The Urgency of Coding Education: Preparing the Future Generation with Digital Skills

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ABSTRACT

Coding education has become an urgent necessity in preparing the younger generation to face the challenges of the digital era. This article analyzes the urgency of coding education through a literature review focusing on its cognitive benefits, social impacts, and policy implications within the Indonesian education system. The findings indicate that early coding education not only develops technical skills but also enhances logical thinking, problem-solving, creativity, and collaboration abilities. The policy to integrate Coding and Artificial Intelligence (AI) subjects into the national curriculum, as part of the Indonesia Emas 2045 vision, faces major challenges such as infrastructural disparities and limited teacher competencies. Proposed solutions include strengthening digital infrastructure, providing continuous teacher training, and implementing project-based learning approaches. Comprehensive implementation requires synergy among the government, schools, industry, and society to create an inclusive and sustainable educational ecosystem. The article concludes that coding education is a strategic investment to develop high-quality human resources capable of competing in an increasingly digital global market.

Keywords: curriculum, coding education, digital skills, education policy

1. INTRODUCTION

In the rapidly evolving digital era, programming or coding skills have become one of the essential competencies that must be possessed by the younger generation, including early childhood learners. This is due to the increasing complexity of technological demands in everyday life and the significant influence of technology across various aspects of human activity, including education, economy, and employment (Firat, 2018). Coding education not only teaches technical skills but also involves critical thinking, problem-solving, and creativity, abilities that are highly needed in today's fast-changing world (Ng, 2017). Early introduction to coding education offers substantial long-term benefits. One of the most significant advantages is the development of higher cognitive skills, such as logical thinking, sequencing instructions, and structured problem-solving (Kanbul & Uzunboylu, 2017). Moreover, teaching coding to children introduces them to fundamental mathematical and scientific concepts in a fun and comprehensible way (Starkey & Popat, 2019). Studies have shown that early exposure to coding can enhance children's understanding of mathematical concepts and strengthen essential problem-solving skills applicable to daily life (Turan & Aydoğdu, 2020).

Beyond cognitive development, coding education also plays a role in improving children's social abilities, such as collaboration and communication. During the coding learning process, children often work in groups to complete projects or challenges, which teaches them teamwork and collective creativity (Başaran et al., 2025). Therefore, introducing coding to children not only focuses on technical competence but also supports the development of character and interpersonal skills that are valuable throughout their lives. The planned inclusion of Coding and Artificial Intelligence (AI) subjects in elementary school curricula represents the implementation of one of the eight missions (Asta Cita) set forth by President Prabowo Subianto and Vice President Gibran Rakabuming Raka. The fourth point of Asta Cita emphasizes strengthening human resource development, science, technology, education, health, sports achievement, gender equality, and the empowerment of women, youth, and people with disabilities (Dikdasmen, 2024). This initiative demonstrates the government's commitment to preparing a technologically literate generation capable of adapting to the dynamics of the Fourth Industrial Revolution and the Society 5.0 era.

However, several challenges present a research gap in the implementation of coding education in Indonesia. First, most previous studies have primarily focused on developed countries with advanced digital infrastructure and highly prepared human resources (Bers, 2020; Kafai & Burke, 2022), while empirical research in developing contexts, particularly Indonesia, remains limited. Second, there is a discrepancy between national policy and practical implementation, as many elementary schools still lack adequate facilities such as computers, internet access, and qualified teachers with coding competencies (Putra et al., 2023). Third, existing studies tend to emphasize cognitive outcomes, while affective and social dimensions, such as learning motivation, digital confidence, and collaborative ability, have not been extensively explored (Rahman & Widodo, 2022).

Therefore, research on coding education for early childhood learners in Indonesia is both relevant and urgent. This study is expected to provide empirical contributions by bridging the gap between national policy and educational practice while enriching the understanding of how coding education can be effectively and sustainably integrated into Indonesia's elementary education system. Introducing coding to children not only equips them with technical abilities but also empowers them to explore creativity, think innovatively, and design solutions to future challenges. Thus, teaching coding from an early age represents a strategic investment in developing high-quality human resources capable of adapting to technological advancements and competing in an increasingly digital global landscape.

