

# DEEP LEARNING TECHNOLOGY IMPLEMENTATION IN EQUIVALENCY EDUCATION: A STUDY OF TEACHER READINESS AND STUDENTS' CRITICAL THINKING ENHANCEMENT IN WEST JAVA, INDONESIA

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**Abstract.** Critical thinking deficiency among equivalency education students in Indonesia represents an urgent challenge demanding innovative solutions. This study investigates the impact of deep learning technology on critical thinking skills among Package B and C students in West Java, Indonesia, with teacher readiness as a moderating variable. A quasi-experimental pre-test post-test control group design was employed, involving 240 students from 30 non-formal education centers randomly allocated to experimental (n=120) and control (n=120) groups, along with 60 teachers. The experimental group received instruction through a deep learning-based AI platform, while the control group used conventional methods. Critical thinking was measured using the Indonesian-adapted Watson-Glaser Critical Thinking Appraisal, and teacher readiness was assessed through a validated questionnaire. Results showed the experimental group achieved a 20.2% improvement in critical thinking scores ( $d=1.65$ ), significantly higher than the control group (5.2%;  $d=0.41$ ). Teacher readiness was the strongest predictor of implementation success ( $\beta=0.45$ ), followed by implementation duration, infrastructure support, and student motivation ( $R^2=0.68$ ). These findings demonstrate that deep learning technology effectively enhances critical thinking in non-formal education when supported by adequate teacher preparation, supporting the strategic adoption of AI platforms for educational equity.

**Keywords:** Deep Learning Technology, Critical Thinking Skills, Non-Formal Education, Equivalency Education, Teacher Readiness

**Abstrak.** Rendahnya keterampilan berpikir kritis peserta didik pendidikan kesetaraan di Indonesia menjadi permasalahan mendesak yang memerlukan solusi inovatif. Penelitian ini bertujuan menginvestigasi dampak implementasi teknologi deep learning terhadap peningkatan berpikir kritis siswa Paket B dan C di Jawa Barat, Indonesia, dengan kesiapan guru sebagai variabel moderasi. Desain kuasi-eksperimental dengan kelompok kontrol pre-test post-test digunakan, melibatkan 240 siswa dari 30 pusat pendidikan non-formal yang dialokasikan secara acak ke kelompok eksperimen (n=120) dan kontrol (n=120), serta 60 guru. Kelompok eksperimen menerima pembelajaran melalui platform AI berbasis deep learning, sementara kelompok kontrol menggunakan metode konvensional. Berpikir kritis diukur menggunakan Watson-Glaser Critical Thinking Appraisal adaptasi Indonesia, dan kesiapan guru dinilai melalui kuesioner tervalidasi. Kelompok eksperimen menunjukkan peningkatan berpikir kritis sebesar 20,2% ( $d=1,65$ ), jauh lebih tinggi dibandingkan kelompok kontrol (5,2%;  $d=0,41$ ). Kesiapan guru merupakan prediktor terkuat keberhasilan implementasi ( $\beta=0,45$ ), diikuti durasi implementasi, dukungan infrastruktur, dan motivasi siswa ( $R^2=0,68$ ). Implementasi deep learning terbukti meningkatkan berpikir kritis dalam pendidikan non-formal secara signifikan apabila didukung kesiapan guru yang memadai, sehingga mendorong adopsi strategis platform AI untuk pemerataan pendidikan.

**Kata Kunci:** Teknologi Pembelajaran Mendalam, Keterampilan Berpikir Kritis, Pendidikan Non-Formal, Pendidikan Kesetaraan, Kesiapan Guru

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## INTRODUCTION

The rapid advancement of information and communication technology over the past decade has catalyzed fundamental transformations across various sectors of human life, with the education sector experiencing particularly profound changes (Kimmons et al., 2020). The Industry 4.0 revolution demands educational systems that transcend traditional academic competency development, requiring institutions to cultivate graduates equipped with critical thinking, creativity, and adaptive capabilities essential for navigating an increasingly dynamic technological landscape (Thornhill-Miller et al., 2023). Within this transformative context, the integration of artificial intelligence technology, particularly deep learning, has emerged as a pivotal innovative solution capable of optimizing learning processes and substantially enhancing educational quality across diverse educational settings.

