Data Collection

This research uses several data collection techniques that are tailored to the needs of Classroom Action Research, namely observation, interviews, learning outcome tests, and documentation. Observations were made to record the activities of teachers and students during the learning process, including the level of activity, interaction, and the use of coding media and artificial intelligence in each stage of Tri-N. Informal interviews were conducted with students and teachers to obtain additional information about the learning experience, response to the use of technology, and obstacles that arose during learning. The learning outcome test is used to measure the achievement of understanding of social studies concepts at the end of each cycle through a multiple-choice question instrument and a brief description that is in accordance with the learning objectives. Documentation in the form of photos of activities, process notes, and student work results is used as supporting evidence to strengthen research findings. The use of these various instruments allows researchers to obtain comprehensive data both qualitatively and quantitatively.

Data Analysis

The data analysis technique in this study uses qualitative and quantitative descriptive approaches to describe changes in the process and learning outcomes of students in each action cycle. Quantitative analysis was carried out by calculating the average score of learning outcomes, percentage of individual completeness, and classical completeness to compare pre-action, cycle I, and cycle II achievements. Meanwhile, qualitative analysis is carried out through the process of data reduction, data presentation, and drawing conclusions on the results of observations, interviews, and learning documentation. This technique is used to identify the development of student activity, the effectiveness of the use of coding and artificial intelligence, and the dynamics of learning in each stage of Tri-N. The combination of the two analysis techniques allows researchers to obtain a comprehensive picture of the success of the actions given and the basis for decision-making for improvement in the next cycle.

RESULT AND DISCUSSION

Results of Cycle I

Planning

In the planning stage of Cycle I, the researcher identified the problem of low social studies learning outcomes and the level of student activity in learning at the previous meeting. Based on this needs analysis, the researcher developed a learning design by integrating coding activities and the use of artificial intelligence (AI) within the framework of the Tri-N approach (niteni, nirokke, nambahi). Planning includes the preparation of lesson plans, learning scenarios, teaching materials, student worksheets, and instructions for using digital platforms for coding activities and AI exploration. In addition, the researcher prepared research instruments in the form of observation sheets for learning activities, observation sheets for learning implementation, interview guidelines, and learning outcome tests for the end of the cycle. An understanding of the role of teachers and observers was also agreed to ensure that the implementation of learning runs according to the design of actions. At this stage, the success indicators are determined, namely an increase in the average learning outcomes of IPAS and student activity, as well as the achievement of classical completeness of at least 85%.

Implementation

The implementation of actions in Cycle I is carried out in accordance with the learning plan that has been prepared. Teachers open learning by associating IPAS material with daily life to facilitate the niteni (observing) stage, then introduce coding activities and the use of artificial intelligence as a medium for concept exploration. In the nirokke (imitation) stage, students follow the coding steps exemplified by the teacher through a demonstration on the use of digital platforms to solve simple problems related to IPAS material. Furthermore, students are given the opportunity to work in groups to implement coding instructions independently, with the assistance of teachers to overcome technical and conceptual obstacles. Learning ends with the adding (developing) stage, where students are asked to modify coding commands or utilize AI features to produce more creative outputs that are relevant to the IPAS topic. In general, the implementation went according to plan, although several obstacles were found in the field such as the difficulty of some students in understanding the initial instructions and the management of time that was not optimal.

Observation

Observations in Cycle I are carried out by observers during the learning process using student learning activity observation sheets and learning implementation sheets. Based on the observations, most students showed high interest when teachers started coding and AI exploration activities, but the level of activity was not even across the class. About two-thirds of students actively follow coding instructions and discuss in groups, while others are passive and tend to wait for the teacher's direction. The Observer also noted that some students experienced confusion in the early stages of using the coding platform, thus requiring additional assistance. Time management becomes a challenge, especially at the incremental stage when students begin to develop variations of coding commands independently. In terms of learning implementation, most of the Tri-N syntax is well implemented, but the effectiveness at the addition stage is not optimal because it is still limited to simple modifications. Observational data showed an increase in engagement compared to previous learning, but indicators of student activity and concept understanding still did not reach the expected target.

