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Building Resilient Elementary Schools in the Digital Era: Integrating Deep Learning Pedagogy and Artificial Intelligence

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Abstract

Small elementary schools often face serious challenges, particularly in terms of low student enrollment, limited community support, and insufficient teacher capacity to meet curriculum and technological demands. SDN Temenggungan in Banyuwangi is one such school that, at one point, did not receive any new student enrollments. Through a community service program based on a participatory action approach, teachers were supported in designing and implementing student-centered, inquiry-oriented learning strategies ("deep learning" in a pedagogical sense) and introduced to artificial intelligence (AI) as a learning tool through simple digital tools and chat-based applications. The program resulted in a significant increase in new student enrollment, improved teacher competence in lesson design and technology integration, and a positive shift in community perception toward the school. The participatory approach proved effective in fostering teacher engagement and ownership of instructional innovations. These quantitative outcomes substantiate the program's impact on both pedagogical quality and community trust. Such an initiative can serve as a replicable model for empowering teachers in other elementary schools facing similar challenges in different regions.

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INTRODUCTION

Basic education is the fundamental foundation for shaping students' character and initial competencies. In Indonesia, various challenges remain in ensuring equitable and quality education, especially in elementary schools with small enrollments and limited resources. These schools, often located in remote or socially marginalized areas, struggle to attract new students (Widiastuti, 2025). This is evident in the case of SDN Temenggungan in Banyuwangi, which has experienced a steady decline in enrollment over the past few years.

Low community engagement also contributes to the decline in the quality of teaching and learning in small schools. Teachers may feel isolated and demotivated due to limited support from both the community and the education system (Muchtar et al., 2025). Consequently, learning becomes routine and lacks innovation. This suggests that

improving basic education is not solely a matter of pedagogy, but also a systemic issue involving families, local governments, and institutions (Mulyana et al., 2025). Such conditions are consistent with international evidence showing that community involvement plays a decisive role in sustaining small schools and preventing their marginalization (Franz et al., 2023).

To address these challenges, recent curriculum reforms in Indonesia have begun to implement Deep Learning pedagogy, defined here as learning at higher-order thinking levels, focusing on conceptual understanding, critical thinking, collaboration, and meaningful engagement with real-world issues (not to be confused with AI deep learning algorithms) (Suryadarma & Jones, 2013). This shift aims to transform education into a process where students construct knowledge through active participation rather than passive memorization (Randall et al., 2022). However, several studies indicate that without systematic mentoring and professional development, the adoption of Deep Learning pedagogy in schools with limited resources remains partial and inconsistent (Haryono et al., 2025; Regina et al., 2025).

However, implementing Deep Learning in under-resourced schools is difficult. Teachers in small schools often lack access to professional development that supports constructivist and student-centered learning approaches (Khatun et al., 2024). Therefore, external collaborations, such as partnerships with universities, are essential for building teacher capacity and ensuring sustainability.

In addition to curriculum transformation, digitalization has become increasingly central in education. Artificial Intelligence (AI) is beginning to impact how students learn, with applications ranging from adaptive learning systems to intelligent tutoring (Ettyani, 2025). When used effectively, AI can provide personalized learning paths and improve student outcomes (Haetami, 2025). Yet, effective AI integration must align with pedagogy and local culture, involving teachers, parents, and school leaders to build acceptance and meaningful engagement (Rahmayantis et al., 2025).

Despite this promise, the integration of AI into education in Indonesia remains uneven. Many small schools lack the infrastructure, training, and confidence to adopt these technologies meaningfully (Sumartono et al., 2025). Teachers often struggle with basic digital literacy, and there is community skepticism regarding the role of technology in early education. Studies show that successful AI implementation depends on a holistic strategy that includes technical, pedagogical, and socio-cultural support (Mutiara Ningtyas & Haris, 2024).

This was evident at SDN Temenggungan, where teachers initially lacked awareness of how to integrate AI tools into their teaching. Additionally, many parents remained wary of digital devices, associating them with distractions rather than learning. This aligns with Silva et al. (2024), who emphasize that digital inclusion must go hand-in-hand with digital education for both students and their families.

One promising strategy to address these challenges is Participatory Action Research (PAR), which promotes inclusive problem-solving and strengthens ownership among educators (Pangestu, 2024). Rather than being passive recipients, teachers become co-researchers and change agents who identify problems, test solutions, and evaluate outcomes collaboratively.

