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Integrating Artificial Intelligence and Coding Education in Elementary Schools: A Systematic Literature Review of Pedagogical Strategies and Learning Outcomes

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Abstract

This study aims to systematically examine pedagogical strategies and the impact of integrating artificial intelligence (AI) and coding education in primary schools. Inclusion criteria covered peer-reviewed articles focusing on primary education (ages 6–12), discussing the integration of AI and/or coding, and addressing pedagogical strategies and learning outcomes. From a total of 1,247 identified articles, 32 met the criteria and were analyzed using thematic and content analysis. The findings reveal that the most frequently applied pedagogical strategies include project-based learning, gamification, unplugged activities, and AI-assisted personalized learning. These strategies were found to positively influence students' computational thinking, problem- solving skills, creativity, collaboration, and learning motivation. Significant differences were identified between developed and developing countries, particularly in terms of ICT infrastructure availability and the implementation of AI in primary education. The review also highlights research gaps, including the limited number of studies in Southeast Asia and the lack of discussion on AI ethics for children. This study offers valuable implications for teachers, policymakers, and curriculum developers in designing AI- and coding-based learning that is contextual, inclusive, and sustainable.

INTRODUCTION

In the era of the Industrial Revolution 4.0, digital literacy and computational thinking (CT) skills have become fundamental competencies that must be instilled from elementary school. These skills not only train students to understand technology but also develop problem-solving, creativity, and logical thinking skills essential for facing future challenges.

Artificial Intelligence (AI), as a disruptive technology, has begun to be adopted in elementary education, through AI-based learning platforms, educational robotics, and simple coding programs tailored to the age range of elementary school students. This approach is believed to create a more personalized, adaptive, and contextual learning experience.

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However, there is a significant gap in the implementation of AI integration and coding education at primary school level. Limited curricula, low teacher readiness, unequal access to infrastructure, and a lack of specific and proven pedagogical models pose major challenges. In addition, research mapping effective pedagogical strategies and their real impact on primary school student learning outcomes in this context is still limited, especially in developing countries.

The rapid development of digital technology has changed various aspects of human life, including education. One innovation that has become increasingly prominent in the last decade is the application of artificial intelligence (AI) in the learning process. AI not only serves as a tool to automate administrative tasks, but is also beginning to be used to support adaptive learning, personalise materials, and develop 21st-century skills, such as critical thinking, problem solving, and creativity. On the other hand, coding education has become an important part of the curriculum in many countries as an effort to prepare the younger generation to be technologically literate and able to actively participate in a digital-based society.

The integration of AI and coding education at primary school level has become a new focus in technology education studies. At this age, children are in an important period of cognitive and computational thinking development, so technology-based learning can have a long-term impact on their logical and analytical thinking skills. However, the application of AI concepts in the context of primary education still faces various challenges, such as teacher readiness, infrastructure limitations, curriculum suitability, and effective pedagogical approaches for early childhood.

Previous studies have shown that introducing coding concepts at an early age can improve problem-solving and systematic thinking skills. Meanwhile, the application of AI in learning has been proven to increase efficiency, motivation, and personalisation of the learning process. However, there are still limited studies reviewing how these two approaches — AI and coding — can be effectively integrated in primary school environments, especially in the context of pedagogical strategies and their impact on student learning outcomes. Therefore, this systematic literature review aims to identify, analyse, and synthesise previous studies discussing the integration of artificial intelligence and coding education at primary school level. This study is expected to provide a more comprehensive understanding of effective pedagogical strategies, learning outcomes achieved, as well as the challenges and opportunities that arise in its implementation. Thus, the results of this study can be used as a basis for the development of education policies and technology-based learning innovations in the future.