Reflection

The results of reflection at the end of Cycle I showed that the integration of coding and artificial intelligence based on the Tri-N approach had a positive impact on students' motivation and involvement in science learning, but the implementation was not fully optimal. Some of the success can be seen in the increased enthusiasm of students when participating in *the niteni* and *nirokke* stages, as well as the emergence of basic computational thinking skills in completing coding tasks. However, the main obstacles are still found in the difficulty of students in understanding the initial instructions for using digital platforms, dependence on teachers in solving technical problems, and inefficient time management in *the adding phase*. In addition, the level of activeness and ability to develop coding commands is not even across the group. Based on these findings, the research team and teachers agreed on the need for improvements in Cycle II through the addition of scaffolding at the demonstration stage, the provision of simpler task examples at the beginning, a more structured time division, and a variety of mentoring that encourages student independence. This improvement is directed to ensure an increase in learning outcomes and an equal distribution of student activity in the next cycle.

Results of Cycle II

Planning

Planning in Cycle II focuses on the implementation of improvement strategies based on the results of reflection in Cycle I. Researchers and teachers evaluate the obstacles that arise, especially related to students' difficulties in understanding initial coding instructions, dependence on teacher assistance, and lack of optimal time allocation at the addition stage. Therefore, in the planning stage of Cycle II, learning scaffolding was added in the form of more systematic coding steps, visual guidance, and simpler examples of AI utilization tasks to ensure that all students understand basic instructions before proceeding with independent tasks. Planning also includes adjusting learning scenarios with a more proportional time division for each Tri-N phase, increasing the role of collaborative work in groups, and mentoring rotation mechanisms so that teacher monitoring is more evenly distributed in each group. The observation instruments and assessment of learning outcomes were updated to measure the improvement of the quality of students' independence and creativity in completing coding tasks and the use of AI features. The success indicators of Cycle II are determined to achieve an increase in learning activity, an increase in the average score of IPAS learning outcomes, and classical completeness of at least 85% consistently in all students.

Implementation

The implementation of actions in Cycle II is carried out based on the improvement plan that has been prepared. Teachers again apply science learning based on the integration of coding and artificial intelligence through the Tri-N approach, but with a more structured scaffolding strategy. At *the niteni* stage, students are reintroduced to the concepts and examples of using coding platforms and AI through visual guidance, simplified work steps, and affirmation of learning objectives. In the *nirokke stage*, students imitate the example of coding instructions through demonstrations carried out by the teacher in stages while being given step-by-step guidance for the whole group to follow. After that, at the *addition* stage, students begin to develop coding commands and utilize AI features independently according to the challenges given, with a more equitable distribution of teacher assistance through group rotation. The time allocation at each stage is arranged more proportionally so that students have enough opportunities for creative exploration at the adding stage. In general, the implementation of learning in Cycle II is more effective than Cycle I, as can be seen from the increased independence of students in completing coding tasks, clarity of learning flow, and reduced technical confusion during the learning process.

Observation

Observations in Cycle II were carried out using the observation sheet of student learning activities and the learning implementation sheet, the same as in Cycle I. Based on the results of observations, student involvement experienced a significant increase compared to Cycle I. Almost all students actively participated in the niteni and nirokke stages with a faster response rate, because the visual and scaffolding guidance provided made it easier to understand coding instructions. In the addition stage, students showed better computational thinking skills, reflected in their ability to modify coding commands and utilize AI features to generate more creative and diverse outputs. Independence and collaboration between group members also increased, so the dependence on teacher assistance was drastically reduced. Running time management is more effective; The observer notes that the new time division provides optimal exploration opportunities without disrupting the learning flow.

Reflection

The results of reflection at the end of Cycle II show that the improvement of the implemented actions has succeeded in optimizing IPAS learning based on coding integration and artificial intelligence through the Tri-N approach. The increase in student activity occurred evenly, not only limited to certain groups as in Cycle I. Students also showed increased independence in carrying out coding activities and utilizing AI, especially in the adding stage, which was previously a weakness in Cycle I. Technical obstacles that used to interfere with the learning process are almost no longer found, and students are able to overcome most problems on their own or through group collaboration. The learning outcome data showed an increase in line with the observational findings, and classical completeness was above the set target. Thus the learning action was declared successful, and no continuation to Cycle III was required. Coding–AI-based learning through the Tri-N approach has been shown to be effective in improving social science learning outcomes, student engagement, and computational thinking skills.