Deep learning, representing a sophisticated subset of machine learning and artificial intelligence, has demonstrated remarkable potential across numerous applications, spanning pattern recognition, natural language processing, and personalized learning recommendation systems (COŞKUN et al., 2017). In educational contexts, deep learning technology offers unprecedented opportunities to analyze complex student learning patterns, deliver timely and targeted feedback, and create adaptive learning environments meticulously tailored to individual student needs and preferences (Bengio et al., 2021). However, the implementation of this advanced technology within educational systems, particularly in non-formal education settings, continues to face multifaceted challenges that necessitate comprehensive investigation and strategic intervention.

Non-formal education in Indonesia, encompassing equivalency education programs Package A, B, and C, plays a strategically important role in providing equitable access for communities unable to participate in formal education (Wijayati et al., 2019). Over 2.5 million Indonesians require equivalency education services, with the majority concentrated in West Java, the most populous province (Nugraha et al., 2018). Package B and C programs serve as alternative pathways for adults, working professionals, and marginalized communities seeking quality education suited to their circumstances (Juliati et al., 2018). Despite their importance, non-formal education institutions face significant structural challenges: limited technological infrastructure, conventional teaching approaches with limited digital proficiency, and heterogeneous learner characteristics requiring flexible, personalized pedagogy (Ahmad et al., 2019; Serrano et al., 2019; Raiyn, 2016). In West Java, only 23% of the 687 equivalency education institutions have integrated digital technology, and fewer than 15% of teachers possess adequate AI-based learning competencies (Pribudhiana et al., 2021), reflecting a

critical digital divide that undermines educational equity across the region (Petko et al., 2018). One critical aspect demanding immediate attention within non-formal education is the systematic development of learners' critical thinking abilities (Al-Samarraie et al., 2020). Critical thinking, defined as the capacity to analyze, evaluate, and synthesize information objectively to make appropriate and well-informed decisions (Loes & Pascarella, 2017), represents a fundamental competency essential for successfully navigating the complexities of contemporary digital society (Lo & Hew, 2017). However, existing research indicates that critical thinking abilities among non-formal education students in Indonesia remain predominantly in low to moderate categories, with average scores of 2.4 on a standardized scale of 5 (McKnight et al., 2016).

Low critical thinking skills among students persist due to several interconnected factors: teacher-centered learning methodologies, limited variety in analytical learning media, and insufficient opportunities for students to engage in meaningful problem-solving activities (Nahar et al., 2022). These conditions critically hinder students' ability to analyze, evaluate, and synthesize information effectively in real-world contexts. Without immediate intervention, this gap will continue to widen, leaving students underprepared for the demands of the modern world. Therefore, there is an urgent need for innovative pedagogical approaches that move beyond conventional methods. Deep learning technology integration emerges as a particularly promising solution, offering dynamic, adaptive, and context-rich learning environments capable of actively stimulating higher-order thinking. Addressing this issue promptly is not merely an academic priority but a necessity to equip students with the critical competencies required in an increasingly complex and competitive global landscape.

Deep learning technology offers numerous advantages specifically relevant to addressing persistent challenges in non-formal education settings (Wang & Raj, 2017). First, deep learning's sophisticated capability to perform complex learning pattern analysis enables highly accurate identification of individual student learning styles, preferences, and cognitive strengths (Reynders et al., 2020). This technological capacity proves especially valuable given the heterogeneous characteristics of non-formal education learners who require personalized approaches that accommodate their diverse backgrounds and learning needs. Second, deep learning technology facilitates the implementation of adaptive learning systems that automatically adjust material difficulty levels, learning pace, and instructional delivery strategies based on real-time assessment of individual student abilities and academic progress (Kardoyo et al., 2020). These intelligent systems can provide appropriate scaffolding mechanisms that systematically encourage students to develop critical thinking skills through

