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Preparing Indonesian Primary School Teachers for Deep Learning: Readiness, Challenges, and Institutional Support

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ABSTRACT
The growing influence of deep learning technologies in everyday life has created new demands for educational systems worldwide, prompting efforts to introduce basic concepts of artificial intelligence at earlier stages of learning. In Indonesia, while digital literacy initiatives are gaining momentum, the preparedness of primary school teachers to teach deep learning concepts remains largely unexplored. This study aims to investigate the readiness of Indonesian primary school teachers to teach fundamental deep learning principles, identify the challenges they face, and assess the level of institutional support available to them. A mixed methods design was employed, combining quantitative survey data from 215 teachers with qualitative insights gathered through focus group interviews. The survey measured readiness across technical, pedagogical, and institutional dimensions, while thematic analysis was used to explore deeper experiences and perspectives. The findings reveal that while teachers express strong enthusiasm and recognize the importance of introducing deep learning, their technical understanding and pedagogical confidence remain moderate. Access to training opportunities and digital infrastructure emerged as critical enablers, whereas a lack of curricular guidance and institutional support was cited as major barriers. Teacher motivation is not lacking; rather, systemic support must be strengthened to turn readiness into effective practice. Preparing teachers for deep learning education requires comprehensive strategies that integrate professional development, curriculum design, and infrastructure improvement. This study enriches the limited literature on AI education at the primary level in developing countries and offers practical recommendations for policymakers and educational stakeholders seeking to build future-ready classrooms.
Keywords: *Deep Learning, Primary School, Teacher*

INTRODUCTION

The 21st century has ushered in an era where artificial intelligence (AI) and deep learning are rapidly transforming not only industries and societies but also the ways in which knowledge is created, shared, and applied. As the backbone of many AI systems, deep learning enables machines to recognize (Alnasyan et al., 2025; Islam et al., 2025; Orka et al., 2025), make decisions, and even simulate human cognitive processes with remarkable sophistication. In response to this transformation, educational systems worldwide are beginning to recognize

that preparing students for the future requires more than traditional literacy and numeracy skills. It demands fostering a deep understanding of computational thinking, data interpretation, pattern recognition, and the ethical implications of technology from an early age (Ali et al., 2025; Kousar et al., 2025).

Historically, deep learning education has been predominantly reserved for higher education institutions, particularly within computer science, engineering, and data science programs. However, a growing number of global initiatives have begun advocating for the introduction of fundamental deep learning concepts at the primary and secondary levels. Programs such as AI4K12 in the United States and similar initiatives in countries like the United Kingdom, South Korea, and Singapore aim to demystify AI for younger learners by teaching simplified models of visual recognition, natural language processing, and pattern classification through age-appropriate activities. These efforts recognize that early exposure to complex digital concepts can cultivate critical thinking, creativity, and problem-solving abilities that are essential for thriving in a technology-driven society (Alnasyan et al., 2025; Maqsood & Yasmin, 2025).

In Indonesia, the movement toward digital innovation in education is gaining traction, especially under the government's *Merdeka Belajar* (Freedom to Learn) policy, which emphasizes flexible, student-centered, and technology-enhanced learning environments. Initiatives such as *Sekolah Penggerak* (Driving Schools) and *Digitalisasi Sekolah* (School Digitalization) reflect a national ambition to modernize teaching and learning processes, aligning them with global educational trends. Despite these positive developments, the integration of deep learning into primary education remains largely nascent. While digital literacy and basic coding have started to feature in some curricula, the more advanced concepts of machine learning and deep neural networks are still perceived as too abstract or too complex for young learners and for many educators themselves.

This emerging gap raises critical concerns about teacher preparedness. Teachers are the primary agents of curriculum delivery and innovation in the classroom (Subiyantoro, 2024). Their readiness—both in terms of technical knowledge and pedagogical confidence—determines whether ambitious policy goals can be translated into meaningful classroom practices. However, many primary school teachers in Indonesia have received limited exposure to AI concepts, let alone training in deep learning or related educational strategies. Unlike basic digital skills, which are now often included in pre-service teacher training programs, deep learning education requires a new layer of understanding: familiarity with concepts such as data sets, supervised learning, pattern recognition, bias in algorithms, and the ethical use of AI systems.

