Strategies for Developing Teacher Professional Competence in the Era of Digital Transformation in Education: A Literature Review

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ABSTRACT

The digital transformation of education requires teachers to possess adaptive professional competencies aligned with technological advancements and 21st-century learning dynamics. This study aims to analyze strategies for developing teacher professional competence in the digital era through a *systematic literature review* of 23 national and international journal articles published between 2015 and 2025. The analysis employed a thematic approach based on the PRISMA model, encompassing stages of identification, selection, data extraction, and synthesis. The findings reveal that effective teacher professional development (TPD) strategies include continuous digital training, collaborative learning communities, and the integration of technologies such as artificial intelligence (AI) in training processes. Major challenges involve digital inequality, infrastructural limitations, and resistance to change. Overall, digital transformation positively impacts teachers' pedagogical competence, technological literacy, and professional identity. This review recommends a sustainable, collaborative, and innovation-based TPD model to strengthen teachers' roles as agents of educational transformation in the digital age.

Keyword: teacher professional development; digital competence; educational transformation; technological literacy; professional learning

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1. INTRODUCTION

The development of information and communication technology has brought about fundamental changes across various sectors of life, including education. The accelerating digital transformation compels the education system to adapt to a new paradigm of technology-based learning (Gu et al., 2025; Montero-Mesa et al., 2023). Teachers, as the forefront of educational practice, are required to possess professional competencies that encompass not only pedagogical and social aspects but also digital capabilities that can bridge the learning needs of the 21st century (Sitompul, 2022; Wati & Nurhasannah, 2024). These competencies include skills in using digital media, integrating technology into the learning process, and creating adaptive and contextual learning experiences (Anisah et al., 2024).

The digital era presents both opportunities and challenges for educators. On one hand, digitalization enables more interactive, collaborative, and student-centered learning experiences. On the other hand, many teachers are still unable to fully utilize the potential of technology (Aleksieva, 2025; Annemann et al., 2025). The low participation of teachers in digital-based professional development programs remains one of the main barriers to educational transformation (Amemasor et al., 2025; Hennessy et al., 2022). In this context, Teacher Professional Development (TPD) becomes a key strategy to strengthen teachers' digital readiness and adaptability to modern learning ecosystems (Trevisan et al., 2024; Stavermann, 2025).

Previous studies have shown that technology-based training and professional development significantly enhance teachers' pedagogical abilities and confidence in using ICT in classrooms (Hörmann et al., 2024; Masaeed et al., 2025). Systematic reviews highlight that effective TPD emphasizes ongoing learning, community support, and collaborative approaches that leverage digital tools (Huang et al., 2024; Perry, 2023).

Furthermore, Montero-Mesa et al. (2023) pointed out the existing contradictions between digital education policies and school infrastructure readiness, emphasizing the importance of synergy between teacher training and educational policy.

In Indonesia, similar challenges persist. Many teachers continue to experience a digital divide, not only in operating devices but also in understanding how to integrate technology into pedagogy (Wati & Nurhasannah, 2024; Anisah et al., 2024). Studies by Sitompul (2022) and Ningrum et al. (2024) highlight the need for practical technical training to help teachers adapt to digital learning environments. Such initiatives not only enhance digital literacy but also foster creativity in developing AI-based instructional media, such as the use of platforms like Magic School (Anisah et al., 2024).

Beyond technical skills, professional development is closely tied to educational leadership and institutional policies. Farrell et al. (2024) underscored the importance of collaboration and structural support in facilitating digital transformation within schools. Similarly, Garay Abad and Hattie (2025) argued that the success of TPD programs depends largely on the quality of learning materials and instructional design tailored to teachers' needs. Globally, teachers' participation in digital TPD has been proven to increase technology usage frequency and foster positive attitudes toward educational innovation (Annemann et al., 2025; Gu et al., 2025).