carefully designed challenging questions and scenarios directly relevant to their lived experiences and practical contexts. The success of deep learning implementation in non-formal education environments depends fundamentally on teacher readiness and competency development as effective learning facilitators (Lynch et al., 2017). Teacher readiness encompasses not only technical proficiency in operating sophisticated technological tools but also comprehensive pedagogical understanding of how to strategically integrate deep learning technology to achieve optimal learning objectives and student outcomes.

Based on the Technology Acceptance Model (TAM) framework, teacher readiness to adopt advanced educational technology is significantly influenced by perceived usefulness and perceived ease of use (Kirschner, 2015). In deep learning contexts, perceived usefulness relates directly to teachers' perceptions regarding the tangible benefits of this technology in enhancing overall learning effectiveness and measurable student learning outcomes (Sharma & Chaudhary, 2023). Meanwhile, perceived ease of use encompasses teachers' confidence in their ability to learn, master, and consistently utilize deep learning technology within their instructional practice.

As Indonesia's most populous province, West Java faces unique challenges in delivering equitable non-formal education across its 18 regencies and 9 cities, where rapid urbanization and diverse socioeconomic conditions make quality education difficult to access for all communities. Data from the West Java Central Statistics Agency indicates approximately 1.2 million productive-age residents have not completed basic and secondary education, with 45% working in informal sectors requiring flexible learning schedules, 28% being housewives with significant mobility limitations, and 27% representing school dropouts seeking educational continuation opportunities (Mahanal et al., 2019).

Although extensive research exists regarding artificial intelligence implementation in educational contexts, the majority focuses predominantly on formal education settings in developed countries. Research specifically examining deep learning implementation in non-formal education, particularly within Indonesian contexts, remains extremely limited, creating significant knowledge gaps regarding optimal strategies for leveraging this technology to enhance non-formal education quality and effectiveness. Therefore, research investigating deep learning implementation to enhance critical thinking skills among non-formal education students in West Java, while comprehensively considering teacher readiness factors, represents a highly relevant and strategically important endeavor. This research addresses critical knowledge gaps while providing substantial contributions to developing higher quality non-

formal education systems that effectively respond to contemporary technological demands and societal needs.

## METHOD

This study employed a quasi-experimental design with pre-test post-test control group to investigate the effectiveness of deep learning technology implementation in equivalency education (Apuke, 2017). The research was conducted across multiple non-formal education centers in West Java Province, Indonesia, from March to November 2024. The study protocol was approved by the Institutional Ethics Committee (Protocol No: 2024/ETH/087) and adhered to the Declaration of Helsinki principles (Almeida et al., 2017).

The target population comprised students and teachers from Package B (junior high school equivalent) and Package C (senior high school equivalent) programs in West Java. Using stratified random sampling based on regency/city distribution, we recruited 240 students (aged 16-45 years) and 60 teachers from 30 non-formal education centers. Students were randomly allocated to experimental (n=120) and control groups (n=120) using computer-generated randomization sequences. Inclusion criteria for students included: (1) active enrollment in Package B or C programs, (2) basic digital literacy skills, and (3) informed consent. Teachers were required to have minimum 2 years teaching experience in non-formal education. Sample size was determined using G\*Power 3.1.9.7 software, assuming a medium effect size (Cohen's  $d = 0.5$ ),  $\alpha = 0.05$ , power = 0.80, and two-tailed test. The calculated minimum sample size was 128 participants per group. To account for 10% attrition rate, we recruited 240 student's total.