Furthermore, the challenges facing teachers are not solely individual but also systemic. Limited access to high-quality professional development programs, insufficient digital infrastructure, curriculum rigidity, and a lack of institutional leadership on emerging technologies can all inhibit the effective teaching of deep learning concepts. Rural and underserved areas face even greater barriers, exacerbating educational inequities that digital transformation initiatives often seek to address. Therefore, while the potential benefits of introducing deep learning education at the primary level are considerable, realizing this potential demands a comprehensive understanding of teachers' current readiness, the challenges they face, and the support systems available to them.

Teacher readiness in this context must be understood as a multi-dimensional construct, encompassing technical knowledge, pedagogical competence, attitudes toward innovation, and access to resources and support. Studies have shown that teacher motivation and positive attitudes towards technology are crucial but insufficient when unaccompanied by structured training and institutional backing (Ahmed et al., 2025; Wang & Gao, 2024). Readiness is not

merely about individual will; it is embedded within a broader ecosystem that includes school leadership, policy frameworks, professional development opportunities, and technological access.

Globally, there is a growing body of research examining teacher readiness for digital literacy and coding education (e.g., Blikstein, 2018), but empirical studies focusing specifically on deep learning at the primary school level are rare, particularly in developing countries. Indonesia, with its vast educational landscape and diverse socio-economic contexts, presents a critical case for exploring how deep learning education can be meaningfully integrated at the foundational stages of schooling. Understanding the current state of teacher preparedness is essential for designing targeted interventions that can bridge gaps and foster more equitable access to future-oriented education.

Against this background, the present study aims to explore the readiness of Indonesian primary school teachers to introduce and teach basic deep learning concepts to young learners. Specifically, the study seeks to assess teachers' technical knowledge, pedagogical confidence, and attitudes toward teaching deep learning; identify the challenges teachers face in integrating deep learning concepts into their instructional practices; and examine the extent and nature of institutional support available to facilitate deep learning education at the primary level. The central research questions guiding this study are:

1. What are the levels of readiness among Indonesian primary school teachers to teach deep learning concepts?
2. What challenges do teachers perceive in implementing deep learning education in primary schools?
3. How does institutional support affect teacher readiness and practice in this emerging field?

Through a mixed methods approach that combines quantitative surveys with qualitative interviews, this study aims to offer a comprehensive and nuanced portrait of the current landscape. It also seeks to contribute to the broader discourse on digital education by highlighting the specific needs and opportunities in the context of developing countries like Indonesia. By examining the interplay between individual teacher factors and systemic institutional conditions, this research aspires not only to illuminate existing barriers but also to identify strategic levers for advancing deep learning education at the primary level. In doing so, it hopes to inform policymakers, educational leaders, curriculum developers, and teacher educators on how to better support the next generation of learners in a world increasingly shaped by intelligent technologies.

METHODS

2.1 Research Design

This study employed a convergent parallel mixed methods design, combining quantitative and qualitative approaches to obtain a comprehensive understanding of Indonesian primary school teachers' readiness for teaching deep learning concepts. The rationale for adopting a mixed methods design lies in the complex nature of readiness, which encompasses not only measurable competencies but also contextual factors, personal experiences, and perceived challenges. By collecting and analyzing both forms of data concurrently, the study aimed to triangulate findings, enhance validity, and provide a more nuanced interpretation of the research problem.

2.2 Participants

Participants in the quantitative phase consisted of 215 primary school teachers from various regions across Indonesia, representing both public and private schools. A convenience sampling strategy was employed, while efforts were made to ensure diversity in terms of

teaching experience, geographic location, and educational background. For the qualitative component, 15 teachers were selected through purposive sampling based on their willingness to discuss their experiences in depth and their varying degrees of exposure to digital learning initiatives. Selection criteria included teaching experience (minimum three years), current employment in primary education, and voluntary participation in focus group discussions.

