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# Enhancing Technology Literacy Competence among Elementary School Teachers in the Era of Educational Digitalization

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ABSTRACT

Enhancing national competitiveness in education, particularly at the elementary level, is essential in addressing the challenges of the Educational Revolution 4.0. Teachers, as the key agents of educational transformation, require continuous capacity building in digital and technological literacy to maintain professional excellence and instructional relevance. This community engagement program aimed to strengthen elementary school teachers' competencies in technology literacy as part of their pedagogical and professional development. The implementation was conducted through a two-phase process focused on integrating technology-based learning media into classroom practices. Data were collected through observations, discussions, and evaluation instruments to assess teachers' progress. The findings revealed significant improvements in teachers' ability to utilize digital tools, design innovative instructional media, and apply technology-based learning strategies effectively. Moreover, participants demonstrated increased confidence in sharing educational innovations through scientific publications. The results underscore that developing teachers' technology literacy not only enhances the quality of learning but also supports sustainable professional growth and contributes to the advancement of digital education ecosystems in elementary schools.

**Keywords**
Digital Learning
Educational Innovation
Industrial Revolution 4.0
Technology Literacy

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## Introduction

In the 21st-century educational landscape, the role of technology has become indispensable in shaping teaching and learning processes, particularly in primary education. Integration of digital tools and media into classroom practice not only supports student learning but also positions schools to respond to the demands of digital societies [1]. For elementary-level teachers, their capacity to leverage technology effectively, often referred to as technology literacy or digital competence, is critical for maintaining instructional relevance and innovation. Teachers who master these competences are better equipped to design engaging learning environments, adapt to emergent pedagogical models, and contribute to sustainable educational ecosystems. At the same time, curricular reforms globally emphasise digital competencies as part of foundational teacher professional standards [2].

Despite the growing emphasis on digital and technological literacies, many primary school teachers continue to face challenges in integrating technology into their pedagogical practices. Internal barriers such as limited time, inadequate skills, and low self-efficacy have been documented to impede effective use of digital tools in literacy and broader instructional domains [3]. In the context of elementary education, the mismatch between the availability of technology and the teachers' ability to utilise it meaningfully remains a critical concern. This has resulted in disparities between policy aspirations and classroom realities, thereby limiting the transformational potential of technology for basic education. Moreover, while attention has focused on student outcomes from technology-based instruction, less emphasis has been placed on the foundational competence of teachers as agents of change. Consequently, the quality of learning experiences and the professional growth of teachers may be undermined.

## Literature Review

Recent literature has explored various facets of teacher digital competence and technology integration. For instance, Dahl-Leonard, Hall & Peacott [4] conducted a meta-analysis of technology-delivered literacy instruction in Grades K-5, finding a small but significant positive effect ($g = 0.24$) on literacy outcomes for elementary students. Similarly, Lohr [5] emphasised the critical role of teacher technology-related skills and school infrastructure in facilitating digital learning. In the specific Indonesian context, Yuliardi [6] examined the relationship between information literacy, learning space optimisation, and TPACK skills among prospective mathematics teachers, revealing significant positive effects of each on digital mathematics literacy. Additionally, studies published in the Indonesian journal landscape demonstrate that teacher digital competence levels remain moderate; for example, Maghfiroh [7] found that only a minority of teacher-candidates in her sample reached higher tiers of digital competence. Furthermore, Harmadi [8] investigated the interplay of digital literacy, teacher motivation, and TPACK among elementary teachers in Indonesia, showing

strong positive correlations (r = 0.857 and r = 0.866, respectively) and suggesting that both factors explain a substantial variance in TPACK scores.

While the literature has advanced understanding of digital competence, technology literacy, and teacher professional development, key gaps remain. First, many studies focus on either student outcomes of technology use or isolated teacher variables (such as digital literacy alone), rather than on the combined effects of teacher technology literacy and other professional-psychological factors (e.g., motivation, self-efficacy) on instructional transformation. Second, although frameworks like TPACK (Technological Pedagogical Content Knowledge) are widely applied, fewer investigations target primary school teachers in elementary settings, especially within developing country contexts, where infrastructural and contextual constraints differ significantly. Third, while digital literacy among teachers is being measured, less work has been done on longitudinal or multi-phase intervention programmes that aim to strengthen technology literacy and observe the subsequent impact on instructional practice and teacher publication behaviour (e.g., educational innovation outputs). Therefore, there is a need for empirical research that both strengthens teacher technology literacy within elementary schools and examines how that strengthening translates into classroom practices and professional contribution (such as scholarly writing or media development).

