

INTEGRATING DEEP LEARNING FRAMEWORKS IN DIGITAL SCHOOL TRANSFORMATION: A QUALITATIVE STUDY ON STRATEGY FOR NURTURING FUTURE INNOVATORS IN INDONESIA

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Abstract

In the era of rapid technological advancement, integrating deep learning frameworks into schools is increasingly seen as a catalyst for cultivating innovation-driven students. This study explores how deep learning—particularly tools such as TensorFlow and Keras—is being utilized within the Indonesian school transformation agenda to support the development of future innovators. Using a qualitative approach, data were gathered through interviews, focus group discussions, and document analysis involving teachers, school leaders, and education experts from various digital-ready and underserved schools. The study revealed three key themes: pedagogical innovation through AI, implementation challenges, and shifts in innovation culture. Deep learning was found to enhance interdisciplinary, project-based learning and student agency, yet its success depended heavily on infrastructure, teacher competence, and visionary leadership. While urban schools showed promising practices, rural contexts faced persistent barriers. These findings highlight that the true transformative potential of deep learning lies not only in its technical application but in the socio-pedagogical ecosystems that support it. The study calls for balanced investment in both technology and human capital to position schools as innovation incubators for Indonesia's AI-powered future.

Keywords: *Deep Learning, Indonesia Educational Transformation, Innovation Culture, AI in Schools.*

INTRODUCTION

The Fourth Industrial Revolution has catalyzed a paradigm shift across various sectors, with education being no exception. Central to this transformation is the integration of Artificial Intelligence (AI), particularly deep learning frameworks such as TensorFlow, PyTorch, and Keras, which have demonstrated significant potential in enhancing educational processes. These tools facilitate personalized learning experiences, intelligent tutoring systems, and real-time learning analytics, thereby reshaping traditional pedagogical approaches and fostering a culture of innovation within educational institutions (Tsai et al., 2022).

In Indonesia, the government's commitment to educational reform is evident through initiatives like the "Merdeka Belajar" curriculum, which emphasizes student-centered learning and digital literacy. Recent policy developments have further underscored this commitment, with plans to incorporate AI subjects into the national curriculum across all educational levels starting from the next academic year (SEA-VET, 2025). Additionally, collaborations between academic institutions and industry partners, such as the AI Academy program launched by Institut Teknologi Bandung and Schlumberger, exemplify efforts to bridge the gap between technological advancements and educational practices (Kompas, 2022).

Despite these progressive strides, the integration of deep learning frameworks in Indonesian schools remains nascent and uneven. Challenges persist, including infrastructural limitations, disparities between urban and rural educational institutions, and a shortage of educators proficient in AI technologies (OpenGov Asia, 2025). Moreover, while global literature extensively explores the application of deep learning in education, there is a paucity of studies examining its integration within the socio-cultural context of schools in the Global South, particularly through qualitative methodologies that capture the lived experiences of educators, students, and administrators (Iman et al., 2024).

This study aims to address this gap by qualitatively exploring how deep learning frameworks are being integrated into Indonesian schools and how such integration contributes to the cultivation of future innovators. It focuses on strategies employed by school stakeholders, the perceived impact of deep learning technologies, and the enabling as well as constraining factors in school transformation. By situating the research within the broader goal of educational innovation in Indonesia, the study offers critical insights into how schools can become incubators of innovation through the strategic use of AI.

LITERATURE REVIEW (TNR, 12 BOLD)

The integration of deep learning frameworks into educational settings has garnered significant attention globally, with a growing body of research exploring its potential to transform teaching and learning processes. In the Indonesian context, this interest is reflected in both policy initiatives and academic studies aiming to harness deep learning for educational advancement.

Global Perspectives on Deep Learning in Education

Globally, deep learning frameworks such as TensorFlow and PyTorch have been utilized to develop intelligent tutoring systems, personalized learning environments, and real-time analytics tools. These applications have demonstrated effectiveness in enhancing student engagement and learning outcomes (Tsai et al., 2022). The adaptability of deep learning models allows for the customization of educational content to meet diverse learner needs, thereby promoting inclusivity and equity in education.