2.3 Data Collection Instruments

Quantitative data were gathered using a structured survey instrument titled the Teacher Readiness for Deep Learning Instruction Scale (TRDLIS), developed based on previous studies on digital pedagogy readiness and adapted to the Indonesian context. The survey employed a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). A pilot test conducted with 30 teachers yielded a Cronbach's alpha reliability coefficient of 0.89, indicating good internal consistency. Each focus group session lasted approximately 60–90 minutes, conducted either face-to-face or via video conferencing, depending on logistical feasibility and health protocols. The instrument comprised three major domains:

1. Technical Knowledge: familiarity with basic deep learning concepts, ability to explain AI-related ideas at an elementary level.
2. Pedagogical Readiness: confidence in designing and delivering learning activities involving deep learning ideas.
3. Institutional Support: perception of support from school leadership, availability of training, and access to digital infrastructure.

Qualitative data were collected through semi-structured focus group interviews. The interview guide included open-ended questions such as:

1. How do you understand the concept of deep learning in the context of your teaching?
2. What challenges do you face when trying to integrate deep learning into your classroom?
3. What forms of support or resources would help you feel more confident in teaching deep learning?

2.4 Data Collection Procedure

The quantitative survey was distributed online through official teacher networks, educational forums, and social media groups targeting primary school educators. Participation was voluntary and anonymous, and informed consent was obtained electronically prior to survey completion. For the qualitative phase, participants were invited after completing the survey. Those who indicated willingness to participate further were contacted individually to arrange focus group sessions. Interviews were audio-recorded with participant permission and transcribed verbatim for analysis. All research procedures adhered to ethical standards, including confidentiality assurances, the right to withdraw at any time, and secure data storage.

2.5 Data Analysis

Quantitative data were analyzed using SPSS (Version 26). Descriptive statistics (means, standard deviations, frequencies) were computed to describe overall readiness levels. To explore differences across demographic groups (gender, teaching experience, geographic location), independent samples t-tests and one-way ANOVA tests were conducted. Prior to inferential analyses, assumptions of normality and homogeneity of variance were checked.

Qualitative data from the focus groups were analyzed using thematic analysis (Braun & Clarke, 2006). The process involved:

1. Familiarization with the data through repeated readings of the transcripts.
2. Generating initial codes based on patterns and meaningful segments.

3. Searching for overarching themes reflecting readiness, challenges, and support needs.
4. Reviewing and refining themes to ensure coherence and relevance.
5. Defining and naming final themes that accurately captured participants' experiences.

The qualitative data were managed and coded using MAXQDA 2022 software to organize codes systematically and facilitate the thematic development process.

To enhance the trustworthiness of the qualitative findings, several strategies were employed:

1. Member checking: Participants were given a summary of key findings to confirm accuracy.
2. Peer debriefing: Research team members discussed emerging interpretations.
3. Audit trail: Detailed documentation of analytical decisions was maintained throughout the research process.

RESULTS AND DISCUSSION

Results

3.1 Quantitative Findings

The survey data provided valuable insights into Indonesian primary school teachers' self-reported readiness to teach deep learning concepts. The survey measured eight key items grouped under three domains: technical knowledge, pedagogical confidence, and institutional support. Table 1 presents the descriptive statistics for each item.

Table 1. Descriptive Statistics of Teacher Readiness for Deep Learning

No	Item	Mean	Std. Dev
1	Understanding of Deep Learning Basics	3.42	0.76
2	Confidence in Explaining Deep Learning Concepts	3.35	0.79
3	Ability to Integrate Deep Learning into Lessons	3.28	0.82
4	Perception of Institutional Support	2.95	0.91
5	Access to Digital Infrastructure	2.88	0.87
6	Participation in Deep Learning Training	2.76	0.85
7	Willingness to Teach Deep Learning	4.05	0.68
8	Confidence in Designing Deep Learning Activities	3.20	0.80

The highest mean score was recorded for *willingness to teach deep learning* (M = 4.05, SD = 0.68), indicating a strong positive attitude among teachers toward incorporating deep learning into their teaching practice. Conversely, *participation in deep learning training* (M = 2.76) and *access to digital infrastructure* (M = 2.88) showed the lowest mean scores, highlighting significant barriers to readiness that go beyond individual motivation.