2. THEORETICAL FRAMEWORK

The theoretical framework of this study is constructed to explain how early coding education contributes to the development of children's cognitive, affective, and social abilities, as well as how contextual factors such as infrastructure readiness, teacher competence, and educational policy moderate these effects. This foundation integrates perspectives from learning theories (constructivism and social constructivism), computational thinking (CT) theory, the revised Bloom's taxonomy, innovation diffusion and policy implementation theories, and the ecological systems framework of child development. The integration of these theories provides a comprehensive understanding of the relationship between coding-based pedagogical interventions and multidimensional learning outcomes within Indonesia's transforming educational context toward the digital era.

In this study, coding education is defined as an instructional process that fosters the ability to write algorithmic instructions, understand programming logic, and design systematic solutions to problems. Meanwhile, computational thinking (CT) is conceptualized as a set of cognitive skills encompassing decomposition, pattern recognition, abstraction, and algorithmic design, core intellectual processes underlying problem-solving and computational reasoning (Wing, 2006). Furthermore, this study focuses on two main skill domains: cognitive skills (logical reasoning, problem solving, and information processing) and social-affective skills (collaboration, communication, learning motivation, and digital self-efficacy). These two domains are interrelated learning outcomes that jointly contribute to children's readiness for the challenges of the 21st century. Infrastructure readiness and teacher competence are defined as the availability of technological tools, network access, and pedagogical as well as technical capacity of teachers to effectively design and implement coding instruction.

Theoretically, coding education aligns closely with Piaget's constructivism, which emphasizes that children construct knowledge through active engagement, exploration, and manipulation of their learning environment. This is strengthened by Vygotsky's social constructivism, which underscores the importance of social interaction and scaffolding in knowledge formation. Coding activities involving group collaboration and reflective discussion thus provide opportunities for children to internalize logical and algorithmic concepts through social experiences. Moreover, Computational Thinking theory (Wing, 2006) frames coding not merely as a technical skill but as a means to cultivate systematic, analytical, and creative thinking transferable across domains such as mathematics and science.

This framework is further supported by the Revised Bloom's Taxonomy, in which coding learning encourages learners to reach higher-order thinking levels, analyzing, evaluating, and creating. Activities such as algorithm design, simulation development, and debugging compel students to think critically and reflectively about their own learning processes. From an educational policy perspective, Rogers' Diffusion of Innovation Theory (2003) and Policy Implementation Theory (Sabatier & Mazmanian, 1980) explain that the successful implementation of coding and artificial intelligence (AI) curricula is strongly influenced by perceptions of adoption at the school level, resource readiness, and teachers' implementation capacity. These frameworks expand the analysis from pedagogical effectiveness to systemic and institutional dynamics. Similarly, Bronfenbrenner's Sociocultural-Ecological Systems Theory (1979) illustrates that the effectiveness of coding education cannot be separated from cross-level interactions, from macro-level contexts (national policy and curriculum), to meso-level (school and community), and micro-level (classroom and family).

Empirical evidence from developed countries demonstrates that early coding education significantly enhances computational thinking, problem-solving ability, and interest in STEM fields (Bers, 2020; Kafai & Burke, 2022). These studies highlight the effectiveness of project-based and game-based learning approaches that foster emotional engagement and curiosity among children. Findings from Starkey and Popat (2019) and Turan and Aydoğdu (2020) reveal a positive transfer effect between coding and mathematical skills when coding materials are conceptually integrated with logical and mathematical pattern operations. Moreover, Başaran et al. (2025) highlight the emergence of social-affective competencies such as collaboration and communication that naturally develop through group coding projects. However, in developing contexts such as Indonesia, empirical literature remains scarce and predominantly descriptive, focusing mainly on implementation challenges. Common barriers include gaps in digital infrastructure, limited teacher competence, and misalignment between curricular policies and actual school conditions (Putra et al., 2023).

Methodological limitations also persist in existing studies. Many employ pre-post designs without control groups, making it difficult to isolate the pure effects of coding education on learning outcomes. While qualitative studies provide rich insights into learning experiences, they lack empirical generalizability. Moreover, affective dimensions such as motivation, digital confidence, and collaboration are rarely measured quantitatively with culturally validated instruments. Thus, significant research gaps remain in contextual, affective, and methodological dimensions.