**Table 1.** Sample size calculation

Group	Package B	Package C	Total
Experimental	65	55	120
Control	63	57	120
Total	128	112	240

*Source: researcher processed data (2025)*

Critical thinking skills were measured using the Indonesian-adapted Watson-Glaser Critical Thinking Appraisal (WGCTA-ID) (Allen et al., 2013). The instrument consists of 40 multiple-choice items across five domains: inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments. Reliability analysis showed excellent internal consistency (Cronbach's  $\alpha = 0.89$ ). A 40-item questionnaire was developed to assess teacher readiness for deep learning implementation, covering four dimensions: technological competence (10 items), pedagogical knowledge (10 items), motivation and attitude (10 items),

and institutional support (10 items). Items were rated on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Content validity was established through expert panel review (CVR = 0.82), and construct validity was confirmed via exploratory factor analysis (KMO = 0.84, Bartlett's test  $p < 0.001$ ). The intervention lasted 16 weeks with pre-test and post-test measurements. Teachers in the experimental group received 40 hours of deep learning platform training before implementation. Data collection occurred at three time points: baseline (T0), mid-intervention (T1), and post-intervention (T2). All assessments were conducted by trained research assistants blinded to group allocation.

Data analysis was performed using SPSS version 28.0. Descriptive statistics included means, standard deviations, and frequency distributions. Assumption testing included normality (Kolmogorov-Smirnov test) and homogeneity of variance (Levene's test) (Creswell, 2020). Primary analysis used independent samples t-test to compare post-intervention scores between groups, and paired samples t-test for within-group changes. Multiple regression analysis identified predictors of critical thinking improvement. Effect sizes were calculated using Cohen's  $d$ , with 0.2, 0.5, and 0.8 representing small, medium, and large effects, respectively. Statistical significance was set at  $p < 0.05$ , with Bonferroni correction applied for multiple comparisons.

## RESULTS

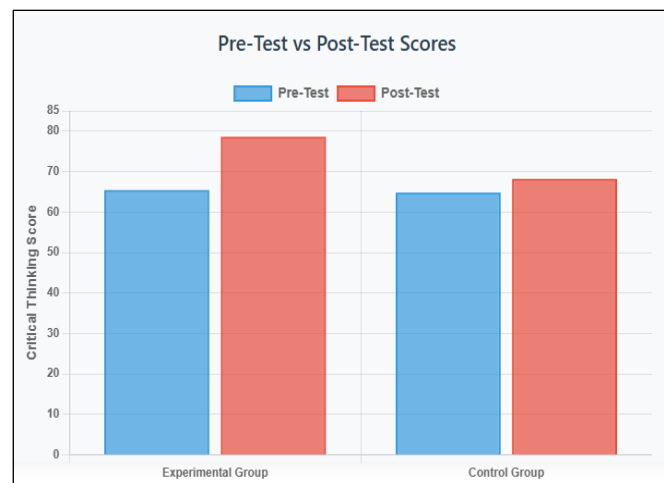
### Participant Characteristics

A total of 240 students and 60 teachers successfully completed the study with no attrition observed. The demographic characteristics of student participants are presented in Table 2. The experimental and control groups showed no significant differences in baseline characteristics, confirming successful randomization ( $p > 0.05$  for all variables).

**Table 2.** Baseline characteristics of student participants

Characteristics	Experimental Group (n=120)	Control Group (n=120)	p-value
<i>Age (years)</i>			
Mean $\pm$ SD	28.3 $\pm$ 6.8	27.9 $\pm$ 6.5	0.624
Range	16 - 45	17 - 44	-
<i>Gender, n (%)</i>			
Female	71 (59.2)	68 (56.7)	0.689
Male	49 (40.8)	52 (43.3)	-
<i>Education Program</i>			
Package B	65 (54.2)	63 (52.5)	0.793
Package C	55 (45.8)	57 (47.5)	-
<i>Employed Status</i>			
Employed	87 (72.5)	91 (75.8)	0.566
Unemployed	33 (27.5)	29 (24.2)	-