In response to these identified gaps, the present study intends to investigate the strengthening of technology literacy among elementary school teachers and to examine how such enhancement influences their pedagogical practice and professional development. Specifically, the objectives are: To assess the baseline level of technology literacy among elementary school teachers, To implement a structured capacity-building programme aimed at strengthening teachers' technology literacy, including training and mentoring phases, To evaluate changes in teachers' instructional practices following the intervention, particularly in the design and use of technology-based learning media, To explore how enhanced technology literacy correlates with teachers' output in professional forums, such as development of educational media and readiness to publish, To derive implications for sustainable teacher professional development programmes in primary education, particularly in the era of digital transformation and the Industrial Revolution 4.0

## Material and Methods

### A. Research Design

This research adopted a qualitative descriptive approach framed within a participatory action research (PAR) model to strengthen technology literacy among elementary school teachers. The study emphasized real-world intervention through professional development workshops, mentoring, and reflective evaluation. The participatory design was selected because it enables researchers and teachers to collaborate as co-learners in identifying issues,

implementing solutions, and reflecting on outcomes [9]. The process was structured in iterative cycles of planning, action, observation, and reflection to align with community-based educational improvement frameworks [10]. This design was deemed suitable for addressing the contextual challenges of digital transformation in basic education, where teacher readiness and institutional resources vary significantly across schools [11].

The data comprised both primary and secondary sources. Primary data were gathered from 20 elementary school teachers at SD Islam Nurul Iman in Bogor, Indonesia, representing grades 1–6. These teachers were participants in the professional-development programme focusing on digital and technology literacy integration. Demographically, most participants had between five and fifteen years of teaching experience and limited prior exposure to technology-based pedagogy. Secondary data included institutional documents, digital-competence assessment rubrics, and field notes obtained during mentoring sessions. This dual-source structure ensured data triangulation and increased the reliability of qualitative interpretation [12].

**B. Data Collection Technique**

Data collection was conducted in three sequential stages: preparation, implementation, and evaluation [13]. See Fig. 1.




**Fig. 1.** Data Collection Stages

During the preparation stage, researchers conducted a comprehensive needs analysis to identify teachers' baseline digital literacy levels, instructional practices, and pedagogical challenges related to technology integration. The survey collected quantitative and qualitative data regarding teachers' familiarity with digital tools, confidence in using educational technologies, and perceived barriers in digital instruction. The findings provided a diagnostic profile of teachers' competencies and needs. This information guided the design of targeted professional development activities that were relevant, context-sensitive, and aligned with teachers' instructional responsibilities and school technology environments and expectations.

During the implementation stage, researchers facilitated a structured professional development programme consisting of workshops and mentoring sessions conducted over six weeks. These sessions integrated lectures, live demonstrations, and collaborative digital media design activities to promote active engagement and experiential learning. Teachers participated in hands-on tasks, including developing technology-supported lesson plans and digital learning materials. Researchers documented the process through systematic observational field notes. Additionally, teachers maintained reflective journals and submitted

instructional artefacts, enabling continuous monitoring of participation, engagement, skill development, and pedagogical transformation throughout training activities.

During the evaluation stage, researchers analysed multiple sources of data to assess changes in teachers' digital literacy, pedagogical knowledge, and attitudes toward technology integration. Pre- and post-intervention questionnaires provided measurable indicators of competency development. Semi-structured interviews and reflective focus group discussions offered deeper insights into teachers' experiences, perceptions, and professional growth. The analysis of instructional artefacts further demonstrated applied skill development. This triangulated approach enabled comprehensive validation of findings, capturing behavioural changes, perceptual shifts, and tangible instructional improvements, ensuring a robust and credible evaluation of professional development outcomes.

### C. Data Analysis

The analysis followed a thematic-content approach [14], involving literative coding, categorisation, and interpretation. Data from interviews, observations, and documentation were transcribed and coded using an inductive strategy to identify recurring themes such as digital awareness, instructional innovation, and pedagogical transformation. To ensure trustworthiness, the analysis adhered to the criteria of credibility, transferability, dependability, and confirmability [15]. Member checking and peer debriefing were employed to validate the findings, while triangulation across data sources increased analytical rigour.

Quantitative indicators (e.g., pre- and post-training self-assessment scores) were descriptively summarised to complement the qualitative insights. The combined approach enabled a comprehensive understanding of how technology-literacy strengthening influences teachers' instructional practices and professional identity.

## Results and Discussions

The implementation of the technology-literacy strengthening program resulted in a substantial improvement in teachers' digital competence, instructional creativity, and confidence in integrating technology into daily classroom practice. Pre- and post-training evaluations were conducted using a self-assessment questionnaire aligned with UNESCO's ICT Competency Framework for Teachers [16]. The results indicated measurable progress across key competency domains, including technological knowledge, pedagogical integration, and digital content development. Teachers also demonstrated increased willingness to experiment with innovative instructional strategies supported by digital tools. Furthermore, participants reported greater confidence in selecting appropriate technologies to enhance student engagement and learning effectiveness.