Results of Analysis of Each Cycle

The results of the descriptive analysis in Table 1 show a consistent increase in the achievement of students' social studies learning outcomes at each stage of action. In the pre-action stage, the total score was 2,944 with an average of 73.6, which illustrates that most students have not reached the Learning Objective Completeness Criteria (KKTP). After the implementation of Tri-N-based coding and artificial intelligence learning in cycle I, the number of scores increased to 3,156 with an average of 78.9. This improvement indicates that the learning design applied is starting to have a positive impact on the understanding of IPAS concepts. A more significant increase occurred in cycle II, where the number of scores reached 3,380 with an average of 84.5. This achievement shows that all students have passed the KKTP and the quality of learning has increased substantially. Overall, the trend of increasing grades at each stage proves that the integration of coding and artificial intelligence with the Tri-N approach is effective in improving the learning outcomes of elementary school students.

Table 1. Statistical Description of the Value of Social Science Learning Outcomes at Each Action Stage

Action Stage	Total Value (ΣX)	Number of Pupils (N)	Average ($\bar{X}$)
Pre-Actions	2,944	40	73.6
Cycle I	3,156	40	78.9
Cycle II	3,380	40	84.5

Table 1 shows that the improvement in IPAS learning outcomes occurred consistently at each stage of action. In a comparison between pre-action and cycle I, the average student score increased by 5.3, or equivalent to an increase of 7.20%, indicating that Tri-N-based coding and artificial intelligence learning is starting to have a positive impact on student comprehension. In the next stage, the continuous improvement continued from cycle I to cycle II, with an average increase of 5.6 or 7.10%, which indicates that the improvement of strategy in cycle II is able to optimize the learning process and student engagement. If the increase is calculated from pre-action to cycle II as a whole, there is a more significant spike with a total increase of 10.9 or 14.80%. These results show that learning interventions delivered over two cycles have succeeded in improving the quality of learning in a sustainable manner and encouraging stronger improvement in learning outcomes. Overall, this diagram confirms the effectiveness of the application of Tri-N-based coding and artificial intelligence learning in improving students' science learning outcomes.

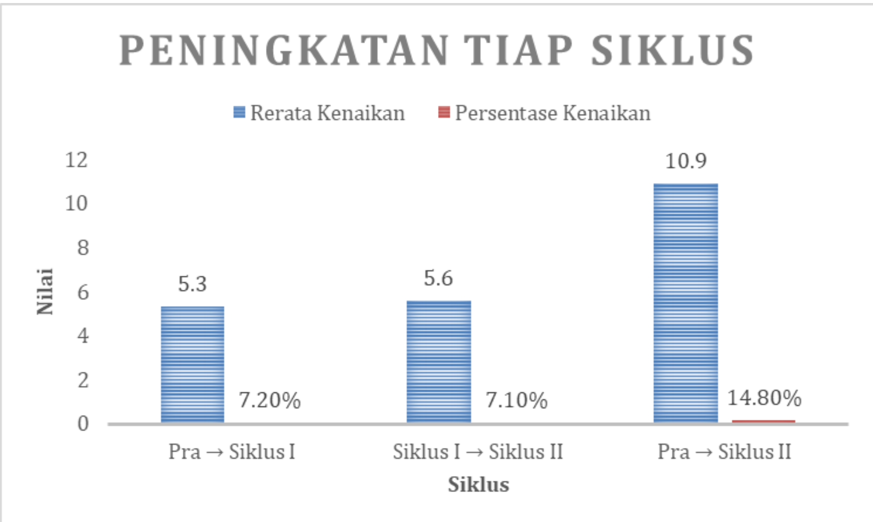

Figure 1. Cycle Improvement Chart

The results of the qualitative analysis in Table 2 show that the Tri-N-based coding and artificial intelligence learning process has a positive impact on student engagement and skill development at each stage of action. At the data reduction stage, preliminary findings show that students show high enthusiasm when using coding and AI, although some students still face obstacles in following coding instructions independently. Tri-N activities began to be seen through the students' ability to do *niteni* by observing the examples given and *nirokke* by imitating the programming steps shown by the teacher. Observational data showed that many students actively asked questions during cycle I, while the interview results confirmed that they found learning to be more engaging and easy to understand. Photo documentation shows that students work in small groups, showing interaction and collaboration in the learning process. These findings suggest that technology integration is starting to improve student engagement, although learning instructions need to be adjusted so that all students can follow along.

At the data presentation stage, the improvement in learning quality was more evident in cycle II. The Tri-N approach is applied more optimally, characterized by increased group discussions and students' activeness in completing coding and AI-based tasks. Students begin to enter the *adding* stage, which is the ability to modify and develop simple coding results that were previously imitated. Observations showed an increase in the activity of asking questions and discussing, while interviews showed that students felt more confident in using AI applications. Documentation of students' work results also shows growing creativity. Overall, the data at this stage confirms that the learning design is able to facilitate the gradual learning process according to the Tri-N principle starting from understanding, imitating, to developing.