The items measuring *technical understanding* and *pedagogical readiness*—such as *understanding of deep learning basics* (M = 3.42) and *confidence in designing learning activities* (M = 3.20)—were rated moderately, suggesting that while enthusiasm is high, substantial gaps remain in practical competencies.

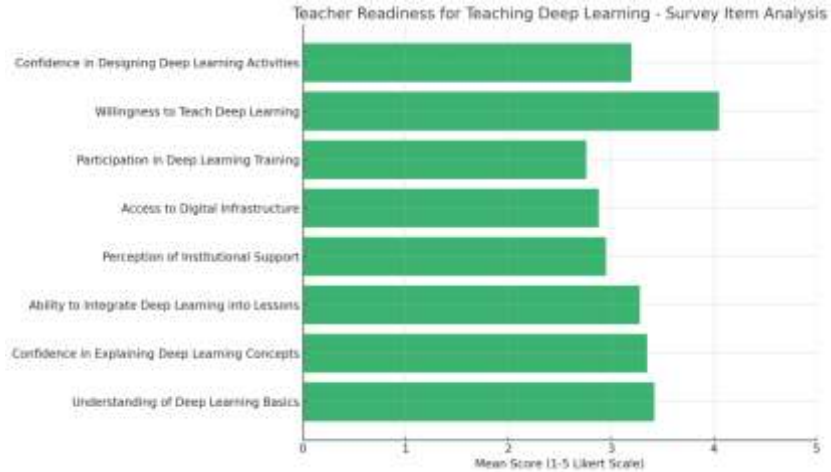

Figure 1. Teacher Readiness for Teaching Deep Learning

As illustrated in Figure 1, while willingness is evidently strong, other dimensions such as institutional support and technical training lag considerably, potentially affecting the effective implementation of deep learning education. Further statistical analyses were conducted to explore differences in readiness based on demographic characteristics such as teaching experience and geographic location.

Table 2. Teacher Readiness by Teaching Experience

Years of Experience	N	Mean Readiness	Std. Dev
1–5 years	52	3.29	0.41
6–10 years	68	3.34	0.38
11–20 years	61	3.55	0.36
>20 years	34	3.48	0.39
ANOVA			
F(3, 211) = 4.19	p = 0.007		

The one-way ANOVA revealed a statistically significant difference in readiness across teaching experience groups ($F(3, 211) = 4.19$, $p = 0.007$), with mid-career teachers (11–20 years) reporting the highest readiness levels. Post-hoc comparisons indicated that teachers with 11–20 years of experience were significantly more ready than those with less than five years of experience.

Table 3. Teacher Readiness by Geographic Location

Location	N	Mean Readiness	Std. Dev
Urban	83	3.53	0.37
Suburban	74	3.42	0.39
Rural	58	3.23	0.44
ANOVA			
F(2, 212) = 6.78	p = 0.002		

Teachers working in urban areas reported significantly higher readiness compared to their rural counterparts ($p < 0.01$). This reflects persistent infrastructural and access gaps between different regions in Indonesia.

3.2 Qualitative Findings

Thematic analysis of the focus group interviews uncovered three major themes relating to readiness, challenges, and institutional support.

Theme 1: Enthusiasm and Recognition of Deep Learning's Importance

Teachers consistently expressed a strong enthusiasm for exposing students to deep learning concepts, emphasizing the relevance of teaching young learners about pattern recognition, simple decision-making processes, and algorithmic thinking. *"If our students can understand how machines recognize objects and solve problems, they will be more prepared for the future. I think it's exciting,"* (Participant 6).