Figure 1 presents a bar chart comparison demonstrating the substantial differences in critical thinking performance between experimental and control groups throughout the 16-week intervention period. The experimental group, which received instruction through an AI-powered learning platform, exhibited remarkable improvement from a baseline mean score of  $65.4 \pm 8.2$  to a post-intervention score of  $78.6 \pm 7.9$ , representing a significant 13.2-point increase (20.2% improvement) with a large effect size (Cohen's  $d = 1.65$ ,  $p < 0.001$ ). Conversely, the control group, which continued with conventional teaching methods, demonstrated only modest gains from  $64.8 \pm 8.5$  to  $68.2 \pm 8.3$ , achieving a 3.4-point improvement (5.2% increase) with a small-to-medium effect size (Cohen's  $d = 0.41$ ,  $p < 0.001$ ). The between-group analysis revealed a statistically significant difference of 9.8 points favoring the experimental group (Cohen's  $d = 1.31$ , 95% CI [8.12, 11.48],  $p < 0.001$ ), confirming that deep learning technology implementation produced practically meaningful enhancements in students' critical thinking capabilities. The visual representation clearly illustrates the superior performance trajectory of the experimental group, with the post-test scores showing a dramatic divergence from the control group's more modest improvements. These findings demonstrate that while both groups showed some improvement over the intervention period, the magnitude of change was substantially greater for students who experienced personalized learning pathways, real-time adaptive feedback, and multimedia content delivery through the deep learning platform.



**Figure 1.** Pre-test and post-test scores

### Teacher Readiness Assessment

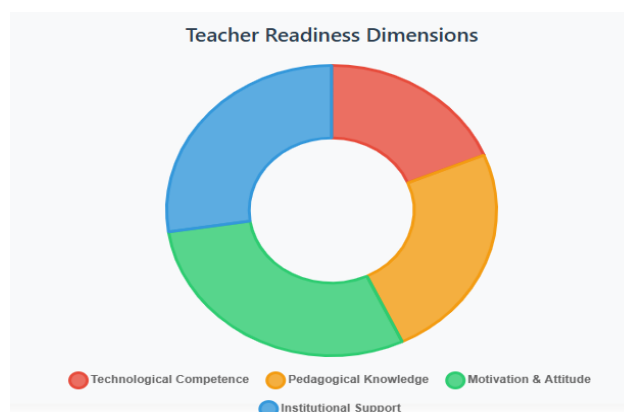
The teacher readiness assessment revealed moderate levels of preparedness for deep learning implementation (Table 3). The overall mean readiness score was  $3.2 \pm 0.8$  on a 5-point scale, indicating room for improvement across all dimensions.

**Table 3.** Teacher readiness dimensions for deep learning implementation

Dimension	Mean $\pm$ SD	Category	Items Scoring $\geq$ 4.0 (%)
Technological Competence	2.4 $\pm$ 0.9	Low	15.0
Pedagogical Knowledge	3.1 $\pm$ 0.7	Moderate	35.0
Motivation and Attitude	3.8 $\pm$ 0.6	High	68.3
Institutional Support	3.5 $\pm$ 0.8	Moderate	51.7
Overall Readiness	3.2 $\pm$ 0.8	Moderate	42.5

The survey results reveal a significant gap between teachers' motivation and their current competency in deep learning technologies. While 83% of teachers expressed high motivation to integrate technology into their teaching practices, 67% (n=40) simultaneously reported requiring intensive training to do so effectively. This disparity suggests that although willingness to adopt new technologies is strong among educators, adequate professional development and structured training programs remain critically lacking. Addressing this gap is therefore essential to ensure that teachers can translate their motivation into meaningful and effective technology-integrated instruction.