At the conclusion level, applied learning results in a more interactive, collaborative, and challenging learning environment for students. The use of AI-based simulations helps students understand the concept of IPAS in a more concrete and visual way. The Tri-N model has been proven to be effective in supporting the improvement of students' creativity and problem-solving skills through coding activities and technology exploration. Observational and documentation findings show that student activities are becoming more structured, while interviews with teachers indicate that learning efficiency is improved because AI is able to provide automated feedback. Overall, the results of this qualitative analysis reinforce the evidence that Tri-N-based coding and AI integration not only improves concept understanding, but also significantly boosts student engagement, creativity, and learning outcomes.

Table 2. Results of Qualitative Analysis of Tri-N-Based Coding and AI Learning

Qualitative Analysis Stage	Key Findings	Evidence of Data (Observations, Interviews, Documentation)	Conclusion
Data Reduction	- Students show high enthusiasm when using coding and AI.- The initial obstacle can be seen in the students' ability to follow coding	- Observations showed students actively asking questions in cycle I.- Brief interviews revealed that students felt learning was "more exciting	Technology-based learning is starting to increase student engagement, but instructional adjustments are needed to keep all

	instructions.- Tri-N activities begin to be seen: students actively observe (*niteni*) and imitate steps (*nirokke*).	and easier to understand".- Photo documentation showed students working in small groups.	students along.
Data Presentation	- The implementation of Tri-N is more optimal in cycle II.- The increase in student activity can be seen from the increase in group discussions.- Students begin to be able to modify simple coding results (*add).*	- Observations show that students are more active in asking questions in cycle II- Interviews note that students feel more confident using AI applications.- Documentation of students' work results shows increased creativity.	Learning design is able to facilitate the gradual learning process from understanding–imitating–developing through coding and AI activities.
Conclusion	- Learning becomes more interactive, collaborative, and challenging.- Students can more easily understand the concept of IPAS through AI-based simulations.- The Tri-N model has been proven to support increasing students' creativity.	- Learning outcomes improved significantly with each cycle.- Teachers reported that learning was more efficient because AI provided automated feedback.- Documentation showed pupils' activities were more structured.	The integration of coding and Tri-N-based AI is effective in increasing students' concept understanding, engagement, and creativity, thus having a positive impact on IPAS learning outcomes.

Discussion

The improvement in science learning outcomes at each stage of the intervention demonstrated that the integration of coding and Tri-N-based artificial intelligence significantly impacted students' academic achievement. Field observations showed a consistent increase in average grades, from 73.6 in the pre-intervention phase to 78.9 in Cycle I and 84.5 in Cycle II, with 100% learning completion at the end of the study. Coding activities improved students' logical thinking skills and academic achievement (Hingve et al., 2024), and AI was effective in strengthening conceptual understanding through automated feedback (Gursky & Grow, 2024; Kabashkin et al., 2023). These research findings support the constructivist view that active learning based on direct experience can foster deeper understanding (Adams, 2006; Yakar et al., 2020). Rapid feedback from AI accelerated the internalization of concepts. Thus, the integration of coding and AI has been proven to provide a real contribution in improving science learning outcomes through a more structured, interactive learning mechanism that is oriented towards conceptual understanding..

Increased student activity and engagement during the learning process was evident in each action cycle, particularly in cycle II, when students asked more questions, discussed, and collaborated more frequently in completing coding activities and AI explorations. This fact was reinforced by interview results, which showed that students felt more confident and motivated because AI-based learning was perceived as more engaging and easier to understand. Coding and AI-based learning can increase student engagement due to its interactive, visual nature and provide a sense of immediate achievement (Hingve et al., 2024; Liao et al., 2021; Wu, 2024). Student cognitive, emotional, and behavioral engagement increases when learning media can stimulate curiosity and active participation (Bahri et al., 2024; Salam et al., 2018). The use of AI as a learning support provider aligns with the concept of scaffolding, where technology can function as a "more capable tool" that expands students' Zone of Proximal Development (Vygotsky, 1978). The increased student engagement in this study reflects the effectiveness of the combination of coding and AI in encouraging more active, meaningful, and collaborative learning interactions..