Based on this synthesis of theoretical and empirical evidence, the present study proposes a conceptual model that illustrates the relationship between coding education as the independent variable and children's learning outcomes as the dependent variable, covering three major domains: cognitive (computational thinking, problem solving, mathematical ability), affective (motivation and digital self-efficacy), and social (collaboration and communication). These relationships are mediated by pedagogical methods, particularly project-based and collaborative learning approaches, and moderated by infrastructure readiness, teacher competence, and school policy support. The model emphasizes that the success of coding education depends not solely on curricular content but on the synergistic interaction between pedagogical components and the broader educational ecosystem.

This study thus occupies a strategic position in filling the literature gap by providing contextual empirical evidence from Indonesia on the impact of early coding education on children's cognitive, affective, and social domains. It also contributes theoretically by integrating learning theories, computational thinking, and policy frameworks into a unified conceptual model that explores how and under what conditions coding education can be implemented effectively, sustainably, and inclusively. Through a stronger methodological approach, such as a longitudinal quasi-experimental design, this research aims to advance scientific understanding of the role of coding education in shaping a digitally literate, critical, creative, and collaborative generation aligned with the vision of *Indonesia Emas 2045*.

3. METHOD

The method used in this study is a literature review, which serves as a systematic approach to collecting, analyzing, and interpreting written sources related to the research topic. This method not only focuses on understanding and analyzing the substantive content (such as theories and methodologies) from various references but also involves a critical assessment of the validity, relevance, and contribution of each source to the discussion. The sources reviewed include academic texts, scholarly articles, research reports, books, and policy documents, all of which were selectively chosen to ensure credibility and analytical depth (Ardiana et al., 2021), particularly in describing coding education policies. This method was chosen because it allows the researcher to explore, evaluate, and synthesize both theoretical and empirical sources comprehensively in relation to the research topic.

The process began with identifying the research question, namely: how can coding education equip young generations with the digital skills needed for the future? The focus was placed on its cognitive benefits, social impacts, and relevance to educational policy. The literature search was conducted systematically through reputable academic databases such as Google Scholar, ERIC, and ScienceDirect, using relevant keywords. The inclusion criteria required that publications be indexed and published within the last ten years to ensure the relevance and currency of the data.

Subsequently, the selected sources were analyzed qualitatively to identify key themes, including: (1) The Importance of Early Coding Education, (2) Educational Policy Implications and Future Digital Skills, and (3) Challenges and Solutions in Implementing Coding Education. The analysis employed a comparative narrative approach, enabling the researcher to compare findings across different contexts, such as variations in implementation between developed and developing countries.

FINDINGS AND DISCUSSION

The Importance of Early Coding Education

Based on the reviewed literature, coding education for children holds critical importance in a world increasingly dominated by technology. Teaching children about coding or programming from an early age does not merely equip them with technical skills; it also opens opportunities to develop critical thinking, problem-solving abilities, and creativity. Data suggest that children exposed to coding education at an early age experience improvements in several key competencies, such as:

Problem-Solving and Logical Thinking Skills

Coding education plays a vital role in fostering children's cognitive development, particularly in sharpening their problem-solving and logical reasoning capacities. Through the process of programming, children engage in analytical thinking—identifying problems, designing step-by-step solutions, testing them, and reflecting on errors to achieve optimal outcomes. This cyclical process mirrors the scientific method, allowing learners to cultivate persistence, accuracy, and metacognitive awareness. Moreover, coding inherently demands a structured way of thinking, since programming languages operate on precise rules and logical frameworks. As a result, children internalize mathematical reasoning patterns and systems thinking applicable beyond computer science (Stamatios Papadakis et al., 2022).

Research underscores that coding activities stimulate higher-order thinking skills, including critical analysis and deductive reasoning, as learners break down complex challenges into manageable subproblems (Kanbul & Uzunboylu, 2017). This process aligns closely with the concept of computational logic, which underpins digital literacy and modern scientific inquiry. In this sense, coding is more than a technical competence—it is a fundamental cognitive skill that trains individuals to reason systematically and algorithmically (Demir, 2021). Furthermore, such training nurtures computational thinking, a mindset essential for navigating and solving technology-driven problems in contemporary life (Çiftci & Bildiren, 2020). Hence, early exposure to coding lays the foundation for rational thinking and systematic decision-making across multiple disciplines.