Moreover, the paradigm shift in education triggered by the COVID-19 pandemic accelerated the adoption of technology in teaching and learning. Teachers worldwide were forced to adapt to online and hybrid learning models (Perry, 2023; Eradze et al., 2023). This situation prompted the emergence of new forms of technology-driven TPD that emphasize flexibility, continuity, and emotional support for teachers (Huang et al., 2024; Trevisan et al., 2024). In this regard, digital professional development is no longer optional but has become an integral part of modern teacher professionalism (Stavermann, 2025; Amemasor et al., 2025).

Therefore, this study aims to analyze strategies for developing teachers' professional competencies in the era of digital transformation in education through a literature review of national and international research published over the last decade (2015–2025). This review focuses on (1) the forms and strategies of effective digital-based TPD, (2) the supporting and inhibiting factors of TPD implementation in the digital era, and (3) the implications of strengthening teachers' digital competence for improving learning quality.

The findings of this review are expected to provide conceptual contributions to formulating adaptive, sustainable, and contextually relevant models of teacher professional development that align with 21st-century educational needs. Furthermore, this article seeks to reinforce the role of teachers as agents of change in responding to global challenges and the Fourth Industrial Revolution, grounded in digital innovation, collaboration, and technology-driven pedagogy (Zou et al., 2025; Pei et al., 2025; Wati & Nurhasannah, 2024).

2.   RESEARCH METHOD
A.   *Research Design*

This study employs a descriptive qualitative approach using a systematic literature review (SLR) method. This approach was chosen to obtain an in-depth understanding of strategies for developing teachers' professional competence in the era of digital transformation in education. The SLR method enables researchers to identify patterns, trends, and research gaps through a directed analysis of prior studies (Amemasor et al., 2025; Huang et al., 2024). The research procedure consists of four main stages:

(1) literature identification,
(2) selection and inclusion criteria,
(3) data extraction and thematic categorization, and
(4) analysis and synthesis of findings (Hennessy et al., 2022; Trevisan et al., 2024).

B.   *Sources and Literature Criteria*

The data sources in this study consist of national and international peer-reviewed journal articles indexed in DOAJ, Scopus, ScienceDirect, MDPI, and SINTA, published between 2015 and 2025. A total of 23 articles were purposively selected based on the following inclusion criteria:

- Focus on teacher professional development (TPD), teacher competence, or digital literacy in education;
- Present empirical or systematic findings related to educational digital transformation;
- Include a valid DOI and full-text access;
- Written in English or Indonesian;
- Relevant to educational contexts ranging from primary to higher education.

Articles that did not meet these criteria (e.g., unrelated to teacher competence or lacking an official DOI) were excluded from analysis. The selection process resulted in 23 final articles representing both global and national research spectra, covering publications from MDPI journals (Education Sciences, Frontiers in

Education, Behavioral Sciences) to Indonesian journals such as Jurnal Pendidikan Tambusai and Jurnal Review Pendidikan Dasar (JRPD) (Sitompul, 2022; Wati & Nurhasannah, 2024).

C.   Data Collection Technique

Data were collected through a systematic search of electronic databases using the following keywords: "teacher professional development," "digital competence," "educational transformation," "online training," "digital literacy," and "teacher competence in the digital era."

All relevant articles were downloaded in PDF format and organized using reference management tools such as Mendeley to ensure citation consistency in APA-7 style. National articles (e.g., Sitompul, 2022; Anisah et al., 2024) were obtained from the SINTA portal and university journal repositories, while international articles (e.g., Gu et al., 2025; Annemann et al., 2025; Trevisan et al., 2024) were sourced from reputable international journals.

D.   Data Analysis

Data were analyzed thematically (thematic analysis) through three stages:

- Open Coding: Identifying main concepts such as TPD strategies, digital competence, and the role of educational policies (Gu et al., 2025; Montero-Mesa et al., 2023).
- Axial Coding: Grouping findings into three major themes:
  a) Strategies and models of teacher professional development,
  b) Challenges and barriers in digital TPD implementation, and
  c) The impact of TPD on competence enhancement and learning quality.
- Selective Coding: Synthesizing results to identify patterns and relationships among themes and to determine research gaps and future policy directions (Hörmann et al., 2024; Farrell et al., 2024).