**Table 1.** Changes in Teachers' Technology-Literacy Dimensions (n = 20)

| Literacy Domain | Pre-Test Mean (%) | Post-Test Mean (%) | Δ Improvement (%) |
|---|---|---|---|
| Information and Media Literacy | 54.2 | 82.6 | +28.4 |
| Pedagogical Integration of Technology | 49.7 | 79.8 | +30.1 |
| Digital Ethics and Safety | 61.3 | 85.0 | +23.7 |
| Creative Use of Learning Media | 52.5 | 86.5 | +34.0 |
| Collaborative Online Practice | 46.0 | 76.8 | +30.8 |

The largest gains occurred in creative use of learning media (+34%) and pedagogical integration of technology (+30%), demonstrating that practical workshop experiences significantly enhanced teachers' design and application skills. Observational data revealed increased engagement during sessions, as teachers collaborated in designing interactive slide-based materials, digital quizzes, and short video-based lessons. See Fig. 2.

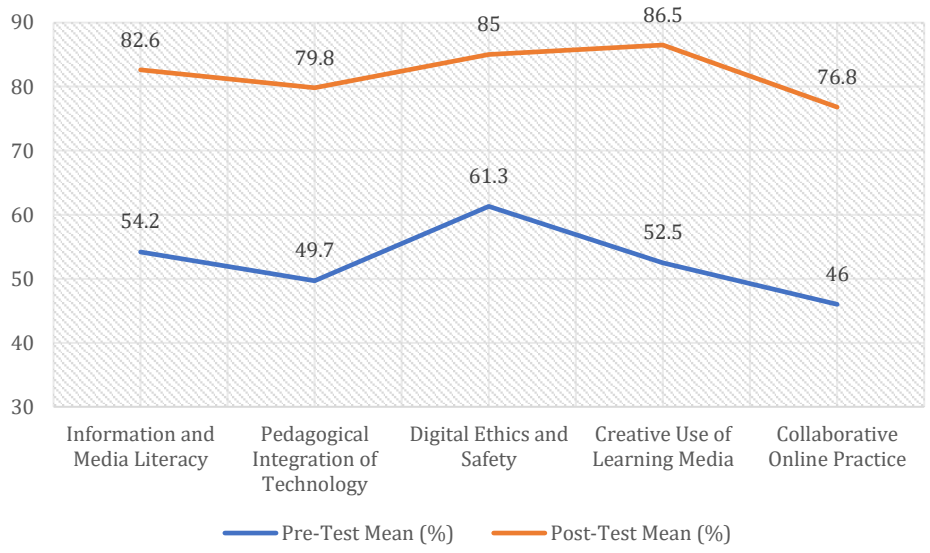



**Fig. 2.** The Pre- and Post-Test Means

Through inductive thematic analysis, four major themes emerged:

1. Digital Awareness and Self-Efficacy: Teachers' initial anxiety about technology shifted toward confidence and curiosity. Many participants expressed a new sense of "ownership" of digital learning tools.
2. Pedagogical Transformation: Teachers began designing lessons incorporating digital media—such as Quizizz, Canva, and PowerPoint Interactive—as extensions of traditional instruction.
3. Collaborative Learning Culture: Mentoring fostered peer collaboration through online groups, facilitating ongoing idea exchange beyond the formal training sessions.

4. Professional Empowerment and Reflection: Teachers developed reflective habits by documenting their learning processes, with several drafting short practitioner articles for local educational bulletins.

These themes indicate that the intervention not only improved technical competencies but also cultivated positive attitudes toward continuous professional learning.

The quantitative and qualitative findings collectively demonstrate that targeted professional-development initiatives can substantially enhance elementary teachers' technology literacy and instructional innovation. The 25–30% average gain across domains aligns with findings by Arifin and Setiawan [17], who observed similar improvements following blended digital-literacy workshops among Indonesian teachers. Moreover, the empowerment of teachers through reflective and collaborative learning echoes Dede et al. [18], who emphasised the sustainability of online professional learning when combined with community support. The development of self-efficacy was particularly evident in this study; participants' confidence grew as they experienced success in producing and applying digital media. This corroborates Bandura's [19] social-cognitive perspective that mastery experiences are the most influential source of self-efficacy. The improved collaboration among teachers also reflects López-Gómez et al. [20], who identified collegial support as a critical factor in sustaining digital transformation within schools. Comparative research underscores similar trajectories. There is found strong correlations between teacher motivation, digital literacy, and TPACK competence, suggesting that intrinsic motivation amplifies the effect of technological training. Likewise, reported that digital-literacy enhancement programs significantly improved preservice teachers' ability to design mathematics learning content using digital tools. These consistent patterns reinforce that technology literacy is not an isolated skill set but a multifaceted construct integrating cognitive, pedagogical, and affective dimensions.