Enhancement of Computational Thinking

Computational thinking, as conceptualized by Wing (2006), refers to the mental process of formulating problems and their solutions in a form that can be effectively executed by a computer. It involves decomposition, abstraction, pattern recognition, and algorithmic design (Rosadi et al., 2020). Coding serves as a direct medium to cultivate this mode of thought because it requires students to translate abstract ideas into structured instructions. Beyond programming, computational thinking fosters a mindset that is transferable to other cognitive domains—enabling learners to analyze data, model real-world phenomena, and reason logically across diverse academic contexts.

Empirical studies reveal that children engaged in coding are more adept at applying mathematical and scientific concepts to practical problems, thereby bridging the gap between theory and practice (Starkey & Popat, 2019). For example, when coding simulations or digital experiments, students apply arithmetic logic, geometry, and causal reasoning to observe outcomes in real time. This pedagogical process enhances cognitive flexibility and encourages interdisciplinary learning, allowing students to perceive problem-solving as a holistic endeavor (Kocaman, 2023). Moreover, coding nurtures algorithmic literacy through iterative testing and debugging, reinforcing accuracy, patience, and reflective judgment (Kemendikdasmen, 2025). Thus, computational thinking cultivated through coding becomes a core literacy in the 21st century, parallel in importance to reading, writing, and numeracy (Turan & Aydoğdu, 2020).

Development of Creativity and Imagination

Beyond logical reasoning, coding education nurtures creativity and imagination by providing children with tools to construct digital artifacts such as games, animations, and interactive applications. This process transforms learning into an exploratory, design-oriented experience, where students combine logic and artistry to produce original work. Unlike rote learning, coding encourages creative experimentation, allowing learners to explore multiple solutions, test hypotheses, and innovate through trial and error. It also stimulates intrinsic motivation, as students experience the tangible outcomes of their ideas in real-time (Turan & Aydoğdu, 2020).

Stamatios Papadakis et al. (2022) emphasize that early exposure to coding and robotics not only enhances cognitive and linguistic development but also contributes to socio-emotional growth. By engaging in collaborative digital projects, children learn communication, empathy, and teamwork—skills essential in today's interconnected world. Furthermore, creativity in coding fosters divergent thinking, enabling learners to approach challenges from multiple perspectives and to envision novel solutions (Stamatis Papadakis, 2021). In this sense, coding education operates as a bridge between logic and imagination, cultivating well-rounded innovators who can navigate both technological and human-centered problem spaces.

Readiness for the Digital Era

The integration of coding and artificial intelligence (AI) education within Indonesia's national curriculum is a forward-looking policy designed to equip future generations with the competencies required for the digital age. This initiative aligns with the broader agenda of developing a technologically literate society capable of adapting to and leading innovation in a globalized economy (Kemendikdasmen, 2025). Coding education thus functions as both a pedagogical strategy and a socio-economic imperative, linking education with workforce readiness and national competitiveness.

Children who acquire coding skills early gain a critical advantage in terms of digital adaptability, creativity, and resilience. These competencies are indispensable for navigating future job markets shaped by automation, data analytics, and AI integration (Fathurrohman et al., 2022). Research by Başaran et al. (2025) shows that exposure to coding from an early age enhances not only technical proficiency but also future-oriented learning dispositions, such as curiosity, collaboration, and innovation. Consequently, coding education serves as a cornerstone of digital citizenship, preparing students not just to use technology effectively but to shape its development ethically and sustainably. With sustained policy support, cross-sector collaboration, and equitable access, coding education in Indonesia can play a transformative role in realizing the national vision of "Indonesia Emas 2045."

Educational Policy Implications and Future Digital Skills

Coding education is not merely about learning to write computer code—it is a transformative pedagogical tool that fosters both logical and creative thinking, two of the most essential cognitive capacities in a world increasingly dependent on digital technology. It teaches not only syntax and logic but also persistence, abstraction, and problem decomposition—skills that form the foundation of computational thinking (Wing, 2006). In the Indonesian context, the government's initiative to include Coding and Artificial Intelligence (AI) as integral components of the basic education curriculum demonstrates a forward-looking vision to prepare the younger generation for an innovation-driven society. This policy aligns with the national long-term development framework, the Indonesia Emas 2045 Vision, which emphasizes digital transformation as a cornerstone of economic and human capital advancement (Prabowo Subianto & Gibran Rakabuming Raka).