The analysis was conducted manually with the aid of literature tables and thematic matrices to ensure interpretive accuracy. Each article was cross-checked based on its abstract, methodology, and findings to avoid interpretative bias (Huang et al., 2024; Trevisan et al., 2024).

E.   Validity and Reliability

The validity of the findings was maintained through source and thematic triangulation, comparing results across studies from different countries and educational contexts. Reliability was strengthened through internal peer review, where researchers cross-checked the consistency of themes and citations. This approach ensured that the resulting synthesis is credible, representative, and academically accountable (Amemasor et al., 2025; Stavermann, 2025).

F.   Research Ethics

Since this study does not involve direct human participants, formal ethical approval was not required. However, all sources were properly cited following APA-7 citation style and academic integrity principles, with DOIs and relevant journal details duly included.

G.   Summary of Research Stages

Table 1. Summary of Research Stages

Stage	Main Activity	Objective
Identification	Searching articles (2015–2025) from academic databases	To find relevant literature
Selection	Determining articles based on inclusion criteria	To ensure contextual relevance
Data Extraction	Reading, annotating, and recording key points	To construct the literature matrix
Thematic Analysis	Grouping and synthesizing findings	To identify patterns and formulate recommendations
Validation	Rechecking citations and themes	To ensure result reliability

Through this methodology, the study aims to provide a comprehensive overview of how teachers can continuously develop their professional competencies amid the rapid digital transformation in the education sector.

3.   RESULTS AND DISCUSSION

A.   Strategies for Developing Teachers' Professional Competence in the Digital Era

The digital transformation of education requires teachers to continuously adapt to emerging technologies and modify their instructional practices to meet 21st-century learning demands. Numerous studies affirm that digital-based Teacher Professional Development (TPD) strategies are most effective when they emphasize sustainability, collaboration, and contextual relevance (Amemasor et al., 2025; Trevisan et al., 2024; Stavermann, 2025).

Online professional development programs have emerged as one of the most prominent approaches. Gu et al. (2025) found that national policy–driven digital training in China and the United States significantly enhanced teachers' abilities to integrate technology into learning and adapt to online platforms. Similarly, Huang et al. (2024) demonstrated that technology-based TPD during the COVID-19 pandemic improved both the efficiency and quality of online instruction.

In addition to formal training, collaborative learning among teachers and the establishment of Professional Learning Communities (PLCs) play a vital role. Pei et al. (2025) highlighted that online learning communities strengthen a sense of belonging and promote the sharing of best practices among educators. Farrell et al. (2024) further noted that the Erasmus+ program, which fosters cross-country collaboration, enriched teachers' digital and social competencies through reflective and intercultural teamwork.

Meanwhile, Hörmann et al. (2024) emphasized that teacher flexibility and intrinsic motivation are critical factors for successful digital training. Blended learning and micro-learning models have proven effective in overcoming teachers' time constraints. In the Indonesian context, Sitompul (2022) and Wati and Nurhasannah (2024) underscored the importance of continuous professional training and mastery of 21st-century skills (4Cs) — critical thinking, creativity, collaboration, and communication — as integral components of teacher professionalism.

The integration of artificial intelligence (AI) into training activities has also begun to gain traction. Anisah et al. (2024) demonstrated the effectiveness of technical workshops in improving teachers' digital literacy through the creation of AI-based learning media using Magic School. This approach fosters creativity while enhancing teachers' adaptability to new technologies.

Overall, effective digital-era teacher professional development strategies encompass four key components:
1. Continuous digital training supported by strong policies and infrastructure;
2. Experience-based collaborative learning communities;
3. Flexible training formats (online, offline, or hybrid); and
4. Integration of technological innovations such as AI and learning analytics to strengthen TPD effectiveness.

