

## Integrating Coding and Artificial Intelligence in Indonesian Schools: A Systematic Literature Review of Needs and Curriculum Frameworks (2015–2024)

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### Abstract

The integration of coding and Artificial Intelligence (AI) into primary and secondary education has transitioned from an option to an imperative in the digital era. This systematic literature review (SLR), guided by the PRISMA framework, synthesises global evidence to identify the core requirements for implementation and the characteristics of effective integrative curricula in the Indonesian context. Our analysis of 25 peer-reviewed studies revealed that successful integration is contingent upon four fundamental pillars: comprehensive teacher professional development, developmentally appropriate curriculum design, strategic technological infrastructure, and robust assessment frameworks. Furthermore, effective curricula are characterised by progressive and interdisciplinary integration, a strong emphasis on ethical considerations, and the use of engaging pedagogical approaches, such as project-based and game-based learning. Although international best practices provide valuable models, Indonesia still faces significant challenges related to resource equity and teacher readiness. This review concludes by proposing a phased implementation framework and outlining critical future research directions to bridge the gap between policy ambitions and classroom realities, thereby equipping Indonesian students with essential 21st-century competencies.

**Keywords:** Systematic Review, Coding Education, Artificial Intelligence, Curriculum Integration, Teacher Professional Development, Indonesian Education

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## 1. Introduction

The Fourth Industrial Revolution has fundamentally transformed the global landscape, creating an increasingly digital and interconnected world. Rapid advancements in artificial intelligence (AI) (Taj & Jhanjhi, 2022) automation, and computing have revolutionised human life, work, and interaction. This digital transformation has profound implications for education systems worldwide, including Indonesia, demanding not only the teaching of traditional knowledge but also the equipping of students with 21st-century skills. Competencies in computational thinking, programming, and understanding of AI have become essential skills for survival and competitiveness in the digital. Consequently, the integration of coding and AI into educational curricula has transitioned from an option to an imperative (George, 2023).

The Indonesian educational context has undergone significant changes with the introduction of the Merdeka Curriculum in response to the challenges of the digital era. This curriculum incorporates informatics subjects encompassing elements of computational thinking and basic programming. However, its implementation continues to face complex and multidimensional systemic constraints. Many schools, particularly in disadvantaged regions, struggle with basic infrastructure, such as computers and adequate Internet connectivity (Waly et al., 2025). Furthermore, the competency gap among teachers in delivering coding and AI materials presents a significant challenge that requires immediate attention (Kusdarini, 2025). This situation creates an urgency to develop more systematic and structured approaches.

The findings from the Programme for International Student Assessment (PISA) 2022 reveal that Indonesia has consistently ranked lower in mathematical and scientific literacy (AlAli & Wardat, 2024; Lailatul et al., 2025; Prabawa et al., 2024). These results indicate fundamental weaknesses in mastering the basic concepts essential for understanding coding and AI. Students' low problem-solving and logical thinking abilities further exacerbate this condition. Meanwhile, the demand for digital talent in the job market continues to grow exponentially. The World Bank projects a need for up to nine million digital workers in Indonesia by 2030 (Gayatri et al., 2022). This supply-demand gap poses a threat to the national competitiveness of the global economy.

International experience demonstrates various best practices for integrating coding and AI into educational curricula. Singapore's "Smart Nation" initiative has introduced coding since Primary 4 through a structured and comprehensive approach (Pereira et al., 2023). Finland has developed an AI education strategy that integrates AI with other subjects through a transdisciplinary approach. Australia and several European nations have developed age-appropriate and progressive curriculum frameworks. These countries recognize that early exposure to computational thinking and AI concepts is crucial for developing digital literacy (Zeeshan et al., 2024). These international experiences provide valuable lessons for Indonesia.

Previous research on coding and AI education in Indonesia is fragmented and insufficiently comprehensive. Some studies focus on aspects of teacher training without considering curriculum and infrastructure (Jannah et al., 2025). Other studies have developed specific tools without comprehensive implementation frameworks. Few studies have conducted comprehensive needs analyses and designed integrative curricula that synergise coding and AI (Haetami, 2025). These limitations in existing research create significant knowledge gaps, necessitating more holistic and systematic approaches

through systematic literature reviews.