Theme 2: Lack of Conceptual Understanding and Pedagogical Models

Many teachers admitted feeling overwhelmed by the technical nature of deep learning and uncertain about how to simplify these concepts for primary school students. The lack of ready-to-use teaching models or lesson plans was a recurring concern. *"I understand the idea of machine learning a little, but how do I explain it to a third grader without using technical words? That's the challenge,"* (Participant 2).

Theme 3: Institutional Barriers and Uneven Support

Participants highlighted a scarcity of formal training programs specifically targeted at deep learning education, as well as limited administrative support for such initiatives. Teachers in rural areas particularly noted that even basic digital infrastructure was lacking, making deep learning instruction almost impossible. *"Our school has good internet, but no one talks about AI or deep learning. Training is always about basic computer skills,"* (Participant 10). *"In my village school, we don't even have stable electricity every day. Talking about AI feels like a dream,"* (Participant 14).

3.3 Integration of Quantitative and Qualitative Results

The integration of survey and interview data suggests a consistent pattern: while Indonesian primary school teachers are highly motivated to engage with deep learning education, their technical readiness and access to institutional support are moderate to low. Teachers' enthusiasm alone cannot compensate for the lack of training, resources, and leadership support necessary for implementing deep learning pedagogies effectively. The significant disparities based on teaching experience and school location also underscore the need for differentiated support strategies. Tailored professional development programs, context-sensitive curriculum resources, and targeted investments in digital infrastructure are essential to bridge these readiness gaps.

Discussion

The findings of this study offer a detailed portrait of Indonesian primary school teachers' readiness to introduce deep learning concepts into their classrooms. Although teachers express a strong willingness to embrace deep learning education, this enthusiasm is not yet matched by their technical understanding, pedagogical confidence, or institutional support (Islam et al., 2025). These results reflect a pattern observed in broader educational technology research, where positive attitudes towards innovation often coexist with significant implementation barriers.

The highest rated item in the survey—teachers' willingness to teach deep learning—indicates a crucial foundation for future progress. Motivation and openness are often identified as key precursors to successful technology adoption in education (Maqsood & Yasmin, 2025). However, motivation alone is insufficient when teachers lack the necessary

technical knowledge and practical strategies for translating abstract concepts into accessible learning experiences for young children. In this study, readiness scores related to understanding of deep learning basics and confidence in explaining concepts were only moderate, suggesting that teachers are willing but not fully equipped.

Qualitative findings reinforce this interpretation. Teachers' narratives reveal a clear recognition of deep learning's future relevance, yet a lack of clarity on how to teach it in developmentally appropriate ways. This highlights a fundamental pedagogical challenge: simplifying complex computational ideas for a primary audience. Existing global initiatives, such as AI4K12 in the United States, emphasize breaking down AI and deep learning concepts into "big ideas" that can be adapted for younger learners (Shabber et al., 2025). Indonesia currently lacks equivalent frameworks or resources, leaving teachers to improvise without adequate guidance.

Another striking finding concerns institutional support. Quantitative data show low scores for perceived institutional support and access to digital infrastructure, particularly among teachers in rural areas. The significant differences in readiness by geographic location corroborate previous research on the digital divide in Indonesian education (Antezana Lopez et al., 2025). Access to reliable technology, professional development opportunities, and leadership endorsement are not evenly distributed, creating structural inequalities that limit some teachers' ability to engage with emerging technologies like deep learning.

The importance of professional development emerged strongly from both quantitative and qualitative strands. Teachers who had participated in digital training, even if not specific to deep learning, tended to report higher confidence and readiness. This finding echoes international studies emphasizing that sustained, hands-on professional development—not one-off workshops—is essential for building deep technological pedagogical content knowledge. For deep learning education to take root at the primary level, training programs must go beyond general digital literacy to include practical strategies for scaffolding AI and deep learning concepts through age-appropriate learning activities.