This educational reform represents not only a curricular innovation but also a strategic response to global technological shifts. By embedding coding in formal education, Indonesia aims to cultivate a generation capable of critical innovation, digital creation, and ethical technology use, bridging the gap between technological literacy and national competitiveness. Coding education thus functions as an interdisciplinary connector that strengthens the quality of STEM (Science, Technology, Engineering, and Mathematics) learning, fostering integrative thinking and problem-solving across fields (Kemendikdasmen, 2025). When implemented effectively, it enhances both the nation's technological sovereignty and its capacity to compete in global markets increasingly shaped by artificial intelligence and automation.

Curriculum

The Coding and AI curriculum is designed as a dynamic and adaptive framework aligned with rapid technological developments and the diverse learning needs across educational levels. According to Law No. 20 of 2003 on the National Education System, a curriculum should encompass not only objectives and content but also pedagogical strategies and assessment mechanisms aimed at achieving holistic learning outcomes. In this regard, the Coding and AI curriculum is constructed on the principle of progressive competency development, where learning outcomes evolve from basic digital understanding in elementary schools to advanced computational problem-solving in secondary education.

Beyond technical knowledge, the curriculum integrates co-curricular and extracurricular dimensions, emphasizing computational thinking, ethical digital behavior, and social responsibility in technology use. This is particularly crucial in preparing students not only as competent coders but as digitally literate citizens who can evaluate and create technology responsibly. The teaching methodologies recommended—problem-based learning, project-based learning, inquiry-based learning, and gamification—reflect constructivist and experiential learning theories, which position students as active participants in constructing knowledge rather than passive recipients (Kemendikdasmen, 2025).

Digital learning tools, online collaborative platforms, and authentic assessment models such as performance-based evaluation and competency certification ensure that learning remains both relevant and measurable. The integration of these elements underscores the curriculum's dual purpose: fostering creativity and ensuring technological adaptability as part of lifelong learning in the digital era.

Teacher Qualification and Competence

Teacher competence stands at the heart of successful Coding and AI education. Teachers act as facilitators of computational thinking, bridging abstract programming concepts with real-world problem-solving. In alignment with Ministerial Regulation No. 16/2007, educators are required to possess at least a D4/S1 qualification and demonstrate proficiency across four domains—pedagogical, personal, social, and professional competencies. However, in the context of coding education, additional expertise is demanded: mastery of digital literacy, algorithmic logic, and fundamental AI principles (Kemendikdasmen, 2025).

At the elementary level, teachers are expected to introduce coding concepts in an intuitive and playful manner, promoting curiosity and digital ethics. At the secondary level, the focus expands to algorithmic problem-solving, data-driven reasoning, and applied AI practices. The development of these competencies requires ongoing professional growth through structured capacity-building programs, including workshops, Bimbingan Teknis (Bimtek), peer mentoring, and partnerships with academic institutions or technology industries.

The pedagogical role of the teacher thus shifts from that of an information provider to a learning architect—a professional capable of designing engaging, student-centered learning ecosystems. Moreover, reflective teaching practices and collaborative communities of practice foster a culture of continuous innovation and adaptability, essential for sustaining relevance in a rapidly evolving digital landscape.

Implementation Strategy

The implementation of Coding and AI education in Indonesia adopts a phased and adaptive model to accommodate disparities in regional infrastructure, teacher readiness, and access to technological resources. In its initial phase, the program prioritizes schools with adequate digital facilities and trained teachers to serve as pilot institutions. This gradual rollout allows for iterative refinement of pedagogical strategies and resource distribution before nationwide expansion (Kemendikdasmen, 2025).

Key to the strategy's success are capacity-building initiatives and multi-stakeholder collaboration. Partnerships with global technology companies such as Google, Microsoft, and local tech ecosystems enhance resource sharing, professional development, and innovation transfer. Additionally, universities and teacher training institutions play a critical role in ensuring the academic rigor and sustainability of the initiative.

Continuous monitoring and evaluation mechanisms are integrated to measure both learning outcomes and policy effectiveness. These include assessments of student competency growth, teacher performance, and infrastructure utilization. Data-driven insights from these evaluations inform policy refinement, ensuring that implementation remains evidence-based and contextually responsive. Ultimately, this approach aims to create a self-sustaining educational ecosystem where technological literacy and innovation culture become integral to Indonesia's national education identity.

