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Managing Teacher Competence Improvement through Leadership, Professional Development, and Digital Innovation: A Systematic Literature Review

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ABSTRACT

Teacher competence is a key factor in improving education quality and student outcomes in the 21st century. This systematic literature review analyzes 41 peer-reviewed studies published between 2020 and 2025, examining the roles of leadership, professional development, and digital innovation. Using PRISMA methodology and a critical assessment framework, the review identifies that instructional and transformational leadership enhance teacher competence by promoting collaboration, innovation, and accountability. Effective professional development models include mentorship, coaching, and learning communities, particularly when adapted to local contexts. Digital innovations—such as AI, gamification, and mobile learning—offer new pathways for teacher growth but face challenges related to infrastructure, training, and socio-economic disparities. The review highlights significant inequalities between developed and developing regions, especially in rural areas. Findings underscore the need for equity-focused policies, localized implementation of global frameworks, and sustainable investment in teacher development. Enhancing teacher competence remains a global and local priority to prepare students for the demands of an increasingly complex world.

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INTRODUCTION

In the 21st century, education plays a critical role in equipping individuals to meet the demands of a rapidly changing world. Globalization, technological disruption, and shifting labor markets have redefined what it means to be "educated" in contemporary society. At the heart of this transformation is the role

of teachers, who are not only responsible for transmitting knowledge but also for fostering innovation, critical thinking, creativity, and digital competence in students. As a result, teacher competence has emerged as a major concern for policymakers, educators, and researchers alike. According to Varghese & Musthafa (2021) and Santosa et al. (2022), competent teachers are foundational to school improvement and are key drivers of educational success. The importance of teacher competence lies in its direct impact on both cognitive and non-cognitive student outcomes, including academic performance, civic engagement, and emotional development. Therefore, improving teacher competence is not only essential for educational systems but also vital for societal progress. The increasing complexity of modern education underscores the urgent need to support teachers in developing the competencies necessary to navigate this evolving landscape.

Despite global recognition of the importance of teacher competence, educational systems worldwide continue to face significant challenges in ensuring that teachers possess and continually develop the necessary skills. One of the major problems is the gap between educational policy and classroom practice, where teachers are often expected to adopt innovative strategies without sufficient support or training (Zulkifli, 2021). Moreover, the demands on teachers have increased, requiring them to adapt to new technologies, shifting pedagogical approaches, and diverse student needs. Empirical research (Ata & Alpaslan, 2024; Sulaiman & Ismail, 2020) highlights that many teachers lack access to high-quality professional development, leadership support, and digital tools—factors that are critical to fostering competence. The result is an uneven educational landscape in which teacher capacity is highly variable, contributing to persistent inequalities in student learning outcomes. These challenges are especially acute in under-resourced settings, where teachers are often left to navigate complex expectations without systemic support. Thus, there is an urgent need to address the underlying structural and contextual barriers that hinder teacher competence development.

In practice, significant disparities exist in how teacher competence is developed and supported across different educational contexts. For instance, studies from Southeast Asia reveal that digital literacy and innovative pedagogical practices are often limited to urban or well-resourced schools, while rural areas struggle with minimal infrastructure and training opportunities (Kurniawan et al., 2020). These disparities are not just about access to technology, but also about leadership support, professional culture, and institutional readiness. Teachers in low-income or rural settings frequently report inadequate mentoring, lack of collaborative learning environments, and limited exposure to digital tools. Furthermore, while education systems may introduce reforms

aimed at innovation, these often fail to reach the classroom level due to weak implementation strategies and lack of alignment with teachers' daily realities (Caingcoy, 2023; Said et al., 2022). The gap between policy aspirations and on-the-ground realities has led to fragmented efforts in improving teacher competence. This highlights the importance of understanding how leadership, professional development, and digital innovation intersect and function differently across diverse educational environments.

A substantial body of research has examined the individual components that contribute to teacher competence. Leadership, especially instructional and transformational leadership, is consistently cited as a key enabler of teacher growth (Zulkifli, 2021; Arendse et al., 2024). Professional development models have evolved from traditional workshops to more sustainable formats such as coaching, mentoring, and learning communities that emphasize reflective practice (Safrizal et al., 2022; Vehachart et al., 2022). Likewise, scholars have explored the impact of digital innovation—including AI, gamification, mobile learning, and flipped classrooms—on both teaching practices and student engagement (Parody et al., 2022; Wu & Mao, 2023). These studies underscore the multifaceted nature of teacher competence, which encompasses pedagogical knowledge, digital literacy, collaboration, and adaptability. However, while each of these domains is well-researched in isolation, few studies have systematically integrated them into a coherent framework for understanding how they interact to shape teacher competence in diverse educational contexts.

