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Implementing AI and Deep Learning to Improve Teacher Competence in Elementary Education: A Case Study in Papua

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ABSTRACT

This study aims to enhance teacher competence in implementing Artificial Intelligence (AI) and Deep Learning as innovative learning tools at SD Inpres Koya Tengah, Jayapura. A Participatory Action Research approach combined with competency-based training was applied, involving 15 teachers. The program consisted of needs assessment, material development, training and mentoring, and evaluation. Data were collected using pre-test and post-test instruments and analyzed using paired sample t-test and qualitative triangulation. The results show a significant improvement in teacher competence, with an average increase of 30.8 points and a significance level below 0.05. The highest improvement was observed in understanding Deep Learning (+40 points). The program effectively supported the transition toward digital learning environments and strengthened teacher readiness to implement the Merdeka Curriculum.

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INTRODUCTION

Recent technological advancements have driven fundamental transformation in education, requiring teachers not only to master subject matter but also to select and implement innovative models and methods of instruction to ensure that teaching and learning processes are more effective and meaningful (Sanjaya & Santoso, 2025; Ristiani et al., 2025). Such demands are particularly relevant given that elementary schools, as the foundation of formal education, play a strategic role in establishing digital literacy from an early age. Consequently, teachers' capacity for innovation becomes a decisive factor in the success of educational transformation.

Nevertheless, a significant gap persists between global technological advancement and the actual conditions in Indonesian elementary schools, particularly in Papua. SD Inpres Koya Tengah in Jayapura exemplifies this disparity, where limited access to technology, inadequate digital infrastructure, and low teacher competence in integrating technology into instruction constitute the primary barriers that prevent students from receiving education of optimal quality. Within this context, the adoption of advanced technologies such as Artificial Intelligence (AI) and Deep Learning has become increasingly relevant, as these tools have been shown to enhance learning effectiveness through content personalization, adaptive pacing, and more interactive material delivery (Luckin et al., 2016; Lestari & Mariana, 2024; Hariyanto et al, 2025). Despite growing interest in AI-based education, there is limited research on the implementation of AI and Deep Learning training programs for elementary school teachers in underserved regions such as Papua, where infrastructure constraints and limited professional development opportunities create additional barriers to digital adoption.

The conditions at SD Inpres Koya Tengah, Jayapura, which remain heavily dependent on conventional teaching methods, underscore the need for comprehensive mentoring for both teachers and students in implementing Artificial Intelligence (AI) and Deep Learning. This program was designed not only to provide technical training but also to build teachers' capacity to design technology-based learning tailored to local needs and Papua's cultural potential. Such efforts align with the mandate of the Merdeka Curriculum, which emphasizes flexible, innovative, and student-centered learning, while also supporting Papua's development agenda under Special Autonomy, where education is prioritized as a key sector. With the backing of national policies such as the Digital Learning Program (Bernadetta et al., 2025), SD Inpres Koya Tengah holds strong potential to serve as a model for AI-based digital classroom implementation in Papua.

The urgency of this program is further reinforced by the mandate of the Merdeka Curriculum, which encourages educators to be creative in selecting and utilizing instructional media capable of facilitating students' competencies holistically — including digital competence, which has become a fundamental necessity in the present era. The integration of AI and Deep Learning into classroom instruction is fully aligned with the spirit of the Merdeka Curriculum, which prioritizes innovation, relevance, and a strong commitment to advancing student learning (Jamil & Pulukadang, 2025). Moreover, this program resonates with Papua's development agenda under the Special Autonomy framework, which designates education as its primary and non-negotiable priority.

Enhancing the quality of education in Papua — particularly through the adoption of AI and Deep Learning technologies — represents a strategically significant long-term investment aimed at preparing a generation of Papuan learners who are intellectually capable, globally competitive, and able to contribute meaningfully to national development. Accordingly, this community service initiative carries

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value not only in academic terms, but also in its broader social impact on educational advancement across Papua and its contribution to Indonesia's wider digital transformation agenda.