B.   Challenges and Barriers in Implementing Digital TPD

Despite the growing variety of strategies, the implementation of digital TPD continues to face several challenges. Studies indicate that digital inequality, workload pressure, and resistance to change remain the primary obstacles (Montero-Mesa et al., 2023; Annemann et al., 2025; Masaeed et al., 2025).

Annemann et al. (2025) found that teacher participation in digital TPD varies widely across countries, influenced by social and economic contexts. Teachers in low-income countries often face limited access to digital devices, while in developed countries, the challenges are more psychological—such as digital fatigue and low intrinsic motivation. Hennessy et al. (2022) similarly noted that teachers in developing nations are frequently constrained by inadequate infrastructure and insufficient educational policy support for digital initiatives.

From a policy standpoint, Montero-Mesa et al. (2023) revealed a misalignment between digital education policies and teacher readiness. Many policy frameworks adopt a top-down approach that overlooks teachers' contextual needs, resulting in ineffective and poorly integrated training. Meanwhile, Masaeed et al. (2025) discovered that teacher performance evaluations in Palestinian schools rarely assess digital competencies, which reduces teachers' motivation to develop these skills.

Pedagogical and emotional capacity also present significant challenges. Aleksieva (2025) found that many teachers—especially senior ones—lack confidence in using new technologies, being more accustomed to conventional teaching methods. Trevisan et al. (2024) added that the complexity of digital platforms and the absence of technical support often diminish the effectiveness of online learning programs for teachers.

In Indonesia, similar challenges persist. Sitompul (2022) and Wati and Nurhasannah (2024) reported that most teachers remain at the digital awareness stage and have yet to creatively integrate technology into instruction. This gap is compounded by limited school facilities and the absence of institutional incentives for continuous training.

Thus, the successful implementation of digital TPD requires a systemic approach that not only focuses on technical training but also strengthens policies, infrastructure, and teachers' psychosocial well-being.

C.   The Impact of Digital Transformation on Teachers' Competence and Professionalism

Digital transformation has had a significant impact on enhancing teachers' competence and professionalism. Several studies indicate that participation in digital TPD programs improves teachers' pedagogical competence, digital literacy, and innovative capacity (Gu et al., 2025; Stavermann, 2025; Pei et al., 2025).

Stavermann (2025) found that online-based TPD increased teachers' confidence and shifted their instructional paradigm from teacher-centered to learner-centered learning. Huang et al. (2024) confirmed that technology enables personalized learning experiences, allowing competence development to occur more rapidly and contextually. On a global scale, Annemann et al. (2025) identified a positive correlation between the frequency of digital training participation and teachers' proactive attitudes toward ICT integration in classrooms.

Positive impacts also emerge in the form of teaching innovation and cross-border collaboration. Farrell et al. (2024) emphasized that international collaborative programs encourage teachers to develop global perspectives on digital pedagogy. Likewise, Hennessy et al. (2022) noted that digital TPD in developing countries contributes to expanding educational access and promoting equity in learning opportunities.

In Indonesia, technology-driven training programs, such as those developed by Anisah et al. (2024) and Wati and Nurhasannah (2024), have been shown to enhance teachers' digital literacy while fostering creativity in designing innovative learning media. This demonstrates that digitalization influences not only technical skills but also the affective and social dimensions of teacher professionalism.

However, these positive impacts are cumulative and depend on the continuity of training. Trevisan et al. (2024) and Amemasor et al. (2025) highlighted that short-term or isolated programs tend to yield temporary effects. Therefore, digital TPD should be structured as a sustainable learning ecosystem, supported by school leadership and institutional incentives.

In summary, the findings reveal that digital transformation contributes to three major aspects of teacher professionalism:
1. Enhancement of digital pedagogical competence through technology integration in teaching;
2. Strengthening of collaboration and professional learning communities; and
3. Transformation of teachers' mindsets toward innovation, reflection, and technology orientation.