Most studies either focus narrowly on one aspect—such as leadership or digital innovation—or examine specific regional contexts without offering comparative insights. For example, studies in high-income countries emphasize advanced technological integration and data-driven instruction (Boontonglek et al., 2023), whereas studies in developing contexts focus more on basic access and capacity-building (Juharyanto et al., 2023). There is limited understanding of how leadership, professional development, and digital innovation collectively contribute to building teacher competence in both resource-rich and resource-poor settings. Additionally, while policy frameworks like the OECD's TALIS have offered global benchmarks, they often lack local adaptability (Ziling et al., 2024). This study positions itself at the intersection of these domains, offering a systematic literature review that synthesizes global evidence, identifies thematic patterns, and highlights contextual nuances. By integrating these strands, this research seeks to fill the gap and provide a more holistic and comparative understanding of teacher competence development.

The novelty of this study lies in its integrative approach to examining teacher competence through the lens of leadership, professional development, and digital innovation across global contexts. Unlike previous research that treats

these factors in isolation or focuses narrowly on one region, this study employs a systematic review methodology to uncover how these dimensions interact to influence teacher growth and effectiveness. It builds on and advances previous scholarship by offering a cross-contextual synthesis, emphasizing the socio-economic, infrastructural, and cultural conditions that shape teacher competence. Furthermore, this research introduces an equity-sensitive perspective, addressing how disparities in access to professional development and digital tools affect competence development, particularly in marginalized communities. By drawing from studies published between 2018 and 2025, this article reflects the most current trends, technologies, and policy shifts influencing education. The findings are not only academically relevant but also practically valuable for education leaders, policymakers, and teacher training institutions aiming to design sustainable and impactful teacher development strategies in the 21st century.

Based on the issues outlined above, the central research problem of this study is: How do leadership, professional development, and digital innovation interact to enhance teacher competence across diverse educational contexts, and how do these factors influence student outcomes? This research argues that addressing this problem requires an integrated framework that goes beyond isolated interventions. Teacher competence is not the result of individual effort alone but is shaped by systemic and contextual factors that include school leadership practices, ongoing professional support, and access to digital innovation. The working assumption of this study is that a synergistic interaction among these three pillars leads to more sustainable improvements in teacher capacity and student learning. This research contributes by identifying the mechanisms through which these factors operate, the barriers that impede their effectiveness, and the strategies that enable their successful integration. In doing so, it provides valuable insights for both local and global educational stakeholders committed to improving teacher competence as a foundation for educational transformation in the 21st century.

This study contributes to both the scientific literature and policy discourse by offering a comprehensive and systematic review of how teacher competence can be improved through leadership, professional development, and digital innovation. It fills a notable gap by providing an integrated perspective that accounts for contextual diversity, from high-income digital classrooms to under-resourced rural schools. Furthermore, this research proposes a conceptual framework that links leadership practices with professional development structures and digital innovation strategies to explain how teacher competence is developed and sustained. It also highlights the need for equity-driven and locally adapted policies, arguing that one-size-fits-all models are ineffective in

addressing the complexity of global education systems. The findings of this study are intended to inform future research agendas, support policy formulation, and guide the design of teacher development programs that are responsive to 21st-century demands. Ultimately, by positioning teacher competence as both a local and global imperative, this research underscores the urgency of investing in teachers as the cornerstone of educational quality and equity.

METHOD

This Study Search Strategy uses a systematic review methodology following the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA), which is widely recognized to ensure transparency and accuracy in the systematic literature review (Rokeman & Kob, 2024; Flemban, 2024). PRISMA provides a structured approach that guides researchers through the stages of review's identification, screening, eligibility, and inclusion, thereby improving reproducibility and minimizing bias (Rezki et al., 2023; Ngendabanga et al., 2025). In line with this standard, searches are conducted at Scopus, given the comprehensive coverage of peer-reviewed publications in education and related fields.

The search uses a combination of keywords and Boolean operators to maximize coverage. The keywords include: "teacher competence", "professional development", "instructional leadership", "digital innovation", and "student outcomes." These terms were identified based on previous studies and research objectives, allowing for the retrieval of 150 initial records. To ensure accuracy, both title-abstract-keyword fields are searched, and synonyms or related terms are included where relevant. The PRISMA methodology further ensures consistency in reporting the literature identification process.