Challenges and Solutions in Implementing Coding Education

The implementation of coding education in Indonesia faces several challenges, primarily related to infrastructure and teacher capacity. Adequate infrastructure, such as computers, hardware, and stable internet connectivity, is still unevenly distributed across regions. Sarjito (2024) noted that infrastructure inequality in Papua has significantly affected educational access, while Ahmed et al. (2021) highlighted that limited investment in digital facilities has widened the educational gap. Similarly, Tambaip et al. (2025) emphasized the shortage of staff and resources in remote areas. Teacher competence in coding instruction remains another major challenge. Windiarti et al. (2023) found that low technological pedagogical competence hinders innovation in AI and coding-based education. To address these challenges, several comprehensive solutions are proposed:

Infrastructure Enhancement

One of the most pressing challenges lies in the unequal distribution of digital infrastructure—including access to computers, adequate hardware, electricity, and reliable internet connectivity. While urban schools in Java and major cities benefit from government-supported digitalization programs, many rural and remote regions still lack basic technological facilities. Sarjito (2024) reported that infrastructure disparities in Papua have significantly limited students' access to digital learning environments, creating a widening gap in educational equity. Similarly, Ahmed et al. (2021) observed that insufficient investment in digital infrastructure exacerbates existing socioeconomic inequalities, as technological access increasingly determines educational opportunities.

The digital divide also affects the consistency of learning outcomes and the scalability of coding initiatives. Tambaip et al. (2025) further emphasized that limited human resources and technical support staff in rural areas impede maintenance and sustainability of educational technology programs. To mitigate this, infrastructure development must be re-envisioned as part of a national digital inclusion strategy rather than isolated school-level initiatives.

Proposed solutions include public–private partnerships that leverage corporate social responsibility (CSR) funds for technology provision, the utilization of renewable energy sources to support power sustainability in off-grid areas (Amalia et al., 2024), and the adoption of cloud-based educational technologies to reduce dependence on local hardware (Arsal et al., n.d.). Programs such as the School Digitalization Initiative and BAKTI Internet Expansion for underserved regions are promising steps toward ensuring equitable access to digital learning infrastructure.

Teacher Training and Capacity Building

The success of coding education is profoundly dependent on teacher preparedness, particularly in terms of technological pedagogical content knowledge (TPACK). Windiarti et al. (2023) identified that the limited pedagogical integration of digital tools remains a major barrier to innovation in AI and coding instruction. Many teachers are proficient in general pedagogy but lack confidence in applying computational thinking principles and coding concepts in classroom settings.

This issue highlights a mismatch between curriculum expectations and teacher capability, which can undermine the quality and consistency of coding instruction. To address this, continuous professional development (CPD) must become a central pillar of implementation. National initiatives such as Bimbingan Teknis (Bimtek), certification programs, and partnerships with global technology companies (e.g., Google for Education, Microsoft Education) should be expanded to strengthen teachers' competence.

Capacity-building should also emphasize peer collaboration and reflective practice, allowing teachers to share best practices and co-develop instructional resources. Embedding coding and AI modules in teacher education programs (LPTK) can further institutionalize competence from pre-service levels. In addition, incentives and career advancement pathways linked to digital teaching excellence could motivate teachers to engage in lifelong learning.

Integration of Innovative Learning Models

Beyond infrastructure and teacher competence, pedagogical adaptability determines how effectively coding education translates into meaningful learning outcomes. Traditional, theory-heavy instruction often fails to sustain students' engagement or stimulate creative problem-solving. Thus, integrative and experiential learning models are essential.

Combining STEAM (Science, Technology, Engineering, Arts, and Mathematics) with project-based learning (PBL) offers an interdisciplinary framework that connects coding with real-world contexts (Ningsih et al., 2023). Through this model, students learn to apply coding to design prototypes, animations, or data-based solutions that reflect both analytical and creative thinking. Such approaches also encourage collaboration, communication, and critical reflection, key components of 21st-century skills (Demir, 2021).

Moreover, gamification and design thinking pedagogy can further enhance motivation and foster innovation-oriented mindsets. Integrating coding activities with local culture and community-based projects (e.g., digital storytelling, environmental data mapping) can make learning more contextual, culturally relevant, and inclusive.

Policy Consistency and Systemic Integration

Despite strong policy direction, inconsistent implementation remains a challenge. Variations in regional governance capacity, budget allocation, and bureaucratic coordination often result in fragmented execution. Ensuring sustainability therefore requires policy coherence across national, provincial, and school levels. Clear standards for curriculum delivery, teacher training, and performance evaluation must be institutionalized.

