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Assistance in the Development of Deep Learning–Based Instructional Tools for Junior High School Science Teachers in Pacitan Regency

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Abstract: This community service program aims to support junior high school science teachers across Pacitan Regency in developing instructional tools grounded in deep learning principles. The program adopted a Participatory Action Research (PAR) approach implemented through systematic training and mentoring activities involving 74 science teachers. The activities were organized into two main sessions. The first session focused on enhancing teachers' conceptual understanding and providing practical guidance in designing deep learning–oriented instructional tools. During this stage, participants developed initial drafts that emphasized higher-order thinking skills, inquiry-based learning strategies, and the integration of digital media. The second session consisted of collaborative evaluation and refinement of the drafts through feedback from facilitators and fellow participants. The evaluation process employed facilitator assessment instruments to examine the alignment of the instructional tools with deep learning principles, along with participant questionnaires to document teachers' perceptions and learning experiences. Quantitative data obtained from the questionnaires were analyzed using descriptive statistics, while qualitative feedback from facilitators and participants was examined to support the interpretation of the findings. As a result, each participant produced a finalized deep learning–based instructional tool tailored to the specific needs of their classroom context. The findings indicate that 95.67% of participants rated the program as very good, and 93.4% reported an increased understanding of deep learning concepts. To ensure the sustainability of the program outcomes, all finalized instructional tools will be compiled into a single volume and submitted for ISBN registration. Overall, this initiative enhanced teachers' pedagogical and technological competencies and provides a replicable model of professional development for other science education contexts.

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Introduction

Education plays a pivotal role in preparing future generations to face the challenges of the 21st century, which is characterized by rapid technological advancement, complex global problems, and ever-increasing demands for critical, creative, and digital competencies (Tondeur, 2020). In this context, teachers serve as key agents of educational transformation. They are expected not only to deliver knowledge but also to facilitate meaningful learning experiences that foster students' higher-order thinking, problem-solving abilities, and scientific literacy, especially in science subjects at the junior high school level.

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The accelerated progress of scientific knowledge and information technology has significantly transformed educational practices at all levels of education. Within the framework of the Industrial Revolution 4.0 and the development of Society 5.0, learning is no longer limited to the transmission of factual content but is oriented toward fostering meaningful comprehension, critical and creative thinking, as well as problem-solving abilities rooted in real-world contexts. Accordingly, science education at the junior high school level is expected to implement pedagogical strategies that prioritize conceptual depth, reflective learning processes, and active learner participation (Kalyani, 2024).

Science education at the junior high school (SMP) level is crucial for nurturing students' curiosity, inquiry skills, and understanding of natural phenomena. However, the effectiveness of science education largely depends on the quality of teaching, particularly the learning tools and strategies employed by the teachers. The integration of deep learning-based approaches both pedagogically and technologically offers a promising avenue to enhance the quality of science learning. Deep learning in education refers to both a learning approach that promotes deep conceptual understanding and long-term retention, as well as the use of artificial intelligence (AI) techniques, especially deep learning algorithms, to support educational processes (Goodfellow, Bengio, & Courville, 2016; Aljaraideh & Al Bataineh, 2020).

From a pedagogical perspective, deep learning is contrasted with surface learning. It emphasizes students' ability to relate ideas, critically evaluate evidence, and apply knowledge in real-life contexts (Biggs & Tang, 2011). Meanwhile, from a technological standpoint, deep learning, as a subset of AI, enables computers to learn from large amounts of data through artificial neural networks, allowing applications such as intelligent tutoring systems, adaptive assessments, and content recommendation (LeCun, Bengio, & Hinton, 2015). In today's educational landscape, both aspects of deep learning should be synergized to design and implement innovative, student-centered learning.

In Indonesia, the national curriculum (including the *Kurikulum Merdeka*) advocates for student-centered learning, differentiated instruction, and the integration of digital technology. Teachers are encouraged to develop learning tools such as lesson plans, teaching modules, digital media, and assessments that are not only curriculum-aligned but also responsive to technological trends and the specific needs of learners (Kemendikbudristek, 2022). Despite this policy direction, many science teachers, particularly those in rural or less-developed regions like Pacitan Regency, face challenges in adopting deep learning-based learning tools.