This study conducted a systematic literature review to map the requirements and design an integrative coding-AI curriculum. The SLR methodology was selected for its capacity to provide a comprehensive, evidence-based synthesis from various credible sources. This study addresses two fundamental questions.

1. What are the requirements for implementing coding and AI in elementary and junior high schools?
2. What are the characteristics of effective integrative curricula based on the literature?

## 2. Method

This study employed a systematic literature review (SLR) methodology, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Haddaway et al., 2022). This process ensured transparency, reproducibility, and rigor in identifying, evaluating, and synthesising research on integrating coding and AI in K-9 education.

A comprehensive literature search was conducted in July 2024 using the Scopus and Web of Science databases. These databases were selected for their comprehensive coverage of high-quality, peer-reviewed literature in education, the social sciences, and technology. The search string used Boolean operators: ("coding" OR "programming" OR "computational thinking") AND ("artificial intelligence" OR "AI" OR "machine learning") AND ("elementary school" OR "primary school" OR "junior high school" OR "middle school") AND ("curriculum" OR "implementation" OR "integration" OR "pedagogy"). The search was limited to publications between 2015 and 2024 to ensure relevance to the current technological and educational contexts.

Studies were included if they met the following criteria: (1) focused on coding and/or AI education in K-9 educational settings; (2) provided empirical findings or theoretical frameworks regarding curriculum implementation; (3) were published in peer-reviewed journals or conference proceedings; and (4) were available in English or Indonesian. The exclusion criteria were as follows: (1) studies focusing on higher education; (2) non-empirical commentaries or editorials; (3) publications without a peer-review process; and (4) studies not specifically addressing curriculum integration aspects.

The study selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency and reproducibility. Figure 1 illustrates the flow of study identification, screening, eligibility, and inclusion. Identification: Initial database and register searches yielded 250 records. Screening: After removing duplicates (n = 20) and records marked as ineligible by automation tools or for other reasons (n = 100), 130 records were screened based on their titles and abstracts. Eligibility: Of these, 95 reports were sought for retrieval, and 45 were not retrieved from the database. Fifty (50) full-text articles were assessed for eligibility. Inclusion: Twenty-five (25) studies met all the inclusion criteria and were included in the qualitative synthesis. The primary reasons for exclusion during the full-text assessment were irrelevance to the topic (n = 15) and inability to access the full texts (n = 10).