The transformation of education from conventional classrooms toward the digital era in Indonesia has become increasingly evident with the emergence of Artificial Intelligence (AI) and Deep Learning technologies. This shift represents far more than a mere substitution of instructional media — from chalkboards to digital screens — but rather the creation of a more adaptive and personalized learning Ecosystem. AI enables learning systems to tailor instructional content to individual student needs, while Deep Learning supports the analysis of learning patterns to enhance the effectiveness of teaching methods. As affirmed, the application of Deep Learning in education is capable of producing interactive media that is more effective and responsive to the diverse learning needs of students.

SD Inpres Koya Tengah, Jayapura, serves as a compelling case of how schools in technologically underserved regions can undergo meaningful digital transformation through guided AI implementation. Backed by national policy support and structured teacher training programs, this school holds strong potential to emerge as a replicable model for AI-based digital classroom implementation throughout Papua. The mentoring provided has not only enhanced the digital competencies of both teachers and students but has also opened pathways toward greater equity in educational quality across eastern Indonesia. Consistent with the perspective of Schlippe (Chen et al., 2020), the transition from conventional classrooms to the digital era is not merely a technical reconfiguration, but rather a strategic undertaking to cultivate an education system that is inclusive, innovative, and globally competitive. Consequently, this community service initiative holds significance not only in academic terms but also in its far-reaching social impact on educational advancement in Papua, as reflected in a growing body of research on the utilization of adaptive AI to support inclusive learning at the elementary school level (Hidayah et al., 2025).

METHOD

This community service program employed a Participatory Action Research (PAR) approach, integrated with a competency-based training method. This approach was deliberately selected as it enables the research team to engage directly alongside teachers and students throughout the process of implementing AI and Deep Learning technologies, thereby ensuring that the solutions generated are contextually grounded and precisely tailored to the local needs of SD Inpres Koya Tengah, Jayapura.

Participant

The target participants of this program were as follows:

- Teachers of SD Inpres Koya Tengah, serving as training participants who would implement AI and the Deep Learning approach in their classroom instruction.
- Students of SD Inpres Koya Tengah, serving as the direct beneficiaries of AI and Deep Learning-based instructional media.

This training program involved 15 teachers at SD Inpres Koya Tengah, Jayapura, Papua, ranging from school leadership to subject teachers across multiple grade levels and disciplines. This diverse composition facilitated cross-disciplinary experience exchange and enabled a more contextually relevant application of AI-based Deep Learning tailored to the specific needs of each grade level and subject area.

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Implementation Phases of The Training And Mentoring Program

This study was carried out through the following sequential phases:

- Preparation and Needs Assessment Phase

This phase constituted the foundational stage of the entire community service program. The process commenced with a preliminary survey of the school's digital infrastructure to obtain an accurate baseline of device availability, internet connectivity, and overall technological readiness within the target elementary school environment. The survey findings were further enriched through in-depth interviews with the school principal, teachers, and student representatives, aimed at eliciting first-hand perspectives from key stakeholders regarding their challenges and expectations concerning technology-based learning.

Subsequently, a systematic mapping of teachers' technological literacy levels was conducted to establish a baseline of their digital competencies, serving as the primary reference point for designing a targeted training program. In parallel, the implementation team identified relevant learning needs by considering Papua's geographical, social, and cultural contexts. The entire process during this phase was supported by systematically developed instruments, including observation sheets, semi-structured interview guides, and diagnostic questionnaires. These tools ensured that the data collected were valid, structured, and comprehensive, thereby providing a solid empirical basis for decision-making in subsequent phases.

- Instructional Material Development Phase

Building upon the findings of the preceding needs assessment, the program team advanced to the phase of instructional material and media development. The initial step involved the design of an AI and Deep Learning-based training module, in which the content was deliberately crafted not merely to transfer information, but to actively encourage participants to construct deep, meaningful, and practically applicable understanding within real classroom contexts. In this regard, the Deep Learning approach places particular emphasis on the development of critical thinking, creativity, collaboration, and communication competencies — the four foundational 21st-century skills that are equally relevant for both teachers and students.