Despite growing literature on teacher empowerment and digital innovation, few community service programs have explicitly combined participatory action approaches with AI-assisted deep learning pedagogy in small, under-enrolled elementary schools. This represents a clear research and practical gap in how digital transformation can be localized and humanized through community-based teacher development.

The novelty of this initiative lies in integrating AI literacy with participatory professional learning, empowering teachers not merely as users of technology but as co-

designers of innovation. This approach offers a replicable framework for sustainable digital transformation in rural education contexts.

Therefore, this study aims to explore how participatory action research can empower teachers in small schools to adopt Deep Learning pedagogy and integrate AI tools effectively, thereby improving school resilience, teacher competence, and community trust in the digital era.

METHODS

This community service program was carried out using a Participatory Action Research (PAR) approach, which positions the beneficiaries not merely as recipients but as active partners throughout the entire process. This approach was chosen because it is considered the most appropriate for the context of small elementary schools like SDN Temenggungan, Banyuwangi, East Java, Indonesia, a rural public school with low enrollment and limited digital infrastructure. The program was collaboratively designed with the main objective of supporting teachers in designing and implementing Deep Learning pedagogy (higher-order thinking–oriented instruction) and integrating simple, user-friendly artificial intelligence (AI) tools such as chatbot-based learning support and digital quiz platforms into the teaching and learning process.

The main subjects of the program were the teachers and principal of SDN Temenggungan Banyuwangi, while current students and their parents were indirectly involved as members of the school community. In total, the program involved 1 principal, 6 teachers, 45 students, and approximately 30 parents who participated in the socialization and feedback sessions. Teachers were positioned as key partners in this program, as they are the primary actors in curriculum implementation and instructional innovation. SDN Temenggungan was purposively selected based on preliminary data indicating challenges, including low community participation, limited student enrollment, and minimal use of technology in learning. Moreover, the school had shown positive development after a previous mentoring initiative, making it a promising candidate for further capacity building.

The program was implemented from January to June 2025, with three main phases: (1) needs assessment and planning in January–February 2025, (2) teacher training and classroom mentoring in March–April 2025, and (3) evaluation, reflection, and community engagement in May–June 2025.

The implementation began with observations and problem identification conducted together with the school. Observations covered the learning environment, teachers' digital competencies, understanding of the new curriculum, and the limitations of existing facilities and infrastructure. This was followed by focused group discussions (FGDs) between the service team and teachers to align perceptions and design strategic steps tailored to the local school context. This stage was crucial in fostering a sense of ownership over the upcoming program.

The next phase was intervention design and training, in which the service team provided training on the concept of Deep Learning pedagogy in elementary education (not to be confused with AI deep learning algorithms), strategies for deep learning-based lesson planning, and an introduction to practical AI-based tools suitable for primary school contexts, such as text-to-quiz generators and interactive learning chatbots. The training sessions were not purely theoretical but practice-oriented, including examples of lesson plans (RPP), digital learning media, and simulations of AI tools in classroom activities.

Following the training, the program moved into teaching practice mentoring. Teachers were asked to develop instructional materials that incorporated Deep Learning principles

and AI-based elements according to the subjects they taught. The service team supported classroom implementation, observed the lessons, and provided constructive feedback. This process followed a cyclical PAR model: planning → action → observation → reflection, repeated for two mentoring cycles.

To measure program effectiveness, both formative and summative evaluations were conducted. Formative evaluation took place throughout the implementation via classroom observations, reflective interviews with teachers, and student responses to the new learning model. Summative evaluation was conducted at the end of the program by assessing improvements in teachers' understanding of Deep Learning and AI, changes in teaching practices, and parents' perceptions of the learning transformation at the school. The instruments used included structured observation sheets, semi-structured interview guides, teacher reflective journals, and Likert-scale questionnaires measuring teacher confidence and competence. These data were collected using qualitative instruments such as observation sheets, reflective journals, and in-depth interviews. Quantitative indicators, such as the number of new student enrollments before and after the program, were also tracked to measure impact on school resilience.

Two educational technology experts reviewed all instruments to ensure content validity, and reliability was assessed through a pilot with teachers from a neighboring school. Data validity was further enhanced through triangulation of sources (teachers, parents, and students) and member checking during reflection meetings.

Ethical considerations were observed throughout the process. Written consent was obtained from teachers and the school principal before implementation, and parents were informed about students' involvement in AI-supported activities. Any identifiable student photos used in documentation were blurred or taken from behind to ensure privacy.