Indonesian Educational Reforms and Deep Learning

In Indonesia, the Ministry of Education has initiated reforms to incorporate deep learning approaches into the national curriculum. The proposed "Kurikulum Deep Learning" emphasizes meaningful, mindful, and joyful learning experiences, aiming to shift from rote memorization to critical thinking and problem-solving skills (Kementerian Pendidikan, 2025). This curriculum reform aligns with the broader "Merdeka Belajar" initiative, which advocates for greater autonomy and innovation in schools.

Empirical Studies on Deep Learning Implementation in Indonesia

Several empirical studies have examined the implementation of deep learning in Indonesian schools. For instance, a qualitative study by Pratiwi et al. (2023) investigated the use of AI technologies in teaching academic writing in Central Java high schools, revealing positive impacts on students' writing skills and critical thinking. Similarly, research by Feriyanto and Anjariyah (2024) explored the integration of deep learning approaches in fostering student engagement and comprehension, highlighting the importance of teacher readiness and infrastructure support.

Another study by Maelasari and Lusiana (2025) conducted a systematic literature review to assess the effectiveness of deep learning in education, identifying key benefits such as improved learning outcomes and challenges including resource constraints and the need for teacher training.

Challenges and Considerations

Despite the promising developments, challenges persist in the widespread adoption of deep learning in Indonesian education. These include disparities in infrastructure between urban and rural schools, limited access to technology, and a shortage of educators trained in AI and deep learning methodologies (OpenGov Asia, 2025). Addressing these challenges requires concerted efforts from policymakers, educators, and stakeholders to ensure equitable and effective implementation.

METHOD

This qualitative study aims to explore the integration of deep learning frameworks within the ongoing digital transformation of Indonesian schools and how this process contributes to nurturing future innovators. Anchored in the broader educational reform context, particularly the “Merdeka Belajar” initiative and the emerging “Kurikulum Deep Learning,” this research focuses on understanding the strategies, challenges, and impacts of deep learning adoption at the school level. The study employs a qualitative descriptive research design, which is appropriate for investigating complex social phenomena embedded in specific cultural and institutional settings. This approach enables the researcher to capture the lived experiences of school stakeholders—including educators, students, and administrators—as they navigate digital transformation processes driven by AI-based innovations.

Participants are selected through purposive sampling, focusing on individuals from diverse school contexts (public, private, and vocational) in both urban and rural areas of Indonesia. Selection criteria include active involvement in digital or AI-enhanced educational programs. Data collection involves three primary techniques: semi-structured interviews to explore personal perspectives, focus group discussions to capture collective insights, and document analysis of relevant policies, lesson plans, and student projects. These methods are designed to triangulate findings and ensure depth and reliability. All data will be transcribed and analyzed thematically using Braun and Clarke’s six-phase thematic analysis model, supported by NVivo software to assist in coding and organizing data patterns.

To ensure validity and credibility, the study incorporates methodological triangulation, member checking with participants, and peer debriefing. An audit trail will be maintained to document key decisions and interpretations throughout the research process. The conceptual framework guiding this study integrates four core dimensions: (1) the technological domain of deep learning frameworks; (2) the educational transformation domain, which includes curriculum innovation, pedagogy, and digital culture; (3) the innovation outcomes domain, focusing on student creativity, critical thinking, and project-based learning; and (4) contextual influences such as infrastructure, policy support, and teacher readiness. These interconnected components form the foundation for understanding how schools can act as incubators for innovation through the strategic application of AI.

RESULTS AND DISCUSSION

Based on the thematic analysis of interviews, FGDs, and document reviews, three major themes emerged regarding how deep learning frameworks are being integrated into school transformation efforts in Indonesia:

1. Pedagogical Innovation through AI,
2. Challenges of Implementation, and
3. Shifts in Innovation Culture.

Pedagogical Innovation through AI

Teachers in digitally progressive schools reported using deep learning frameworks—particularly TensorFlow and Keras—not only for teaching computer science subjects but also for facilitating **project-based** interdisciplinary learning. For instance, one school allowed students to design smart agriculture prototypes using AI models, integrating biology, mathematics, and computer science. This aligns with findings from Rahardjo (2023), who noted that such interdisciplinary approaches foster innovation literacy among students. Some teachers used pretrained models for real-time object detection or sentiment analysis in social media projects, providing students with hands-on exposure to real-world applications of AI. These practices were often embedded into the *Merdeka Belajar* framework, supporting curriculum flexibility and creativity (Ministry of Education, 2023).