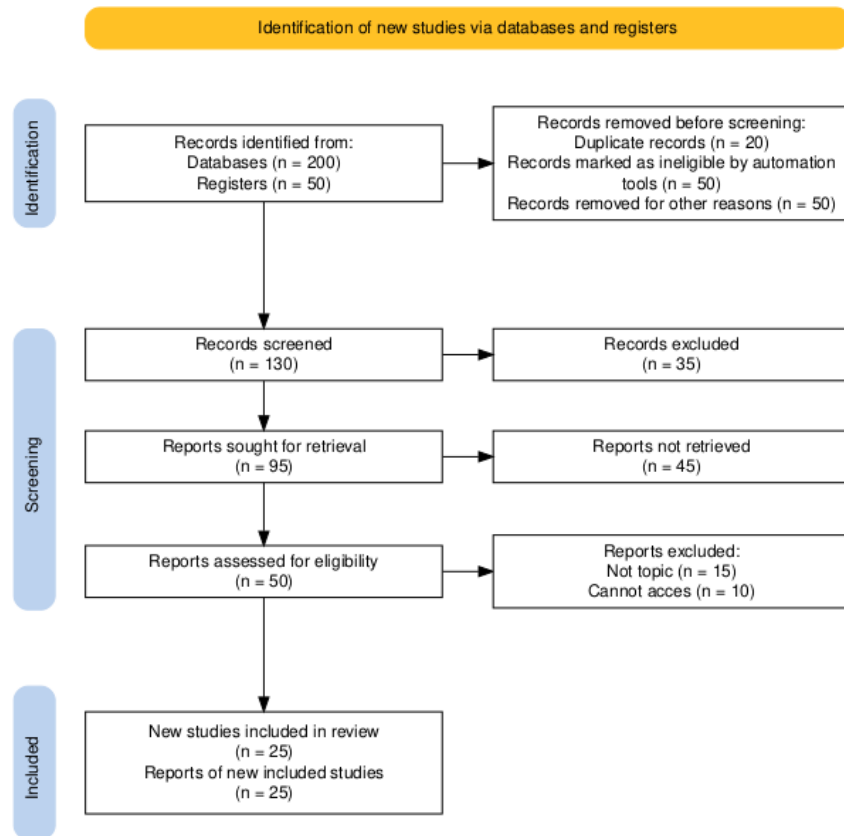


**Figure 1.** PRISMA Flow Diagram illustrating the study selection process.

Data from the 25 included studies were extracted using a standardized form that captured bibliographic information, methodology, and key findings on implementation needs, curriculum design elements, and challenges. A thematic analysis was conducted, following Braun and Clarke's (Braun & Clarke, 2021) approach, to identify, analyze, and report patterns (themes) within the data.

### 3. Result and Discussion

This systematic review identified 25 studies that met the inclusion criteria. Table 1 provides a comprehensive overview of these themes and their prevalence in the literature. The following sections present a detailed narrative synthesis of these findings, contextualised within both global educational research and the Indonesian context.

**Table 1.** Summary of Key Themes and Their Frequency in Included Studies

| Theme Category       | Specific Need/Principle                | Number of Studies | Percentage |
|----------------------|----------------------------------------|-------------------|------------|
| Implementation Needs | Teacher Professional Development       | 25                | 100%       |
|                      | Developmentally Appropriate Curriculum | 21                | 84%        |
|                      | Technological Infrastructure           | 19                | 76%        |
|                      | Assessment Frameworks                  | 16                | 64%        |
| Curriculum           | Progressive Learning Pathway           | 23                | 92%        |

|            |                               |    |     |
|------------|-------------------------------|----|-----|
| Principles | Interdisciplinary Integration | 20 | 80% |
|            | Ethical AI Education          | 17 | 68% |
|            | Inclusive Design              | 15 | 60% |

The distribution and evolution of the methodological approaches employed in the included studies are presented in Figure 2. This progression highlights the increasing recognition of the need to integrate statistical rigor with rich qualitative insights to fully comprehend the complexities of incorporating technology into education.

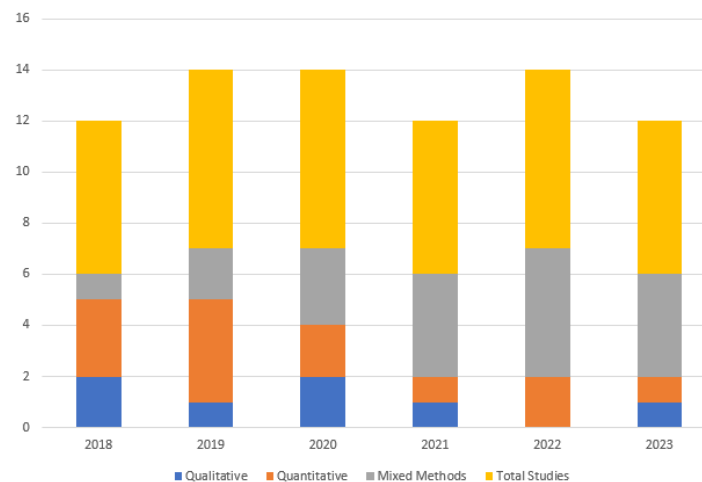


**Figure 2.** Trends in methodological approaches used in studies on coding and AI integration in education (2015-2024). The chart illustrates a notable shift from predominantly quantitative surveys to more integrative mixed-methods approaches over time.

#### A. The Non-Negotiable Pillars: Implementation Needs

The analysis identified four systemic requirements, with teacher competency being the most critical. The thematic analysis of the 25 included studies revealed four fundamental systemic requirements for successful implementation, with teacher competency being the most critical of these requirements. The prevalence of these needs in the literature is summarised in Figure 3. As shown, Teacher Professional Development was identified as a requirement in 100% of the included studies ( $n = 25$ ). This finding highlights the significant gap between policy aspirations and classroom realities.