In the process of developing the instructional media, the team carefully took into account the availability of hardware and the limitations of internet connectivity that frequently pose challenges across various regions of Papua, thereby ensuring that the media produced remain accessible and optimally functional under real field conditions. As a deliberate effort to strengthen relevance and participant receptiveness, Papuan cultural content was systematically integrated into the instructional media so that the learning experience would feel neither foreign nor disconnected but rather grounded, contextual, and deeply rooted in the lived experiences of the participants. All instructional materials were subsequently aligned with the principles of the Merdeka Curriculum — which is, in essence, philosophically consonant with the spirit of Deep Learning — in that both advocate for learning that is flexible, student-centered, and oriented toward deep understanding and holistic character development.

- Training and Mentoring Implementation Phase

This phase constituted the core of the entire community service program, structured around two primary tracks: teacher training and teacher mentoring in classroom practice.

- ✓ Teacher Training

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Teacher training was implemented in a phased and progressive manner, with the Deep Learning approach serving as the overarching pedagogical framework. The program commenced with the introduction of foundational AI concepts and Deep Learning principles, and progressively advanced to the utilization of adaptive learning platforms capable of dynamically adjusting instructional content to meet individual student needs. Subsequently, teachers were trained in designing Deep Learning-based Lesson Plans (DLLP) — technology-integrated instructional plans designed not merely to fulfill curricular requirements, but to actively foster critical thinking skills, collaborative engagement, and active learning among students. Additionally, teachers were equipped with data analytics strategies to systematically identify students' learning difficulties, thereby providing an evidence-based foundation for reflective practice and continuous improvement in teaching quality. All training sessions were conducted through varied and participatory methods — including interactive lectures, hands-on training, group discussions, and case studies — positioning teachers as active agents in the learning process, fully consistent with the core principles of Deep Learning.

- ✓ Teacher Mentoring

  Mentoring was carried out to accompany and guide teachers in implementing the learning activities they had designed during the training phase. This process placed strong emphasis on practical guidance, collaborative problem-solving, and reflective discussion, thereby providing teachers with concrete and sustained support in navigating real classroom challenges. Accordingly, the mentoring component functioned not merely as technical assistance, but more profoundly as professional scaffolding — enabling teachers to progressively internalize AI and Deep Learning-based instructional practices into their everyday teaching routines.

- Reflection and Data Analysis Phase

This phase was conducted on a continuous basis, both throughout and following the completion of the training program. Data were collected through identical pre-test and post-test instruments designed to measure changes in the knowledge and competencies of the 15 participating teachers at SD Inpres Koya Tengah. Quantitative analysis was performed using descriptive statistics and paired sample t-test, while qualitative analysis was conducted through thematic analysis of participants' feedback. Both datasets were subsequently triangulated to yield a comprehensive and multi-perspectival understanding of the overall effectiveness of the training program.

The findings derived from this analysis served as the empirical foundation for formulating program sustainability recommendations, encompassing the strengthening of teacher capacity, the refinement of training modules, and the identification of concrete and actionable steps to ensure that the Deep Learning and AI-based instructional ethos cultivated throughout the program would evolve into an enduring learning culture deeply embedded within the school's institutional fabric.

RESULTS AND DISCUSSION

Results

The training program was conducted at SD Inpres Koya Tengah, Jayapura, Papua, involving 15 participating teachers comprising the school principal, classroom teachers for Grades I through VI, and subject teachers in Religious Education, Physical Education, Local Content, Mathematics, Bahasa Indonesia, and Natural and Social Sciences. The initial survey revealed that the majority of participants possessed a limited understanding of AI concepts and the Deep Learning approach in educational

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contexts. Consequently, the training was designed in a phased and contextually responsive manner, carefully adapted to the local conditions of Papua. Throughout the implementation, participants demonstrated active engagement across a range of activities, including demonstrations of AI-based platform usage, group discussions, case studies directly relevant to the Papua elementary school context, and hands-on practice in designing technology-integrated Deep Learning-based Lesson Plans (DLLP). Facilitators also made deliberate adaptive adjustments by incorporating individual mentoring sessions and simplifying technical terminology for participants who required additional time to grasp AI and Deep Learning concepts.