Preliminary results from needs analysis and informal interviews with science teachers in Pacitan Regency indicate that the majority of educators still apply conventional learning patterns, with limited use of interactive digital devices and learner-centred learning strategies. In line with the findings presented in the abstract, a preliminary survey of 20 representative science teachers revealed that around 80% of respondents had never used artificial intelligence (AI)-based applications in their teaching activities, and none of them had participated in special training on AI integration in the last three years. Teachers also cited various obstacles to integrating technology, including limited access to professional development activities, a lack of supporting resources, and low confidence in using AI-supported applications. In addition, the findings revealed a significant gap in teachers' understanding of pedagogical frameworks that promote deep learning and the development of critical thinking skills (Fullan et al., 2020).

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This situation highlights the urgency of implementing planned and sustainable capacity-building programmes, accompanied by technical assistance for science teachers, particularly in the design and development of learning tools that integrate the principles of deep learning. Strengthening teachers' abilities in developing these tools is expected to not only improve their professional competence but also contribute significantly to improving the quality of student learning outcomes in science subjects.

To respond to this need, the research and community service team from the Manajemen dan Inovasi Pembelajaran Fisika at Universitas Sebelas Maret (UNS) designed a structured community service program. The program aimed to assist junior high school science teachers throughout Pacitan Regency in understanding, designing, and developing deep learning-based learning tools. The activities included workshops, collaborative discussions, demonstrations, and hands-on practice tailored to the teachers’ context and level of digital readiness.

This initiative aligns with the broader goals of the Sustainable Development Goals (SDGs), particularly Goal 4: “Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all” (UNESCO, 2021). Improving teachers’ capacities in using advanced pedagogical and technological strategies is a key step toward inclusive and high-quality education, especially in geographically and digitally disadvantaged regions. Through the program, teachers were introduced to the characteristics of deep learning in teaching, such as:

1) Encouraging metacognitive thinking and reflective learning;
2) Creating problem-based and project-based learning scenarios;
3) Using data and AI tools to personalize learning;
4) Designing authentic assessments that emphasize process and application.

The learning tools developed during the program covered several essential components: learning objectives aligned with higher-order thinking skills, structured learning activities that promote inquiry and collaboration, integration of digital applications such as simulations and interactive media, and assessment strategies that are formative, feedback-oriented, and designed to monitor conceptual growth (Panjaitan, 2025).

Notably, this community service program was formulated to support junior high school science teachers throughout Pacitan Regency in the development of instructional tools grounded in deep learning principles, while remaining responsive to the specific characteristics of the local context. Despite its abundance of natural resources and cultural heritage, Pacitan continues to encounter constraints related to limited digital infrastructure and unequal access to quality professional development for teachers. In response to these conditions, the program implemented a participatory, contextual, and sustainability-oriented approach. The support provided was not confined to the dissemination of knowledge but encompassed ongoing mentoring, collaborative reflection, and structured feedback, thereby enabling teachers to independently design and apply deep learning-based instructional tools within their respective classrooms.

Over the long term, this program seeks to: (1) strengthen teachers’ roles as designers of meaningful and innovative learning experiences; (2) cultivate a community of practice among science educators in Pacitan that facilitates continuous professional growth; and (3) contribute to wider educational transformation in rural areas of Indonesia through pedagogical and technological innovation. This article outlines the implementation process, outcomes, and reflective insights of the community service activity, while also discussing the practical challenges faced by teachers and the strategies adopted to address them. It is

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anticipated that this initiative may serve as a reference model for similar programs in other regions and provide input for educational policies concerning teacher professional development, particularly in relation to the integration of technology and deep learning in classroom practice (Darling, 2017).

Method

This community service activity was conducted using a Participatory Action Research (PAR) approach, whereby teachers were directly engaged in the processes of problem identification, action planning, implementation, and outcome evaluation. The approach prioritized collaborative problem-solving, the co-construction of knowledge, and reflective practice throughout the development of deep learning-based instructional tools (Kemmis, McTaggart, & Nixon, 2014). Based on the premise that sustainable educational improvement depends on the active involvement of stakeholders, this approach positioned teachers not simply as training participants but as partners who played an active role in designing instructional tools for use in their own classrooms (Burns, 2015).