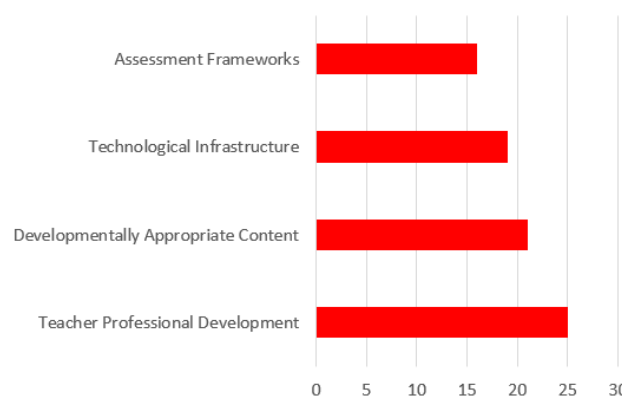


**Figure 3.** Prevalence of key implementation needs identified in the 25 included studies. Teacher Professional Development was a universal requirement, followed by the need for developmentally appropriate curriculum content.

### *1) Teacher Professional Development (100% of studies)*

The universal identification of teacher readiness as the primary implementation challenge highlights the critical gap between policy ambitions and classroom realities. This finding is explicitly supported by (Binti & Hudin, 2023), whose systematic review identifies teacher competency and digital pedagogy as fundamental prerequisites. Similarly, (Farchan, 2025) confirms that success depends on teacher competence and policy support, while (Yusuf, 2025) lists lack of teacher training as a key challenge. This challenge extends beyond technical skills to encompass pedagogical content knowledge specific to AI education. (Yang, 2022) and (Ottenbreit-Leftwich et al., 2022), through interviews with educators, highlight the need for grade-level-appropriate activities and specialized teaching strategies, a need also noted in (Lee et al., 2021). The importance of professional development is further echoed in studies focusing on specific tools and methods, such as educational robotics (Tzagkaraki et al., 2021) and Scratch programming (Kamal et al., 2019). This finding has profound implications for Indonesia, as the successful implementation of the Merdeka Curriculum depends on massive investment in comprehensive, ongoing teacher training, as outlined by (Achmad Farchan, 2025).

### *2) Developmentally Appropriate Curriculum (84% of studies)*

The literature strongly supports a progressive learning pathway that aligns with students' cognitive development. This is a central theme in (Touretzky et al., 2019) "AI for K-12" guidelines, which organise learning around "Big Ideas" across four grade bands. This concept is operationalized in curricula like PRIMARYAI (Ottenbreit-Leftwich et al., 2022), "AI for Kids" (Kreinsen & Schulz, 2021), and the project-based approach of (Trifonova et al., 2024). Empirical support from (Williams et al., 2019) shows that older children performed better on assessments, confirming the necessity of age-appropriate sequencing. Furthermore, (Lin et al., 2021) emphasizes that curriculum design must account for student motivation, which varies by development stage. Studies like (Mutoharoh et al., 2021) and (Voulgari et al., 2021) provide valuable insights for resource-constrained environments, demonstrating that foundational computational thinking can be effectively developed through unplugged activities and digital story writing without sophisticated technology. This progression from simple concepts is also supported by (Estevez et al., 2019), who used Scratch for a gentle introduction to AI, and (Kamal et al., 2019), who used it to build foundational skills.