Analysis of pre-test and post-test data revealed a statistically significant improvement in participants' knowledge and competencies. The paired sample t-test yielded a significance value below 0.05, indicating a meaningful and statistically robust difference between pre- and post-training scores. The most substantial gain was recorded in the indicator of Deep Learning approach comprehension, with an increase of 38 points, while the lowest gain was observed in basic digital literacy at 24 points — an indicator that had already registered a relatively high baseline score prior to the training.

Data triangulation consistently confirmed that the training program was effective in enhancing the competencies of SD Inpres Koya Tengah teachers, particularly in integrating AI and the Deep Learning approach into daily instructional practice, thereby substantively supporting the school's transformation from conventional classroom-based instruction toward a fully digital learning era.

TABLE 1. Teacher Competency Outcomes in the Implementation of AI and Deep Learning as Innovative Instructional Media at SD Inpres Koya Tengah, Jayapura

Indicator	Pre-test	Post-test	Gain	Remarks
A. Transition from Conventional Classrooms to the Digital Era				
Awareness of the importance of digital transformation in learning	50%	85%	+35%	Increased
Teachers' readiness to adopt digital technology in the classroom	47%	80%	+33%	Increased
Ability to integrate digital tools into instructional practice	45%	79%	+34%	Increased
B. Implementation of AI as Innovative Instructional Media				
Understanding of adaptive AI concepts in the elementary school learning context	48%	82%	+34%	Increased
Ability to utilize AI adaptive learning platforms	50%	81%	+31%	Increased
Ability to design AI-based instructional media	46%	80%	+34%	Increased
Ability to identify students' learning needs through AI data analytics	49%	83%	+34%	Increased
C. Application of the Deep Learning Approach in Teaching Practice				
Understanding of Deep Learning	44%	84%	+40%	Increased

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Indicator	Pre-test	Post-test	Gain	Remarks
approach principles				
Ability to design Deep Learning-based Lesson Plans (DLLP)	46%	82%	+36%	Increased
Ability to foster students' critical thinking and collaborative skills	55%	83%	+28%	Increased
Ability to integrate AI and Deep Learning in a unified instructional framework	48%	84%	+36%	Increased
Overall Mean	51.3%	82.1%	+30.8%	Increased

Table 1 shows measurable improvement across all competency indicators, particularly in digital transition, AI utilization, and Deep Learning applications. These gains confirm that the training effectively enhanced teacher readiness to integrate technology into instructional practice. A more detailed elaboration of key competency focuses and outcomes is presented in the subsequent table.

TABLE 2. Teacher Competency Transformation through Guided Implementation of AI and Deep Learning as Innovative Instructional Media

Competency Indicator	Primary Focus	Achievement	Training Outcomes
Transition from Conventional Classrooms to the Digital Era	Awareness, readiness, and foundational skills in digital device utilization	Teachers demonstrate understanding of the urgency of digital transformation, readiness to adopt technology, and the ability to integrate digital tools into instruction	The school has begun transitioning from conventional patterns toward technology-based learning; a stronger foundation for digitalization has been established
Implementation of AI as Innovative Instructional Media	Conceptual understanding, platform utilization, instructional media design, and student needs analysis	Teachers have mastered AI concepts, are capable of utilizing platforms, designing innovative instructional media, and interpreting student learning needs data	AI is effectively utilized as innovative instructional media; learning has become more adaptive, personalized, and responsive to individual student needs
Application of the Deep Learning Approach in Teaching Practice	Understanding of principles, DLLP design, critical thinking strategies, and AI–Deep Learning integration	Teachers demonstrate understanding of Deep Learning principles, are capable of designing DLLPs, fostering students' critical thinking, and integrating AI–Deep Learning in a unified framewor	Learning has become more meaningful, collaborative, and oriented toward 21st-century skill development; students are more actively engaged and reflective

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DISCUSSION

The training outcomes at SD Inpres Koya Tengah, Jayapura, demonstrated significant improvement in teacher competencies across all measured dimensions, as empirically validated through a paired sample t-test yielding a significance value below 0.05. These findings are consistent with Darling-Hammond et al. (2017), who assert that professionally designed teacher training programs that are sustained, contextually relevant, and grounded in authentic practice prove substantially more effective in enhancing teacher competencies than one-time, decontextualized training events.