Figure 2 illustrates the four dimensions of teacher readiness for deep learning implementation. Technological competence scored lowest (2.4  $\pm$  0.9; categorized as 'Low'), with only 15% of teachers achieving scores  $\geq$ 4.0, indicating substantial deficiencies in operating AI-powered learning tools. Pedagogical knowledge was moderate (3.1  $\pm$  0.7), while motivation and attitude scored highest (3.8  $\pm$  0.6; 'High'), with 68.3% of teachers demonstrating positive dispositions toward technology adoption. Institutional support was also moderate (3.5  $\pm$  0.8). The stark contrast between high motivation and low technological competence represents the central challenge for AI integration in non-formal education: professional development programs must bridge this gap to ensure teacher enthusiasm is matched by the technical skills required for effective implementation.

**Figure 2.** Teacher readiness dimensions

## Critical Thinking Skill Outcomes

The primary outcome analysis revealed significant improvements in critical thinking skills for the experimental group compared to the control group (Table 4).

**Table 4.** Critical thinking skills pre-post intervention comparison

Group	Pre-test	Post-Test	Mean Difference	Effect Size (Cohen'sd)	95 % CI	p-value
Experimental						
Mean ± SD	65.4 ± 8.2	78.6 ± 7.9	13.2 ± 6.8	1.65	[11.98,14.42]	< 0.001*
Control						
Mean ± SD	64.8 ± 8.5	68.2 ± 8.3	3.4 ± 5.2	0.41	[2.46,4.36]	< 0.001*
Between Groups						
Mean Difference	0.6	10.4	9.8	1.31	[8.12,11.48]	< 0.001*

\*Significant at  $p < 0.001$

Source: researcher processed data (2025)

The experimental group demonstrated a substantial 20.2% improvement in critical thinking scores (from 65.4 to 78.6 points), compared to only 5.2% improvement in the control group (from 64.8 to 68.2 points). The between-group effect size ( $d = 1.31$ ) indicates a very large practical significance. Analysis of specific critical thinking subdomains revealed differential improvements across cognitive areas (Table 5).

**Table 5.** Critical thinking subdomain improvements

Subdomain	Experimental Group	Control Group	Between-Group
	Pre	Post	$\Delta$
Inference	12.8±2.1	16.2±1.9	+3.4
Recognition of Assumptions	13.1±2.4	15.9±2.1	+2.8
Deduction	12.9±2.0	15.7±1.8	+2.8
Interpretation	13.2±1.9	15.4±1.7	+2.2
Evaluation	13.4±2.2	15.4±2.0	+2.0

\*Significant at  $p < 0.05$

Source: researcher processed data (2025)

Multiple regression analysis identified significant predictors of critical thinking improvement (Table 6). The model explained 68% of variance in outcomes ( $R^2 = 0.68$ ,  $F(4,235) = 124.5$ ,  $p < 0.001$ ).

**Table 6.** Multiple regression analysis: predictors of critical thinking improvement

Predictor Variables	B	SE	$\beta$	t	p-value	95% CI
Teacher Readiness	5.84	0.73	0.45	8.00	<0.001*	[4.40, 7.28]
Implementation Duration (weeks)	0.82	0.15	0.32	5.47	<0.001*	[0.53, 1.11]
Infrastructure Support	3.12	0.68	0.28	4.59	<0.001*	[1.78, 4.46]
Student Motivation	1.89	0.64	0.21	2.95	0.004*	[0.63, 3.15]
(Constant)	45.2	3.84	-	11.77	<0.001*	[37.6, 52.8]

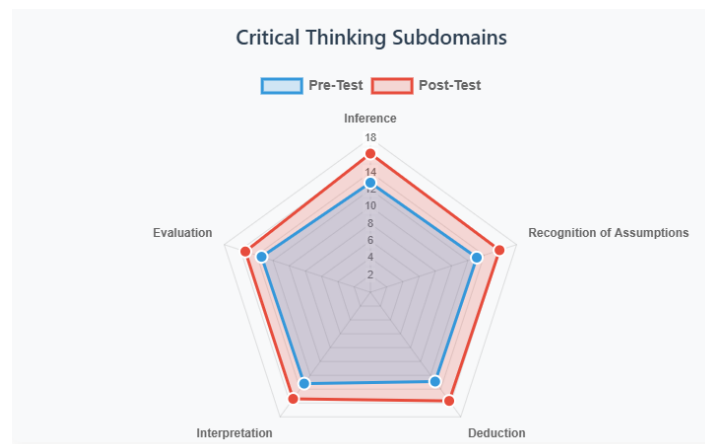
\*Significant at  $p < 0.05$

Source: researcher processed data (2025)