Regular monitoring and evaluation mechanisms can provide evidence-based feedback to refine implementation strategies. This aligns with adaptive policy frameworks advocated by UNESCO (2023), which emphasize flexibility and iterative improvement in digital education reform.

Ultimately, addressing these challenges demands a multi-stakeholder, ecosystemic approach. The integration of government agencies, private industries, universities, and civil society organizations can foster synergy in resource mobilization and innovation diffusion. By aligning investments, training, and curriculum development under a shared national vision, Indonesia can bridge the digital divide and realize equitable access to quality coding education.

Through these strategies—enhancing infrastructure, strengthening teacher competence, innovating pedagogy, and ensuring policy coherence—Indonesia is positioned to transform coding education into a sustainable catalyst for human capital development. This comprehensive approach not only addresses technical and institutional barriers but also nurtures a generation of digitally literate, creative, and globally competitive learners ready to shape the future of Indonesia Emas 2045.

CONCLUSION

Coding education holds significant urgency in preparing younger generations to face the challenges of the digital era. Based on the literature review, early coding education not only teaches technical programming skills but also enhances cognitive abilities such as logical thinking, problem-solving, and creativity. Moreover, coding fosters social skills through collaboration in group projects while equipping students with essential digital literacy for the future.

The Indonesian government's policy of integrating Coding and Artificial Intelligence (AI) subjects into the primary and secondary education curriculum is a strategic step toward strengthening a competitive human resource base. The implementation of this policy encompasses three main aspects: (1) developing a competency-based curriculum, (2) improving teacher qualifications through professional training, and (3) applying a gradual implementation strategy with a multi-stakeholder approach. However, challenges such as infrastructure inequality and limited teacher competence must still be addressed through technological investment, continuous training, and industry collaboration.

Therefore, coding education is not merely a technical subject but a long-term investment in creating an adaptive, creative, and globally competitive generation. For effective implementation, synergy between the government, schools, industry, and the community is essential to ensure equitable access and high-quality learning. Through these efforts, Indonesia can harness technological advancements to enhance global competitiveness and realize the vision of “Indonesia Emas 2045.”

REFERENCES

Ahmed, M. M., AiniHaroon, H., Tambi, F., Kamal, M., & Hossain. (2021). THE CHALLENGES OF SECONDARY LEVEL BUSINESS EDUCATION IN BANGLADESH. Jurnal Pendidikan, 22(1). https://doi.org/10.33830/jp.v22i1.1431.2021

Amalia, Z., Thamrin, S., & Yanto, S. (2024). Pemanfaatan Pembangkit Listrik Tenaga Surya di Infrastruktur Militer guna Mendukung Ketahanan Energi Nasional. 9(1), 82–89.

Ardiana, D. P. Y., Mawati, A. T., Supinganto, A., Simarmata, J., Yuniwati, I., Adiputra, I. M. S., Oktaviani, N. P. W., Trisnadewi, N. W., Purba, B., & Bertha Natalina Silitonga, S. P. (2021). Metodologi Penelitian Bidang Pendidikan. Penerbit Yayasan Kita Menulis.

Arsal, M., Aulia, R., Atriani, E., Wahyuni, S., & Makassar, U. M. (n.d.). Peran teknologi cloud dalam transparansi pelaporan keuangan pada umkm. 29–37.

Başaran, M., Vural, Ö., Metin, S., & Tamur, S. (2025). Early Coding Education and its Multidimensional Impact on Preschool Development: An Analysis of ChatGPT’s Insights. International Journal of Early Childhood. https://doi.org/DOI:10.1007/s13158-024-00411-3

Çiftc, S., & Bildiren, A. (2020). The effect of coding courses on the cognitive abilities and problem-solving skills of preschool children. Computer Science Education, 30(1). https://doi.org/https://doi.org/10.1080/08993408.2019.1696169

Demİr, Ü. (2021). The Effect of Unplugged Coding Education for Special Education Students on Problem-Solving Skills. International Journal of Computer Science Education in Schools, 4(3). https://doi.org/10.21585/ijcses.v4i3.95

Dikdasmen. (2024, November 14). Abdul Mu’ti : Mapel Coding dan AI Itu Pilihan, Hanya Bagi Sekolah Yang Siap. Puslapdik.Dikdasmen. https://puslapdik.dikdasmen.go.id/abdul-muti-mapel-coding-dan-ai-itu-pilihan-hanya-bagi-sekolah-yang-siap/

Fathurrohman, Dikananda, F., Hakim, A., & Hardani, A. A. (2022). Pelatihan Coding Dasar untuk Siswa Sekolah Menengah sebagai Upaya Penguatan Kompetensi Digital. AMMA : Jurnal Pengabdian Masyarakat, 1(3), 266–280.