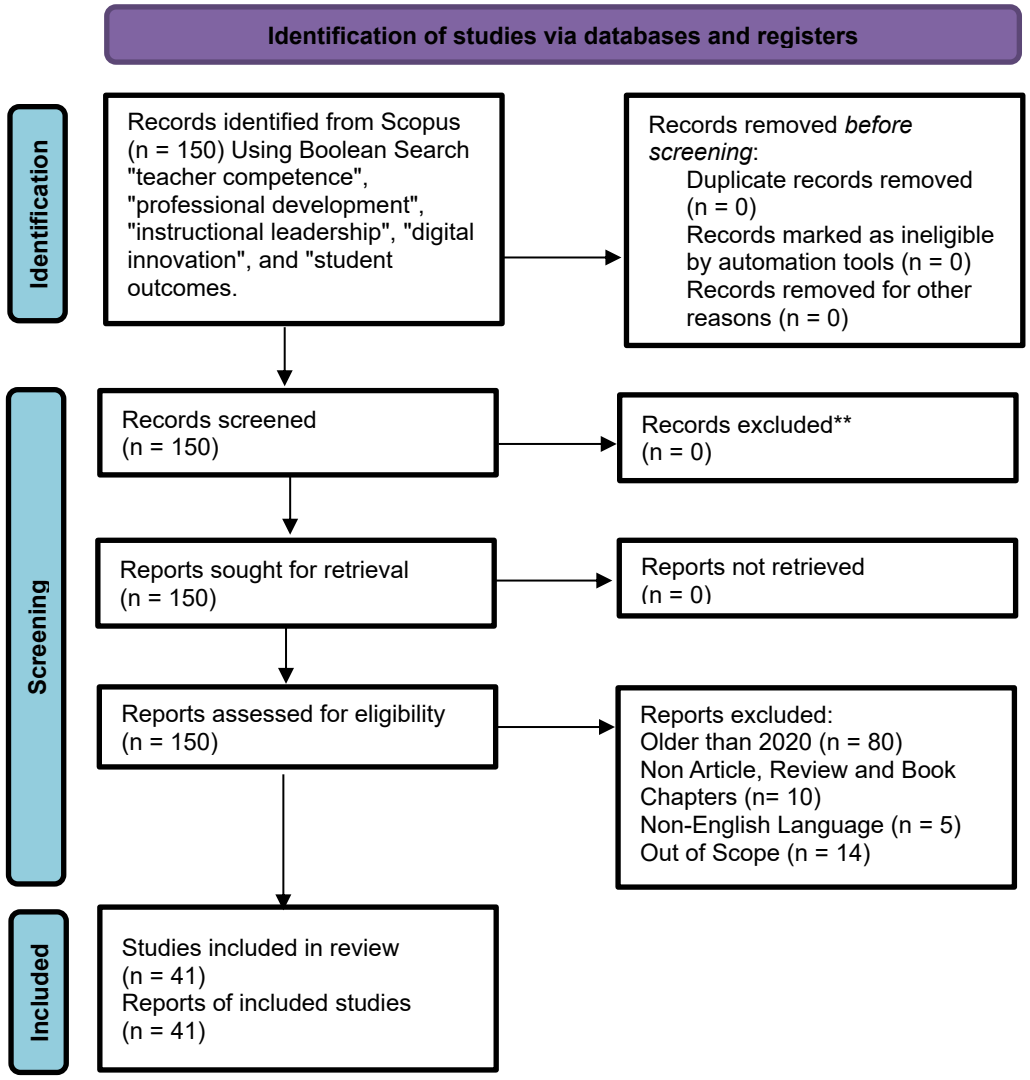

Figure 1. PRISMA Study Selection Flow Chart

This image will illustrate the identification of 150 records, the removal of duplicates, the filtering by abstract/title, and the final inclusion of 41 articles based on inclusion and exclusion criteria. Inclusion and exclusion criteria are established a priori to increase the resilience of the review, as emphasized by Azaña-Lucio et al. (2024) and Darabont et al. (2021). The inclusion criteria consist of: (1) peer-reviewed journal articles, (2) published between 2020 and 2025, (3) written in English, and (4) addressing at least one of the following themes: teacher competence, professional development, instructional leadership, digital innovation, or student outcomes. Exclusion criteria include: (1) publications prior to 2020 (n=80), (2) non-article publications such as editorials or conference abstracts (n=10), (3) non-English studies (n=5), and (4) irrelevant studies that do not align with the scope of this review (n=14). After applying these criteria, a total

of 41 articles were selected for in-depth analysis, ensuring relevance and methodological accuracy.