In this program, the PAR cycle was operationalized through four interconnected stages. The preparation stage was carried out through focus group discussions (FGDs) with the head of the Musyawarah Guru Mata Pelajaran (MGMP) to conduct a needs analysis and to identify teachers' challenges related to deep learning implementation and the use of AI-based tools. The implementation stage consisted of face-to-face workshops conducted over several days, which addressed two main components: (a) deep learning pedagogy, with an emphasis on inquiry-based learning and higher-order thinking skills, and (b) the introduction and hands-on application of AI-supported instructional tools. The mentoring stage required participants to complete independent tasks in the form of lesson plans and instructional materials. These outputs were subsequently reviewed through ongoing feedback and discussion facilitated via WhatsApp groups. The final evaluation and reflection stage focused on examining the outcomes of the program through participant questionnaires, facilitator review instruments, and reflective discussions, enabling both facilitators and teachers to assess the effectiveness of the activities and identify areas for further improvement.

The community service activities were implemented at the Education and Training Center of the Pacitan Regency Education Office in Pacitan, East Java, Indonesia. The program involved 74 junior high school science teachers representing 38 public and private junior high schools throughout Pacitan Regency. Participant recruitment was conducted in collaboration with the MGMP IPA under the coordination of the Pacitan Regency Education Office, which distributed participation invitations to schools across all sub-districts. Teachers who enrolled in the program were selected based on their active teaching roles and their commitment to engage in all phases of the activities. The venue was selected for its strategic accessibility to participants from different geographical areas and for its adequate facilities to support face-to-face workshops and digital-based learning activities. In addition to the in-person sessions, follow-up mentoring was provided through online WhatsApp groups to ensure ongoing guidance and feedback. The adoption of this hybrid model, integrating offline and online support, has been shown to strengthen teacher engagement and enhance the sustainability of professional development outcomes (Trust & Whalen, 2020). The instruments used in this community service program include:

1) Facilitator review forms for expert feedback on lesson plans, student worksheets, and media developed;

2) Participant questionnaires to get the teacher responses and perceptions about the program;
3) Documentation tools, including photo and video recordings of sessions, used for reporting and reflection purposes.

Data were collected through a combination of surveys and participant reflection notes, which are widely recognized as effective tools in teacher professional development research (Larrivee, 2000). The data were analyzed using descriptive quantitative methods for survey responses, while qualitative notes from participants were reviewed thematically to identify key insights and patterns.

Result and Discussion

This community service activity was designed with the primary goal of assisting junior high school science teachers in Pacitan Regency in developing learning tools based on deep learning principles. A total of 74 science teachers from all sub-districts in the regency participated in the program, reflecting strong regional interest and the perceived urgency to innovate science instruction in schools. The community service activities were implemented in two structured sessions, each with specific objectives and outputs:

1) Session 1: Material Presentation and Draft Development

The first session focused on introducing the concept of deep learning from both pedagogical and technological perspectives. Facilitators explained how deep learning involves fostering student inquiry, critical thinking, problem-solving, and meaningful learning, particularly in the context of science education, as seen in Figure 1. Teachers were also guided on how to integrate AI-supported tools, such as simulations, virtual labs, and interactive assessments.

Figure 1. Facilitator give an explanation about *deep learning*

After the material presentation, participants engaged in guided practice to begin developing their own science instructional tools, including:

a) Learning Objectives aligned with Higher-Order Thinking Skills (HOTS),
b) Learning Activities based on project-based and inquiry-based learning,
c) Media integration, especially tools that utilize digital or AI features,
d) Assessment components focusing on conceptual depth and authentic evaluation.

The main product of this session was a draft version of a deep learning-based science learning tool, created individually or in small school-based teams.

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2) Session 2: Review, Feedback, and Finalization

In the second session, teachers brought their draft learning tools for evaluation. As seen in figure 2, this session applied a collaborative review format, where each participant received feedback from both fellow participants and program facilitators, based on a structured rubric covering:

a) Alignment with deep learning principles,
b) Curriculum relevance,
c) Integration of digital tools,
d) Clarity and feasibility of implementation.

Figure 2. Discussion session

Teachers subsequently revised their drafts, resulting in finalized instructional tools that were ready for classroom implementation. One example of the revised product is presented in Figure 3, which shows an excerpt from a lesson plan developed by a participating teacher. In this lesson plan, problem-based learning is explicitly embedded through student activities that require experiments and digital simulation. The teacher also integrated an AI-supported digital tool, enabling students to explore scientific concepts by manipulating variables and observing outcomes in a guided yet exploratory manner.