The implementation of the Tri-N approach in coding and artificial intelligence learning has proven effective and progressive in each cycle of action, as seen in students' abilities through the stages of Niteni, Nirokke, and Nambahi. Field evidence shows that in the initial stage, students were able to carefully observe simulations and programming examples provided through AI media (Niteni), then successfully imitated the coding steps with teacher guidance in cycle I (Nirokke), and in cycle II began to modify and develop simple programs independently (Nambahi), thus indicating increased creativity and conceptual understanding. Tri-N is effective in improving students' analytical skills and creativity when applied to practice-based learning (Hayati et al., 2024). The success of the Tri-N stages aligns with the learning progression theory which emphasizes gradual learning from observation, reproduction, to creation, and is in accordance with the constructivist framework of thinking that positions students as creators of knowledge through meaningful experiences. The integration of Tri-N with modern technology also strengthens the principles of local culture-based learning that is adaptive to the demands of 21st-century digital literacy. The effectiveness of Tri-N in this study not only supports the development of students' computational skills, but also enriches the quality of learning with a contextual, gradual, and creativity-oriented approach.

Students' computational thinking skills improved significantly throughout the implementation of the program, particularly through their ability to decompose problems, recognize patterns, and logically organize programming steps. Field observations indicate that in Cycle II, students were increasingly able to follow the flow of coding instructions, correct program errors, and produce simple output variations, indicating the development of analytical and problem-solving skills. Coding activities in elementary school children can strengthen computational thinking skills through algorithmic exercises and exploration of simple programs (Dindler, 2020; Sengupta et al., 2013). Recent studies on technology-based learning have shown that the use of AI as a simulation and visualization tool helps students understand abstract concepts more concretely (Bani-Hamad & Al-Kalbani, 2024; Özdemir & Hekim, 2018). These results reinforce the view of cognitive development theory, which states that structured tasks such as programming can improve higher-order thinking skills, while also aligning with information processing theory, which emphasizes the importance of organizing steps systematically (Lindsay & Ciresi, 2004). The AI-integrated coding learning in this study not only effectively improved students' computational thinking skills but also contributed to the formation of systematic thinking patterns that are essential for science learning in elementary schools.

The integration of coding, artificial intelligence, and the Tri-N approach in this study provides a new contribution as a holistic learning model capable of simultaneously improving conceptual understanding, creativity, and student engagement. Field evidence shows that students are not only able to understand science material better, but also demonstrate creativity in modifying programs (Nambahi) and actively participate in technology-based learning. This finding goes beyond previous studies that generally only integrate one or two elements, for example, research that focuses only on coding or the use of AI alone, while this study combines both within the Tri-N pedagogical framework based on local culture. Coding enhances problem-solving skills and AI enhances personalized learning (Gold-Veerkamp et al., 2016; Hsieh et al., 2019), but few studies have examined the integration of the two within a local wisdom-based model. This model aligns with the 21st-century learning framework that emphasizes digital literacy, creativity, and computational thinking skills, while utilizing the Tri-N local cultural approach to strengthen knowledge construction in a gradual and contextual manner. This research provides an important conceptual contribution by demonstrating that the combination of modern technology and local approaches can produce a learning model that is innovative, distinctive, and relevant to today's educational needs.

CONCLUSION

This study shows that the integration of coding and artificial intelligence based on the Tri-N approach has proven to be effective in improving the learning outcomes of elementary school students. The increase in average scores from pre-action to cycle II, accompanied by higher student involvement, shows that this learning model is able to strengthen concept understanding, creativity, and computational thinking skills. The stages *of niteni, nirokke,* and *add* run optimally and allow students to learn gradually from observing, imitating, to creating. In addition, the use of Kurt Lewin's PTK model facilitates continuous instructional improvement, so that learning strategies become more adaptive and responsive to students' needs. Thus, this research makes an important contribution to the development of technology-based pedagogy that is relevant to the demands of digital literacy in the 21st century.

Although this study provides significant results, there are some limitations that need to be considered. The research was only conducted in two cycles and in one school with a limited number of samples, so the findings could not be generalized widely. The use of technology devices and internet connections is also an obstacle that has the potential to affect the smooth implementation of coding and AI. Therefore, further research is recommended to be conducted in various school contexts with larger samples, involving more action cycles, and developing infrastructure and teacher training to support optimal technology integration. Future research may also explore non-cognitive impacts, such as creativity, digital literacy, and self-efficacy, as well as develop AI-based evaluation models that are adaptive to student learning development.

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