The results support the integration of Technological Pedagogical Content Knowledge (TPACK) and Self-Determination Theory (SDT) frameworks for teacher-development design. Enhancing technology literacy involves not only technical training but also cultivating autonomy, competence, and relatedness—key motivational drivers in SDT [21], which are strongly associated with sustained professional engagement and digital skill adoption among teachers [22], [23]. Research shows that meaningful professional development integrates reflective practice, collaborative learning, and contextualized application to strengthen teachers' technological and pedagogical competencies [24]. Practically, the study contributes a replicable model for localized teacher-capacity development in developing countries, where structured interventions are essential to overcoming systemic digital inequities [25]. The combination of workshops, mentoring, and reflective documentation offers an adaptable

blueprint for educational institutions seeking to bridge the digital-competence gap at the elementary level while fostering long-term instructional innovation and professional growth [26].

## Conclusion

This study confirmed that strengthening technology literacy through structured training and mentoring significantly enhanced elementary school teachers' digital competence, pedagogical innovation, and professional confidence. The intervention not only improved teachers' technical skills but also stimulated their creative use of digital tools in designing meaningful learning experiences. Quantitative findings revealed consistent improvements across all literacy domains, with the largest increase in creative use of learning media (+34%). Qualitative results indicated that participants developed a stronger sense of digital self-efficacy, collaborative engagement, and reflective practice. These outcomes underscore that technology literacy is not merely a technical proficiency but an integrated professional capacity that supports adaptive teaching, collaborative learning, and lifelong development. Furthermore, the participatory nature of the intervention—linking workshops, mentoring, and reflection—proved effective in fostering sustainable teacher professional growth. The findings align with global trends emphasising the necessity of teacher digital competence as a fundamental component of educational quality and resilience in the era of the Fourth Industrial Revolution. In conclusion, empowering elementary teachers with technology literacy is a strategic investment toward future-ready education systems. Strengthening such competence ensures that schools can transform technological challenges into opportunities for inclusive, innovative, and data-informed learning.

The novelty of this research lies in its integration of participatory action research and reflective mentoring to strengthen teachers' technology literacy within a real-world elementary-school context in Indonesia. Unlike many studies that focus solely on measuring digital competence, this research implemented a multi-phase intervention model that simultaneously built capacity, observed behavioural change, and fostered publication-oriented reflection. Methodologically, the study contributes a hybrid evaluative framework combining quantitative improvement metrics and qualitative thematic insights—linking teacher literacy outcomes to pedagogical transformation indicators. Theoretically, it advances the dialogue between the Technological Pedagogical Content Knowledge (TPACK) framework and Self-Determination Theory (SDT), proposing that sustainable digital competence depends on both cognitive mastery and intrinsic motivation. Empirically, this study provides one of the few documented models demonstrating how technology-literacy training can translate into professional empowerment, as evidenced by teachers' ability to produce creative learning media and scholarly outputs. Practically, the model serves as a replicable blueprint for teacher-

training institutions seeking to operationalise national digital-education agendas through community-based and context-sensitive interventions.

## Limitation and Suggestions

This study's limitations include its relatively small sample size and single-school focus, which may constrain generalisability. Future research should employ mixed-method or quasi-experimental designs across multiple schools to validate these outcomes statistically. Additionally, longitudinal tracking is recommended to examine the persistence of digital-literacy gains and their impact on student learning outcomes.

Theoretically, the study reinforces the integration of Technological Pedagogical Content Knowledge (TPACK) and Self-Determination Theory (SDT) frameworks as guiding principles for teacher-development models. Effective digital literacy enhancement should not only transfer technical knowledge but also address motivational and contextual dimensions promoting autonomy, competence, and relatedness among teachers. Practically, this study offers an applicable model for professional-development programs in developing-country contexts. Institutions are encouraged to:

1. Institutionalize structured training cycles combining theory, practice, and mentoring.
2. Embed reflective documentation and peer collaboration as mandatory components of professional growth.
3. Integrate digital-competence assessment frameworks (such as UNESCO ICT-CFT) into teacher-evaluation systems.
4. Provide infrastructural and policy support, including access to digital devices, Internet connectivity, and continuous learning platforms.

Policymakers should recognize that teacher digital competence is a dynamic construct requiring ongoing reinforcement. Partnerships between universities, local governments, and schools can enhance sustainability through continuous mentoring and certification systems. Future research should adopt longitudinal and mixed-method designs to explore the long-term effects of strengthened technology literacy on student learning outcomes, teacher innovation capacity, and school digital ecosystems. Ultimately, developing technology-literate teachers is vital to realizing the vision of Education 4.0, where human creativity and digital intelligence converge to produce inclusive, adaptive, and sustainable learning environments.

## Conflict of Interest

The authors declare that there is no conflict of interest.

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