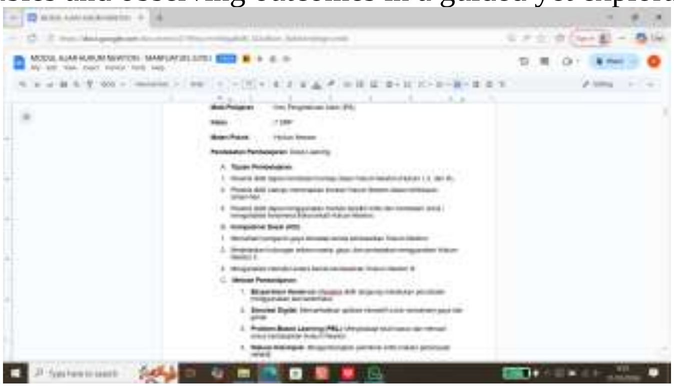

Figure 3. Example of Lesson Plan

The impact of the activity was captured through a post-program survey distributed to all participants. The results show a highly positive response,as seen in **table 1**, with 95.67% of participants stating that the program was "very good" in terms of content relevance, delivery, facilitation, and usefulness.

Table 1. Result of response

Indicator	Result	Category
Training Content	4,85	Very Good
Technical aspects of conducting training	4,79	Very Good
Teaching methodologies used during training	4,86	Very Good

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Question and answer sessions	4,75	Very Good
After the mentoring activities, I gained a better understanding of deep learning.	4,67	Very Good

Additionally, 93.4% of the teachers reported that their understanding of deep learning had improved as a result of the training. This indicates that the activity not only succeeded in delivering the intended material but also enhanced the conceptual clarity and confidence of participants regarding the integration of deep learning into their science teaching practices.

As a tangible indication of the program's sustainability and long-term contribution, all instructional tools finalized by the participants will be compiled into a single publication and submitted for ISBN registration. Beyond serving as a record of program outputs, this compilation is intended to function as a structured professional reference that can be accessed, utilized, and adapted by science teachers both within Pacitan Regency and in other regions. Previous research has demonstrated that instructional resources developed by teachers, when systematically documented and disseminated, play an important role in supporting sustained professional learning and fostering wider improvements in instructional practice (Trust & Whalen, 2020; Burns, 2015).

Moreover, this initiative demonstrates that community service programs can move beyond short-term training activities to produce concrete educational outputs that promote continuous learning and pedagogical innovation. The compiled instructional resources capture teachers' authentic classroom experiences and design choices, which are consistent with participatory professional development principles that emphasize teacher agency and collaborative knowledge construction (Kemmis, McTaggart, & Nixon, 2014). In this regard, the program presents a replicable model for teacher professional development in other regions, particularly those facing comparable challenges related to digital readiness and innovation in science instruction.

Conclusion

This community service program demonstrates the effectiveness of a participatory and reflective approach in strengthening junior high school science teachers' capacity to synergize deep learning pedagogy with the use of AI-supported tools. Through a series of collaborative workshops, structured mentoring, and follow-up activities, participants acquired both conceptual understanding and practical skills necessary to design student-centered instructional tools that integrate digital technologies meaningfully.

This improvement is evidenced by the successful development of 74 validated instructional modules produced by participating teachers. The results indicate a substantial increase in teachers' understanding of deep learning, not merely as a technological concept but as a pedagogical approach that promotes meaningful learning, higher-order thinking skills, and authentic assessment. These findings suggest that, with appropriate mentoring and contextual support, the digital divide often experienced in rural areas such as Pacitan can be effectively addressed through well-designed professional development initiatives.

Recommendation

Based on the outcomes and reflections from this program, the following recommendations are proposed:

1) Ongoing Mentorship and Community of Practice

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Local education authorities should facilitate the formation of teacher learning communities or online forums where teachers can continue to share their innovations, challenges, and experiences with deep learning implementation.

2) Follow-up Support on Digital Integration
Schools and educational institutions should provide regular technical workshops on specific digital tools (e.g., simulation software, quiz platforms, AI-assisted planning tools), especially for teachers with limited ICT background.

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