METHODS

This study utilised a Systematic Literature Review (SLR) to identify, evaluate, and synthesise relevant literature related to the integration of artificial intelligence and coding education at primary school level, particularly in the context of pedagogical strategies and student learning outcomes. The SLR approach was chosen because it allows researchers to collect the latest scientific evidence in a structured and transparent manner in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

RESULT AND DISCUSSION

This systematic literature review (SLR) presents a comprehensive synthesis of the integration of Artificial Intelligence (AI) and coding education at the primary school level. The synthesis results show that there is strong policy consensus, especially in Indonesia, to integrate AI and coding as elective/intracurricular subjects (especially in grades 5-6) or through co-curricular/extracurricular activities, driven by the need to prepare students for the era of Industry 4.0 and Society 5.0 (Academic Paper on Coding and AI Learning, 2025).

In general, the findings are grouped into two main pillars: Pedagogical Strategies and Learning Outcomes. The literature emphasises that the success of this integration is highly dependent on the selection of appropriate pedagogical strategies, tailored to the cognitive development stages of primary school students, as well as support for the development of adequate teacher competencies (Guru Dikdasmen, 2025; Awaluddin & Hadi, 2025).

Table 1: Categorisation of KA and Coding Learning Focus in Primary Schools

Learning Focus	Key Concepts Taught	Examples of Pedagogical Activities/Strategies (Primary School)	Relevant Sources
Basic Coding	Computational Logic, Instruction Sequence, Algorithmic Thinking, Simple Debugging.	Unplugged: Algorithm card games, cup/string activities. Plugged: Visual block-based programming (Scratch Junior, Code.org) to create interactive stories or simple educational games.	(BPMP Jakarta, 2025; Kemendikbudristek, 2025)
Basic KA Concept	Pattern Recognition, Classification, Input-Output Concepts, Data, Digital Ethics.	Simple machine learning experiments with visual tools (Teachable Machine for Kids, AI Playground) to train models to recognise images or sounds. Discussion about data privacy and the impact of deepfakes.	(AICI, 2025; UGM, 2025)
21st Century Skills	Computational Thinking, Problem Solving, Collaboration, Creativity, Critical Thinking.	Project-Based Learning (PjBL), Group project to create a simple chatbot for school assignments or an automatic plant watering system.	(AICI, 2025; JPPGSD, 2025)

Pedagogical Strategies in the Integration of KA and Coding

Discussions on pedagogical strategies are central to the successful integration of KA and coding in primary schools. The literature consistently highlights the need for a gradual and contextual approach for primary school students (Academic Paper, 2025).

Gradual Approach: From Unplugged to Plugged

At the primary school level, the main emphasis should be on developing computational thinking and basic digital literacy through fun and age-appropriate methods. The Unplugged strategy (without digital devices) is highly recommended for instilling computational logic, instruction sequencing, and algorithmic thinking without burdening students with the complexity of programming syntax. Once the basic unplugged concepts have been instilled, students can move on to Plugged using a visual block-based programming environment, such as Scratch or Blockly (BPMP Jakarta, 2025). This transition ensures that students understand the basic principles before interacting with the tools.

Project-Based Learning (PjBL) and Gamification

The strategy most often associated with optimal learning outcomes is Project-Based Learning (PjBL). In the context of AI and coding, PjBL allows students to build real solutions, such as creating simple educational games with Scratch that involve basic AI logic (e.g., If-Then), or designing image classification systems with Teachable Machine (Scribd, 2025). PjBL promotes active, collaborative, and exploratory learning, while developing problem-solving skills (AICI, 2025). Gamification has also emerged as a vital strategy because it can increase student engagement and make abstract concepts more concrete and enjoyable. The use of AI-based educational games and simulations can improve conceptual understanding, such as how algorithms learn from data (AICI, 2025).

Learning Outcomes and Impact of Integration

The integration of AI and coding is not only aimed at producing “young programmers”, but more fundamentally at shaping adaptive, innovative, and critical thinking patterns—known as 21st-century skills.

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Improvement in Computational Thinking and Logic

The most dominant learning outcome identified was a significant improvement in computational thinking, including problem decomposition, pattern recognition, abstraction, and algorithm design. Through coding activities, students were trained to formulate problems, express solutions in algorithmic steps and procedures, and perform debugging. This is a relevant cognitive foundation across various disciplines, training students to become innovative problem solvers (AICI, 2025).