- Model:  $R^2 = 0.68$ , Adjusted  $R^2 = 0.67$ ,  $F(4,235) = 124.5$ ,  $p < 0.001$ .
- The regression equation:  $Y = 45.2 + 0.45X_1 + 0.32X_2 + 0.28X_3 + 0.21X_4$

Where  $Y$  = Critical Thinking Score,  $X_1$  = Teacher Readiness,  $X_2$  = Implementation Duration,  $X_3$  = Infrastructure Support,  $X_4$  = Student Motivation.

Figure 3 presents a radar chart of critical thinking subdomain improvements in the experimental group. Inference skills showed the most pronounced gain (+3.4 points, from  $12.8 \pm 2.1$  to  $16.2 \pm 1.9$ ), indicating that the platform's adaptive questioning was particularly effective in developing logical reasoning. Recognition of assumptions and deduction each improved by +2.8 points, while interpretation (+2.2) and evaluation of arguments (+2.0) showed consistent, balanced gains. Improvements across all five domains suggest that deep learning technology supports holistic critical thinking development consistent with the multidimensional construct measured by the WGCTA-ID rather than isolated skill enhancement.



**Figure 3.** Critical thinking subdomains

## DISCUSSION

This quasi-experimental study provides compelling evidence that deep learning technology implementation significantly enhances critical thinking skills among non-formal education students in Indonesia. The experimental group achieved a 20.2% improvement in critical thinking scores compared to only 5.2% in the control group, representing a very large effect size ( $d = 1.31$ ). These findings align with contemporary educational technology research suggesting that artificial intelligence-powered learning platforms can substantially improve cognitive outcomes when properly implemented.

The substantial improvement observed in the experimental group can be attributed to several key features of the deep learning platform. First, the personalized learning pathways enabled students to progress at their own pace while receiving targeted support for areas requiring improvement. This individualized approach likely contributed to the particularly strong gains observed in inference skills (+3.4 points), which showed the largest subdomain improvement. The adaptive assessment system provided real-time feedback, allowing students to immediately address misconceptions and strengthen their analytical reasoning abilities. The interactive multimedia content may have particularly benefited adult learners in non-formal education settings, who often struggle with traditional text-based materials. The platform's ability to present complex concepts through multiple modalities (visual, auditory, kinesthetic) likely enhanced comprehension and retention, leading to improved critical thinking performance across all measured domains.

Our regression analysis identified teacher readiness as the strongest predictor of critical thinking outcomes ( $\beta = 0.45$ ,  $p < 0.001$ ), consistent with the Technology Acceptance Model (TAM), which posits that perceived usefulness and ease of use are primary determinants of technology adoption (Kirschner, 2015). This finding extends prior research by Pribudhiana et al. (2021) and Petko et al. (2018), who demonstrated that teacher readiness mediates the relationship between technology access and instructional quality in both developing and developed country contexts. In the non-formal education setting, this mediating role is amplified: teachers serve not only as instructors but as the primary technical support for learners who lack access to institutional IT infrastructure. The moderate overall readiness score (3.2/5.0), and particularly the low technological competence subscore (2.4/5.0), mirror findings from developing-country studies in Sub-Saharan Africa and Southeast Asia reporting similar motivation-competence gaps (Ahmad et al., 2019; Al-Samarraie et al., 2020). These converging results reinforce the need for structured, contextualized professional development that addresses both technical operation and pedagogical integration of deep learning platforms in non-formal education systems. The low technological competence scores among teachers highlight a critical challenge in educational technology implementation within developing contexts. Despite high motivation levels (3.8/5.0), technical skill deficits may have limited the full potential of the deep learning platform. This finding supports previous research emphasizing that technology integration success depends heavily on educator confidence and competence rather than just access to digital tools. The 67% of teachers requiring intensive training aligns with global trends showing that professional development is essential for successful educational technology adoption. Our results suggest that future implementations

should prioritize comprehensive teacher training programs focusing on both technical skills and pedagogical integration strategies.