Interestingly, the data also suggest that teaching experience plays a role in readiness. Teachers with 11–20 years of experience reported the highest levels of readiness, possibly because they balance classroom management expertise with a degree of openness to pedagogical innovation. Less experienced teachers, although often digitally native, may still be developing their instructional confidence, while highly senior teachers may feel more distant from emerging technology trends. This nuance highlights the need for differentiated professional development that addresses the specific strengths and challenges of teachers at various career stages.

The theme of pedagogical uncertainty surfaced strongly in the focus groups. Teachers expressed doubts about how to translate deep learning principles into tangible classroom activities without relying heavily on technical jargon. This is a significant obstacle, given that deep learning concepts—such as pattern recognition, classification, and decision-making—can, in fact, be taught through simple, non-digital activities like sorting objects or predicting outcomes based on previous examples. Without clear pedagogical models and curricular resources, however, teachers may not recognize these opportunities.

This gap between potential and practice suggests that curriculum design must play a central role in supporting teachers. A coherent, staged approach to introducing deep learning, embedded within broader digital literacy initiatives, would give teachers a scaffold to build on. Moreover, the integration of ethical discussions—such as bias in machine learning or privacy issues—into classroom conversations would help develop students' critical digital citizenship from an early age.

Finally, the study's findings point to systemic challenges. Even highly motivated teachers cannot be expected to drive deep learning education forward without support at the institutional and policy levels. Leadership at the school and district levels must actively promote the inclusion of deep learning concepts in teaching agendas, provide time for collaborative planning, invest in necessary infrastructure, and recognize the complexity of the pedagogical task involved.

In summary, this study demonstrates that while Indonesian primary school teachers are willing and increasingly aware of the importance of deep learning, significant gaps remain in technical readiness, pedagogical preparedness, and systemic support. Teacher readiness for deep learning is not merely a matter of individual effort but a collective responsibility that requires strategic interventions at multiple levels of the education system.

CONCLUSION

This study explored the readiness of Indonesian primary school teachers to teach deep learning concepts, revealing a complex interplay between high levels of motivation and moderate levels of technical and pedagogical preparedness. While teachers demonstrated strong enthusiasm and recognized the significance of deep learning for future education, they often lacked the technical understanding, practical strategies, and institutional support necessary for effective implementation. Challenges were particularly pronounced in rural areas, where digital infrastructure and training opportunities remain limited. Overall, the findings emphasize that teacher readiness for deep learning education is not solely an individual matter but is profoundly shaped by broader systemic factors, including curriculum design, professional development availability, and leadership support.

The results of this study carry important implications for educational policy, teacher education, and school leadership. Successful integration of deep learning into primary education demands a comprehensive approach that simultaneously addresses teachers' technical competencies, pedagogical adaptation skills, and access to resources. Professional development programs must be reimagined to include hands-on, context-specific training on deep learning concepts, delivered through sustained learning communities rather than isolated workshops. Furthermore, policymakers must ensure equitable infrastructure development, particularly in underserved regions, to bridge the digital divide. Embedding deep learning within the broader framework of digital literacy and 21st-century skills education will also support more coherent and meaningful classroom practices.

Based on the findings, several recommendations are proposed. First, national and local education authorities should develop structured frameworks and age-appropriate curriculum guidelines for teaching deep learning at the primary level. Second, investments in school infrastructure, especially in rural areas, must be prioritized to enable digital-based teaching and learning. Third, teacher training institutions should integrate modules on artificial intelligence and deep learning pedagogy into pre-service and in-service education programs. Finally, future research should extend this study by exploring the long-term impact of professional development interventions on teacher practices and student learning outcomes in deep learning education.

CONFLICT OF INTEREST

The authors declare no conflict of interest in conducting and publishing this research. This research contributes to the growing body of knowledge on early-stage artificial intelligence education by specifically examining the readiness of primary school teachers to introduce deep learning concepts. It addresses a significant gap in existing literature, which has largely focused on higher education or general digital literacy, by offering empirical insights from a developing country context.

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