Development of Critical Skills and Creativity

The integration of KA, in particular, fosters critical thinking skills. Students are encouraged not only to be consumers of technology, but also to question and understand how it works (process engineering). For example, teachers can show deepfake images and invite students to discuss how they work and their ethical implications (UGM, 2025; YouTube, 2025). This instils digital ethics, data privacy, and awareness of bias in AI technology from an early age.

In terms of creativity, block-based coding (such as Scratch) provides a canvas that allows students to create their own stories, games, or animations. The ability to control and build something using code is a powerful driver of creativity and self-expression.

Personalised Learning Outcomes through KA

Interestingly, learning outcomes can also be optimised by utilising AI as a teaching aid. AI has the potential to personalise learning by analysing student learning patterns, adjusting teaching materials, and providing relevant feedback. By processing big data, AI can help teachers predict learning outcomes and optimise learning strategies (data-driven decision-making) (AICI, 2025).

Table 2: Impact of KA and Coding Integration on Primary School Students' Learning Outcomes

Learning Outcomes	Key Improvement Indicators	Evaluation Instruments/Methods (Examples)
Kognitive	Problem decomposition skills, algorithm efficiency, conditional logic (If-Then), understanding of data concepts.	Written tests/concept quizzes, project code debugging rubrics, performance observation in Bebras challenges.
Afective	Interest in learning technology, resilience to failure (grit), digital ethics, data privacy awareness.	Attitude scales, questionnaires, group discussion observations, analysis of essays/reflections on digital ethics.
Psikomotorik	Ability to create functional coding projects, create simple machine learning models (classification), team collaboration in PjBL.	Final project assessment, collaborative assessment rubric, digital portfolio.

Challenges, Implications, and Recommendations

Implementation Challenges

Although the potential for integrating KA and coding is enormous, the literature highlights a number of critical challenges that must be overcome, especially in the context of primary schools:

1. Teacher Readiness: Primary school teachers often lack adequate pedagogical and professional competencies in teaching coding and KA. Intensive and continuous training programmes through LMS are an urgent solution (Ministry of Education, Culture, Research and Technology, 2025).
2. Infrastructure and Access: The gap in technology access and the availability of adequate digital infrastructure remains an obstacle, especially in remote areas. Unplugged strategies can bridge this gap in the early stages.
3. Curriculum Balance: Concerns that KA and coding will sacrifice basic literacy and numeracy learning need to be addressed through harmonious integration, rather than

as an additional burden (UMSIDA, 2025).

Theoretical Implications

This study confirms that constructivism and constructionism theories are highly relevant to KA and coding education in primary schools. PjBL strategies that focus on creation (making) through coding validate the constructionism approach (Papert, 1980), in which students actively construct knowledge as they build digital artefacts. Theoretically, the implementation of KA and coding in primary schools should shift from a knowledge transmission model to a model that fosters creativity and problem solving.

Practical Recommendations

To optimise the integration of KA and coding in primary schools, it is recommended that:

1. Development of Adaptive Modules: The government and educational institutions need to develop highly contextual and adaptive teaching modules, emphasising unplugged learning in lower grades and plugged block-based learning in higher grades (5-6).
2. Teacher Certification and Training: Implement a certification programme that recognises teachers' competence in teaching coding and KA subjects, with a focus on pedagogy-based training rather than merely technical training.
3. Multi-Stakeholder Partnerships: Building partnerships with the technology industry and AI/coding communities to provide affordable, high-quality resources, mentorship, and learning platforms.

CONCLUSIONS

The integration of artificial intelligence and coding education in primary schools is a strategic and essential step in preparing the younger generation with 21st-century skills, particularly computational thinking, critical thinking, and digital ethics. The success of this integration depends heavily on the adoption of tiered, project-based, and gamified pedagogical strategies, as well as the readiness of the educational ecosystem (curriculum, teachers, and infrastructure). This study provides a solid framework for policymakers, school administrators, and teachers in designing effective programmes to maximise student learning outcomes in the digital age.

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