In the dimension of transition toward the digital era, teachers who had previously been accustomed to conventional instructional patterns began to demonstrate genuine openness toward a technology-based learning ecosystem. (Fullan & Miller, 2013) contends that digital transformation in education is fundamentally not a matter of changing tools, but rather a profound shift in pedagogical thinking and teaching culture. The phased and locally adaptive training approach proved instrumental in achieving success in this dimension, consistent with (Voogt et al., 2013), who argue that professional development in technology for teachers must account for local social, cultural, and infrastructural contexts in order to be effective and sustainable.

In the dimension of AI implementation as innovative instructional media, teachers demonstrated not only theoretical understanding of AI but also the practical ability to operationalize it in real classroom settings. (Holmes et al., 2019) assert that AI in education holds immense potential to render learning more adaptive, personalized, and responsive to individual student needs — particularly when teachers possess adequate understanding of its application. (Qomah et al., 2025) further affirm that AI can assist teachers in developing a deeper understanding of each student's learning profile, thereby enabling more precisely targeted instructional interventions.

The dimension of the Deep Learning approach application recorded the most substantial gain, particularly in the comprehension of Deep Learning principles — a finding that underscores the extent to which this concept was largely unfamiliar to most participants before the training. Through intensive mentoring, teachers came to understand that Deep Learning is not merely a teaching method, but a comprehensive educational philosophy that foregrounds meaningfulness, critical thinking, and collaboration. Fullan & Langworthy (2014) define Deep Learning as a process that moves students beyond rote memorization toward genuine problem-solving and productive collaboration — competencies that are indispensable in the 21st-century era. The mastery of AI and Deep Learning integration by teachers opens pathways to more meaningful learning experiences, as affirmed by Ramadan et al. (2025), who argue that AI technology, when paired with sound pedagogical approaches, can foster deeper student engagement and greater reflective thinking.

Overall, the success of this training program substantiates that teachers in Papua possess significant capacity for professional growth when provided with mentoring that is appropriate, sustained, and respectful of local context. Suryadarma & Jones (2013) note that limited access to technology and quality training constitutes a primary barrier to education in Papua, yet one that can be effectively overcome through inclusive and adaptive mentoring programs. This training initiative not only enhanced individual teacher competencies but also laid the foundational groundwork for a broader transformation of the learning culture at SD Inpres Koya Tengah — toward an educational ecosystem that is more digital, innovative, and oriented toward the cultivation of 21st-century skills.

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FIGURE 1. Implementation of Activities

CONCLUSION

The training program involving 15 teachers at SD Inpres Koya Tengah, Jayapura, Papua, produced significant and measurable improvements in teacher competence. Initial surveys revealed limited prior understanding of AI and Deep Learning, informing a phased, context-sensitive training design adapted to local conditions. Quantitative results showed an overall mean gain of 30.8 points, with a paired sample t-test value below 0.05, confirming statistical significance. The greatest improvement was recorded in Deep Learning comprehension (+40 points), while basic digital literacy showed the smallest gain (+24 points), reflecting a higher baseline. Qualitative triangulation further confirmed that teachers developed both conceptual understanding and practical capacity to integrate AI and Deep Learning into classroom practice. Overall, the program successfully supported the transition toward digital learning, strengthened readiness for the Merdeka Curriculum, and fostered more adaptive and collaborative 21st-century learning.

RECOMMENDATIONS

- For Teachers and Schools: Teachers are encouraged to continuously develop their digital and pedagogical competencies through sustained practice, reflection, and peer collaboration, while schools should provide adequate digital infrastructure and facilitate structured professional learning communities to ensure the sustainable integration of AI and Deep Learning in daily instructional practice.
- For Students and Future Researchers: Students should be given broader opportunities to engage in technology-based learning that fosters critical thinking, collaboration, and 21st-century competencies, while further empirical research is needed to explore contextually appropriate AI and Deep Learning mentoring models for Papua, enabling the findings of this study to be replicated and scaled across the region.

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