Firat, Y. (2018). The Importance of Coding and Impacts to a Country Development in Computer Technology Teaching. Conference: 1ST INTERNATIONAL CONGRESS ON NEW HORIZONS IN EDUCATION AND SOCIAL SCIENCES (ICES).

Kanbul, S., & Uzunboylu, H. (2017). Importance of coding education and robotic applications for achieving 21st-century skills in north cyprus. International Journal of Emerging Technologies in Learning, 12(1), 130–140. https://doi.org/10.3991/ijet.v12i01.6097

Kemendikdasmen. (2025). Naskah Akademik Pembelajaran Koding dan Kecerdasan Artifisial Pada Pendidikan Dasar dan Menengah. Badan Standar, Kurikulum, dan Asesmen Pendidikan Kementerian Pendidikan Dasar dan Menengah.

Kocaman, B. (2023). The Effect of Coding Education on Analytical Thinking of Gifted Students. International Journal of Educational Methodology, 9(1), 95–106.

NG, W. S. (2017). Coding education for kids: What to learn? How to prepare teachers. In L. MORRIS & C. TSOLAKIDIS (Eds.), The Proceedings of the International Conference on Information Communication Technologies in Education. Southampton Solent University.

Ningsih, P., Alkhasanah, N., Isnaini, Y., Maulana, I., Hidayati, Y., & Desstya, A. (2023). Penerapan Model Project Based Learning Dengan Pendekatan TPACK Pada Pembelajaran IPA. Jurnal Ilmiah Pendidikan Citra Bakti, 10(4). https://doi.org/https://doi.org/10.38048/jipcb.v10i4.1904

Papadakis, Stamatios, Kalogiannakis, M., & Gözüm, A. İ. C. (2022). Editorial: STEM, STEAM, computational thinking, and coding: Evidence-based research and practice in children's development. Frontiers in Psychology, 13. https://doi.org/https://doi.org/10.3389/fpsyg.2022.1110476

Papadakis, Stamatis. (2021). The Impact of Coding Apps to Support Young Children in Computational Thinking and Computational Fluency . A Literature Review. Frontiers in Education, 6(June), 1–12. https://doi.org/10.3389/feduc.2021.657895

Print, M. (2020). Curriculum Development and Design. Taylor & Francis.

Rosadi, M. E., Wagino, W., Alamsyah, N., Rasyidan, M., & Kurniawan, M. Y. (2020). Sosialisasi Computational Thinking untuk Guru-Guru di SDN Teluk dalam 3 Banjarmasin. Jurnal SOLMA, 9(1).

Sarjito, A. (2024). Dampak Topografi Sulit dan Rendahnya Persebaran Penduduk Terhadap Ketersediaan Pelayanan Publik di Papua. Publisitas: Journal of Social Sciences and Politics, 11(1), 47–60.

Undang-undang (UU) Nomor 20 Tahun 2003 tentang Sistem Pendidikan Nasional, Peraturan.bpk.go.id (2003). https://doi.org/10.24967/ekombis.v2i1.48

Starkey, L., & Popat, S. (2019). Learning to code or coding to learn? A systematic review. Computers & Education, 128. https://doi.org/https://doi.org/10.1016/j.compedu.2018.10.005

Tambaip, B., Tjilen, A. P., & Ohoiwutun, Y. (2025). Transformative Leadership in Equitable Public Management: Advancing Educational Access and Quality in South Papua. Journal of Ecohumanism, 4(2). https://doi.org/https://doi.org/10.62754/joe.v4i2.6424

Turan, S., & Aydoğdu, F. (2020). Effect of coding and robotic education on pre-school children's skills of scientific process. Education and Information Technologies, 25(5), 4353–4363. https://doi.org/10.1007/s10639-020-10178-4