D. Synthesis of Discussion

Based on the analysis of 23 articles, it can be concluded that the development of teachers' professional competence in the digital era is inseparable from technological innovation, educational policy, and collaborative culture. Training strategies oriented toward sustainability and contextual relevance are more effective than short-term, compliance-based programs.

Furthermore, the literature suggests that the success of digital transformation depends largely on the readiness of the educational ecosystem, not merely on individual teacher capabilities. Hence, future research should explore systemic models of digital professional development that involve policymakers, educational institutions, and teacher learning communities (Gu et al., 2025; Montero-Mesa et al., 2023).

4. CONCLUSION

This study concludes that the development of teachers' professional competence in the era of digital transformation is a fundamental prerequisite for the success of 21st-century education. Based on the synthesis of 23 national and international studies, the most effective Teacher Professional Development (TPD) strategies are those that are sustainable, collaborative, contextual, and technology-driven. Digital training, inter-teacher collaboration, and the integration of innovations such as Artificial Intelligence (AI) and learning analytics have been proven to enhance teachers' digital literacy, pedagogical capability, and creativity in learning design (Gu et al., 2025; Huang et al., 2024; Trevisan et al., 2024).

Nevertheless, the implementation of digital TPD continues to face complex challenges, including digital inequality, low motivation, limited infrastructure, and educational policies that are often misaligned with teachers' actual needs (Montero-Mesa et al., 2023; Annemann et al., 2025; Masaeed et al., 2025). In the Indonesian context, such disparities are still evident, particularly among teachers in regions with limited technological access (Sitompul, 2022; Wati & Nurhasannah, 2024). Despite these barriers, digital transformation has yielded significant positive impacts on teacher professionalism, fostering growth in technological competence, pedagogical reflection, and collaborative orientation. Teachers who actively participate in digital TPD programs increasingly demonstrate the role of agents of change within their schools (Stavermann, 2025; Pei et al., 2025; Farrell et al., 2024).

Theoretically, this study reinforces models of lifelong learning and transformative learning theory, positioning teachers not merely as training recipients but as active learners who continuously reflect and innovate. The emerging concept of digital pedagogical competence highlights that professionalism in the digital era extends beyond technical proficiency—it encompasses the ability to integrate technology with pedagogical and humanistic values (Hörmann et al., 2024; Aleksieva, 2025). Practically, the findings suggest several implications for education stakeholders. Educational institutions and policymakers must design continuous, needs-based TPD programs that are flexible and contextually relevant; strengthen digital infrastructure and equitable access across regions (Annemann et al., 2025; Hennessy et al., 2022); promote collaboration through Professional Learning Communities (PLCs) to cultivate reflective and sharing cultures (Pei et al., 2025; Farrell et al., 2024); and integrate AI and learning analytics into TPD to support adaptive and personalized instructional design (Anisah et al., 2024).

Future research is encouraged to develop empirical and ecosystem-based models of digital TPD that connect policy, institutional, and teacher-level dynamics (Gu et al., 2025; Montero-Mesa et al., 2023); conduct longitudinal studies to evaluate the long-term effects of TPD on teacher performance and job satisfaction; and apply mixed-method approaches to capture the multidimensional relationship between digital training, teacher

competence, and student outcomes. Further exploration is also needed on teachers' emotional and social readiness to navigate AI-driven and automated learning systems within the Indonesian educational context.

Overall, this study underscores that professional development in the digital era is not merely a matter of technological adaptation, but a transformation of mindset. Teachers must evolve as lifelong, collaborative, and adaptive learners, capable of leading innovation within their educational ecosystems. Strengthening the synergy among digital training, educational policy, and teacher professionalism will enable the education system to move toward a more inclusive, creative, and future-oriented direction. In this light, teachers are not simply technology users but architects of change, shaping a meaningful and sustainable digital transformation in education (Trevisan et al., 2024; Stavermann, 2025; Wati & Nurhasannah, 2024).

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