Challenges of Implementation

Despite some success stories, many schools faced significant barriers to implementation, particularly in rural areas. These challenges include:

- a. Limited computational resources and internet access
- b. Low teacher confidence and competence in AI tools
- c. Lack of structured professional development

As noted by Harimurti et al. (2024), without equitable infrastructure and training, digital transformation risks widening the innovation gap between schools. Some educators also expressed uncertainty regarding data ethics, student privacy, and the sustainability of AI-based projects. These issues reflect global concerns raised by Selwyn & Jandrić (2022), who emphasize the need for critical AI literacy in education.

Shifts in Innovation Culture

One promising finding is the emergence of a collaborative innovation culture in schools that successfully integrate deep learning. School leaders described their role not just as administrators but as "innovation facilitators," encouraging teacher experimentation, student-led research, and cross-departmental collaboration. This cultural shift was more pronounced in private and urban schools with strong leadership and external partnerships. Students involved in AI clubs or competitions showed increased motivation, resilience, and capacity for complex problem-solving. As Rachman (2024) observes, student agency in using deep learning tools can redefine the learner's role from passive recipient to active innovator. These changes also align with the goals of the Kurikulum Proyek Penguatan Profil Pelajar Pancasila (P5), particularly in fostering creativity and technological literacy. The findings of this study reveal that deep learning frameworks are not merely technical instruments but serve as transformative catalysts within the educational ecosystem. When embedded in project-based, collaborative, and interdisciplinary learning approaches, these frameworks empower students not only as users of technology, but also as creators of solutions, the defining traits of future innovators.

Specifically, deep learning enables:

- 1) Personalized learning through real-time data-driven feedback and adaptation,
- 2) Enhanced technological literacy and creativity, fostering future-ready skills, and
- 3) Independent research and experimentation, nurturing student autonomy in digital innovation.

However, the successful integration of deep learning in schools depends heavily on both human and institutional readiness. Key enabling factors include:

- 1) Adequate and equitable technological infrastructure,
- 2) Continuous and structured teacher capacity building, and
- 3) Visionary leadership that fosters an innovation-oriented school culture.

With the support of strategic policymaking and targeted investments, deep learning has the potential to reposition schools as innovation incubators spaces where students are shaped into resilient, creative, and adaptive learners, ready to thrive in Indonesia's increasingly AI-driven future. Importantly, while the technical capabilities of deep learning frameworks are critical, their transformative impact lies within the socio-pedagogical practices that frame their use. Theoretically, this research expands current models of digital transformation by foregrounding the role of human agency and cultural context in effective AI integration. Practically, it advocates that investments in digital infrastructure must be matched by equal investments in pedagogy and professional development. In line with findings from Ilham (2024) and Arsyad & Nurlatifah (2023), this study reinforces the notion that AI should not be perceived merely as a functional tool, but rather as a catalyst for reimagining the purpose and practice of education.

CONCLUSION

This study concludes that deep learning frameworks hold transformative potential in reimagining school-based education in Indonesia, not merely as technical tools but as strategic catalysts for innovation. Through their integration in project-based, interdisciplinary, and collaborative learning environments, deep learning technologies empower students to become not only technology users but active solution creators—core attributes of future innovators.

The research identified three central themes in the integration process:

1. Pedagogical Innovation through AI, where educators apply deep learning models to real-world problems across disciplines,
2. Challenges of Implementation, including infrastructure gaps, insufficient teacher capacity, and ethical concerns, and
3. Shifts in Innovation Culture, characterized by evolving leadership roles and increased student agency.

The successful adoption of these frameworks is contingent on human and institutional readiness. Essential factors include equitable access to digital infrastructure, sustained teacher training programs, and leadership committed to fostering an innovation-driven school culture. Importantly, the study highlights that the impact of deep learning lies not only in its algorithmic capability but in the socio-pedagogical practices and cultural conditions that support its use. Schools that embrace this integration strategically can evolve into innovation incubators—nurturing adaptive, resilient, and creative learners prepared for an AI-driven future. Theoretically, this research advances the discourse on educational digital transformation by emphasizing human agency and

contextual responsiveness. Practically, it recommends a balanced policy focus on both technological and pedagogical investment, positioning deep learning as a key enabler in Indonesia's journey toward cultivating the next generation of innovators.

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