In addition to focusing on teachers, the program also engaged parents and the surrounding community. Socialization activities were conducted to build understanding and support for digital learning and the use of AI technology. This aspect was vital for creating a supportive learning ecosystem and enhancing parental involvement in their children's education. Through this strategy, school strengthening occurred not only internally but also through sustainable external support.

A roadmap of activities summarizing these stages (Figure 1) was developed to visualize the overall flow: Phase 1 – Observation & Planning → Phase 2 – Training & Mentoring → Phase 3 – Reflection & Community Engagement.

The activities were not top-down initiatives from the service team to the school, but were designed as a mutual learning process that fostered collaboration and complementarity. This participatory approach served as the core value of the community service effort, effectively building healthy relationships, strengthening trust, and encouraging a more organic and sustainable transformation within the context of community-based elementary education.

RESULTS AND DISCUSSION

A comparison of the number of new students registered before and after the community service program is shown in Table 1.

Table 1 Comparison of new student enrollment before and after the community service program

Academic Year	Number of New Students	Description
2023/2024	0 students	No applicants at all
2024/2025	7 students	Increase after the mentoring program

Table 1 shows a significant increase in new student enrollment following the community service intervention, reflecting a growing level of public trust in the school. The results of the teacher competency evaluation in in-depth learning and AI-based teaching are listed in Table 2.

Table 2 Evaluation results of teacher competency in deep learning and ai-based teaching

Competency Aspect	Before (%)	After (%)	Improvement Category
Understanding of Deep Learning Concepts	35	80	High
Ability to Design Deep Learning Lesson Plans (RPP)	25	75	High
Ability to Use AI in Teaching	20	65	Moderate
Readiness to Innovate in Teaching	40	85	High

Data was collected through pre-tests, post-tests, and observation sheets during the mentoring process. There was a significant improvement in teacher competencies, particularly in their understanding of deep learning pedagogy (clarified to avoid confusion with AI deep learning) and their ability to design innovative lesson plans. The frequency with which teachers implement digital learning innovations is shown in Table 3.

Table 3 Frequency of digital learning innovations implemented by teachers

Month	Number of New Innovations (Media, Methods, AI Tools)	Description
1	1	Initial exploration of tools
2	3	Adoption of simple AI-based media
3	5	AI integration into lesson planning
4	6	Consistent use of AI tools

Table 3 illustrates a clear month-to-month growth in the number of innovations, from exploration to consistent classroom integration, including chatbots, AI-generated quizzes, and video-based learning media. Students' non-academic achievements before and after the program are shown in Table 4.

Table 4 Student non-academic achievements before and after the program

Year	Event Name	Achievement Reached
2023 (before)	–	None
2024 (after)	“Pesta Pramuka Siaga”	Consolation Prize 1
2024 (after)	“Lampon Parade”	2nd Place

The rise in student participation and achievements in extracurricular events indicates positive social-emotional development, resulting from a more supportive school ecosystem. Results of the survey of parents' perceptions of the school (before & after the program) are shown in Table 5.

Table 5 Results of parent perception survey on the school (before & after the program)

Perception Aspect	Before (%)	After (%)	Description
The School Provides Quality Education	30	75	Drastic increase
The School is Ready for the Digital Era	15	60	Significant improvement
Willingness to Enroll Children in the School	10	70	Sharp rise in trust
Willingness to Support School Activities	20	65	Improved parental engagement

Data was collected through a simple questionnaire distributed to current and prospective parents. The findings demonstrate a strong shift in public perception, particularly regarding trust in the school's quality and readiness for digital transformation.

The results of the community service program at SDN Temenggungan Banyuwangi demonstrate that a participatory, capacity-building approach focused on empowering teachers and integrating technology into learning can significantly improve the quality of small elementary schools. This is evident from the increase in new student enrollment, heightened teacher motivation, growing adoption of Deep Learning and AI-based instructional innovations, and improved public perception of the school. These improvements did not occur instantly but rather through a collaborative, sustained mentoring process (IDB, 2025; Rahiman & Kodikal, 2024).

When compared to similar community service initiatives conducted at schools with comparable characteristics, these findings are consistent in highlighting that teacher capacity building is the key driver in the transformation of small elementary schools. For instance, in a community service project conducted by (Grassini, 2023) it was found that enhancing teacher competencies through workshops and coaching on 21st-century learning significantly improved teachers' confidence and increased the school's attractiveness to the community. Approaches that position teachers as agents of change, rather than passive recipients of training, have proven effective in fostering contextual and sustainable instructional innovations.