### *3) Technological Infrastructure (76% of studies)*

Although technological access remains a significant barrier (Yusuf, 2025; Akgun & Greenhow, 2021), the literature suggests strategic approaches can mitigate these challenges. The demonstrated effectiveness of unplugged activities (Mutoharoh et al., 2021) provides a viable pathway for initial implementation. Furthermore, the potential of free, cloud-based platforms is highlighted across multiple studies. (Lee et al., 2021) recommends tools like Teachable Machine and Scratch, a tool also successfully evaluated by (Kamal et al., 2019) and (Estevez et al., 2019). (Kotsis, 2024) shows how AI can itself be used as a tool to aid teachers in planning experiments, reducing their burden. The use of social robots (Williams et al., 2019) and game-based environments like ArtBot (Voulgari et al., 2021) and PrimaryAI (Yang, 2022) demonstrates diverse technological solutions. For Indonesia, these findings suggest a strategic focus on reliable connectivity and cloud-based tools (Lee et al., 2021), rather than exclusive reliance on

expensive hardware, represents a more scalable and equitable solution.

#### *4) Assessment Frameworks (64% of studies)*

The need for robust assessment is a recurring theme. Effective integration requires moving beyond technical skills to measure higher-order cognitive abilities, including computational thinking, problem-solving, and ethical reasoning. (Zhang et al., 2023) used a mixed-methods approach with pre/post-tests and interviews to assess understanding of ethics and bias, while (Williams et al., 2023) evaluated both technical skills and ethical empathy through project-based work. (Lin et al., 2021) employed structural equation modeling to assess motivational factors. The absence of standardized tools is noted by (Aravantinos et al., 2024), making it difficult to evaluate impact. In the Indonesian context, developing authentic assessment models—such as the project portfolios from (Zhang et al., 2023), the digital stories from (Voulgari et al., 2021), or the practical demonstrations from (Kamal et al., 2019)—will be essential for meaningful evaluation of student outcomes, aligning with the competency-based philosophy of the Merdeka Curriculum.

#### *B. Synthesis and Implementation Framework for Indonesia*

Synthesising these findings reveals that successful integration requires a systemic approach addressing multiple interconnected elements. These components function synergistically, as weaknesses in one area undermine strengths in others (Binti & Hudin, 2023; Farchan, 2025). Based on this synthesis, we propose a phased framework for Indonesia: Foundation Stage (Grades 1-3): Focus on unplugged activities (Mutoharoh et al., 2021) and educational robotics (Tzagkaraki et al., 2021) to develop fundamental computational thinking with minimal technology. Application Stage (Grades 4-6): Introduce block-based programming (Scratch) (Kamal et al., 2019; Estevez et al., 2019) and simple AI tools (e.g., Teachable Machine) (Lee et al., 2021) through interdisciplinary, project-based learning (Ottenbreit-Leftwich et al., 2022; Trifonova et al., 2024). Creation and Critical Engagement Stage (Grades 7-9): Advance to text-based programming, complex AI concepts, and dedicated modules on ethical considerations (Williams et al., 2023; Zhang et al., 2023; Akgun & Greenhow, 2021), bias detection, and career exploration.

This framework acknowledges Indonesia's diverse educational landscape by allowing schools to begin implementation at developmentally appropriate levels based on existing resources and teacher readiness. Ultimately, this approach aims to develop not only technical skills but also to foster the critical thinking, creativity, and ethical reasoning necessary for Indonesian students to thrive as informed citizens and innovators in the global digital economy.

## **4. Conclusion**

This systematic review aimed to map the requirements and effective curriculum frameworks for integrating coding and AI into basic education. By synthesising global evidence, it provides clear answers to the research questions and offers an evidence-based pathway for Indonesia. In response to the first question, four implementation needs were identified: (1) comprehensive teacher professional development, (2) a developmentally appropriate, progressive curriculum, (3) strategic investment in Internet- and cloud-based tools alongside unplugged strategies, and (4) new assessment models for higher-order skills. Regarding the second question on curriculum characteristics, effective frameworks

are interdisciplinary, ethically grounded, and employ engaging pedagogical approaches, such as PBL and GBL.

This review is limited by its reliance on English and Indonesian literature, which may omit valuable insights. Future primary research is urgently needed in the Indonesian context to test the proposed framework, develop localised content, and address the specific challenges of resource disparity and teacher readiness. Longitudinal studies on the impact of such integration on student outcomes are critical. By addressing these fundamental needs and adhering to core design principles, Indonesia can move beyond policy rhetoric and empower its students to become creators, critical thinkers, and ethical leaders in the global digital economy.

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