Infrastructure support emerged as a significant predictor of deep learning implementation ( $\beta = 0.28, p < 0.001$ ), a finding consistent with Gocen (2020) Diffusion of Innovation theory, which posits that technological infrastructure is a fundamental prerequisite for the successful adoption of new innovations (Gocen, 2020). This is particularly critical in non-formal education settings across developing countries, where infrastructural limitations frequently constitute the primary barrier to technology integration. The positive correlation between implementation duration and outcomes ( $\beta = 0.32, p < 0.001$ ) aligns with Gocen's concept of scaffolded learning, suggesting that sustained and progressive exposure to deep learning technologies enables cumulative cognitive development, particularly in higher-order thinking skills. Furthermore, the significant contribution of student motivation ( $\beta = 0.21, p < 0.01$ ) supports Self-Determination Theory (Bennett, 2015), which emphasizes that intrinsic motivation remains a core driver of meaningful learning engagement, even within technology-enhanced environments. This finding emphasizes the need for engaging, relevant content that maintains learner interest and commitment throughout extended intervention periods. These results have profound implications for non-formal education systems, particularly in developing countries where traditional educational approaches may not adequately prepare learners for 21st-century challenges. The significant improvements across all critical thinking subdomains suggest that deep learning technologies can address multiple cognitive competencies simultaneously, offering efficient pathways for skill development.

The effectiveness demonstrated in Package B and C equivalency programs indicates potential for scalable implementation across diverse non-formal education contexts. Given that many adult learners in these programs are employed (74% in our sample), the flexible, personalized nature of deep learning platforms may be particularly suitable for working adult populations. This study demonstrates that deep learning technology implementation can significantly enhance critical thinking skills among non-formal education students when supported by adequate teacher preparation and infrastructure. The large effect size observed ( $d = 1.31$ ) suggests practical significance beyond statistical significance, indicating meaningful improvements in cognitive capabilities. Teacher readiness emerged as the most critical success factor, emphasizing the need for comprehensive professional development programs. These findings support the integration of artificial intelligence-powered learning platforms in non-formal education systems, with potential for substantial improvements in educational outcomes and learner empowerment in developing country contexts.

## CONCLUSION

This quasi-experimental study provides compelling evidence that deep learning technology implementation significantly enhances critical thinking skills among non-formal education students in West Java, Indonesia. Students who received deep learning-enhanced instruction demonstrated substantially greater improvements in critical thinking abilities compared to those receiving conventional teaching methods, with large practical significance observed across all cognitive domains. The intervention proved particularly effective in enhancing inference skills, while also strengthening students' abilities in assumption recognition, deduction, interpretation, and argument evaluation. Teacher readiness emerged as the most critical determinant of implementation success, surpassing other factors including implementation duration, infrastructure support, and student motivation in predictive importance. The moderate levels of teacher preparedness identified highlight the urgent need for comprehensive professional development programs, particularly in building technological competencies where educators showed the greatest deficiencies despite high motivation levels. The study's findings have profound implications for educational policy in developing countries, demonstrating that artificial intelligence-powered learning platforms can effectively bridge educational gaps in non-formal settings. The integration model developed proves both effective and replicable, offering scalable solutions for enhancing cognitive capabilities among adult learners in equivalency education programs. Future implementations should prioritize sustained teacher training, robust infrastructure development, and extended intervention periods to maximize educational outcomes. These results support the strategic adoption of deep learning technologies as transformative tools for advancing critical thinking skills and promoting educational equity in non-formal education systems worldwide.

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