Furthermore, the introduction of the Deep Learning approach in basic education aligns with the framework proposed by (Segbenya et al., 2023; Strielkowski et al., 2025) in New Pedagogies for Deep Learning, which emphasizes meaningful learning through real-world problem-solving, collaboration, and critical reflection. At SDN Temenggungan, mentoring teachers to design lesson plans (RPP) that go beyond curriculum compliance and encourage deeper student thinking marked a clear departure from the previously dominant traditional teaching models. This is supported by Figure 1, which shows teachers engaged in collaborative lesson planning sessions. This shift addresses the demands of the national curriculum, which now aims to strengthen higher-order thinking skills from the early education level (Beni et al., 2022).

Figure 1 Teachers make lesson plans

The integration of AI in elementary education remains relatively new in many schools, especially in small or rural institutions. However, the outcomes of this initiative demonstrate that, with a gradual and context-sensitive approach, teachers can begin to adopt AI tools creatively. Figure 2 provides a concrete example of how this training was implemented in the field, highlighting teachers' active involvement and engagement with digital tools. These findings support research by (Darling-hammond et al., 2008; Vincent-Lancrin et al., 2019), which argues that AI can catalyze personalized learning when accompanied by adequate digital literacy among educators. In the Indonesian context, (Fauziati, 2025; Ghamrawi et al., 2024) highlight that the effective use of AI in basic education

requires a holistic approach, combining technical training with a transformation in teachers' mindsets.

Figure 2 Teachers of SDN Temenggungan participating in AI-based instructional design training

The use of a Participatory Action Research (PAR) method in this initiative also proved highly effective. As reported by (Hammond LD, Hyle EM, 2017) in a school empowerment program in Lombok, active teacher involvement across all stages—problem identification, planning, implementation, and evaluation—not only accelerates innovation adoption but also fosters a strong sense of ownership. This explains why teachers at SDN Temenggungan were able to maintain consistency in their instructional innovations even after the formal mentoring phase concluded (Akomaning, 2019).

Nonetheless, challenges regarding program sustainability remain. One ongoing issue is the limited understanding among parents of the benefits of technology—particularly AI—in learning. Some parents still hold negative perceptions of digitalization, fearing it may lead to excessive gadget use among children. This finding echoes those of the (Fauziati, 2025; Fullan & Langworthy, 2013), which highlighted that the digital understanding gap between schools and homes is a major barrier to comprehensive digital education reform. Therefore, future strategies must move beyond information dissemination and include educational engagement with the broader community (Guven, 2009).

The emergence of non-academic student achievements, such as those in the Pesta Pramuka and Lampon Parade, indicates that the improved school environment is positively influencing students' enthusiasm to engage cognitively and socially. This supports the theory of self-efficacy, where a supportive learning environment can boost students' confidence and performance. Such developments also reflect the indirect impact of improved teacher quality in creating more meaningful and enjoyable learning experiences (Mwogosi & Simba, 2025; Owoc et al., 2021).

In conclusion, this community service initiative demonstrates that small elementary schools need not be left behind, as long as strategic, contextual, and sustainable interventions support them. Collaboration among universities, schools, and the community is the key to success and offers a replicable model for other small schools across Indonesia, provided local needs and available resources are appropriately considered (Gârdan et al., 2025; Heni et al., 2023).

CONCLUSION

The community service initiative conducted at SDN Temenggungan Banyuwangi demonstrated a significant positive impact in strengthening the profiles of small elementary schools in addressing the challenges posed by the Deep Learning-oriented curriculum and the integration of AI-assisted digital learning. Through a participatory action approach, teachers significantly improved their competencies in designing and implementing student-centered, inquiry-based, and contextually relevant learning activities. The increase in new student enrollment, the development of innovative teaching practices, and the enhanced community perception toward the school indicate that active mentoring and collaborative teacher empowerment programs can serve as effective strategies to rebuild public trust in small schools amid the broader national education transformation. As a follow-up, continuous capacity-building initiatives, teacher learning communities, and stronger partnerships with local education stakeholders are essential to ensure the sustainability, scalability, and long-term impact of these positive outcomes.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, SH and AS; methodology, SH; formal analysis, SH; investigation, SH, AS, and BHS; resources, AS; data curation, SH and BHS; writing, preparation of the original draft, SH; writing—review and editing, AS and BHS; supervision, AS; project administration, SH; funding acquisition, SH. All authors have read and agreed to the published version of the manuscript.

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