The use of transparent inclusion/exclusion rules is in line with best practices in systematic review methodologies, ensuring that the findings are comprehensive, relevant, and replicable (Roslin et al., 2022; Huang et al., 2024). The screening process follows a two-stage approach. First, title and abstract screening is done to eliminate research that clearly does not meet the inclusion criteria. Second, full-text screening is carried out to ensure alignment with the predetermined scope, with a focus on methodological rigor and relevance to teacher competence, leadership, PD, or digital innovation. This two-level process is consistent with the strategies suggested by Nielsen et al. (2024) and Heikkinen et al. (2022), which highlight the importance of repeated refinements in ensuring that only high-quality studies are maintained.

The use of the PRISMA guidelines ensures clarity in documenting the amount of research included or excluded at each stage, encouraging replication. Peer validation of the screening process is also used to minimize researcher bias, in line with recommendations by Belavý et al. (2021) and Liu et al. (2024). To evaluate the methodological quality of the selected studies, this review used two established frameworks: the Critical Assessment Skills Program (CASP) and the Mixed Methods Assessment Tool (MMAT).

These tools facilitate the identification of strengths and limitations in the reviewed studies, providing insight into the overall robustness of the evidence base. The implementation of CASP and MMAT is consistent with the recommendations set to increase transparency and methodological accuracy in educational SLR (Rezki et al., 2023; Rokeman & Kob, 2024). In addition, adopting multiple assessment tools strengthens the credibility of the review, as suggested by Ngendabanga et al. (2025).

FINDING AND DISCUSSION

Teacher Leadership and Competence

Leadership in education plays an important role in shaping teacher competence and improving student outcomes. Effective leadership practices provide the necessary structural, cultural, and motivational foundation for teachers to continue to develop their skills and apply them in classroom practice. This synthesizes the findings of the reviewed studies presented in Table 1.

Table 1. Teacher Leadership and Competence

Author/ Year	Context	Leadership Model	Teacher Competency Results	Limitations
Arendse dkk., 2024	South Africa	Leadership in a culture of change	Improved PD and collaboration	Weak accountability system
Ismail et al., 2020	Malaysia	Instructional leadership	Strong correlation with functional competence	Focus on high-performing schools
Tzeni et al., 2019	Greece	Effective administration	Perception gap between principals and teachers	Limited to sports teachers
Juharyanto et al., 2023	Indonesia	School climate & TQM	School climate predicts competencies & outcomes	Only rural schools
Khan et al., 2020	Thailand	Transformational leadership & KM	Improved teacher skills	Small Bangkok sample
Meneses et al., 2017	Spain	Stress & leadership function	Stress affects competence	Limited context
Setiawan et al., 2017	Indonesia	ICT school management	Increased leadership professionalism	Focus on West Java
Carrera dkk., 2024	America Latino	Leadership with technology tools	Better collaborative teaching	Resistance to change
Chang, 2023	Taiwan	Ecological knowledge leadership	Stronger team competencies	Requires institutional support
Caetano, 2019	Portugal	University governance	Competency challenges highlighted	Legal/structural barriers

One of the most consistent findings across the study was the critical influence of principals and school leaders in fostering teacher competence. Arendse et al. (2024) highlight how leadership in a culture of change in South Africa enhances professional development and collaboration among teachers, although the study also noted weaknesses in accountability systems. This is in line with Fullan's theoretical perspective on adaptive leadership, which emphasizes the creation of an environment that embraces continuous learning and collaboration (Hanafi et al., 2022; Ahn & Bowers, 2023).

Similarly, Ismail et al. (2020) in Malaysia found a strong correlation between instructional leadership and teachers' functional competence. Instructional leaders who set clear curricular priorities and actively support teacher development provide a framework for continued competency growth. This supports previous research by Wiyono et al. (2022) and Awan et al. (2023), which established that instructional leadership fosters teacher motivation, efficacy, and a positive school climate.

The literature reviewed shows that leadership models manifest differently depending on cultural and institutional contexts. For example, Juharyanto et al. (2023) in Indonesia emphasized how school climate and the Total Quality Management (TQM) approach predict teacher competence and student outcomes, especially in rural schools. These findings underscore the importance of connecting leadership practices with school climates to encourage competency development in resource-constrained contexts.

In Thailand, Khan et al. (2020) described the role of transformational leadership combined with knowledge management, which significantly improves teacher skills. These findings resonate with transformational leadership theory, which emphasizes motivation, support, and shared vision as a mechanism for empowering teachers (Heenan et al., 2023). Nonetheless, the small sample size in Bangkok shows caution in generalizing the findings across the broader context. Similarly, Carrera et al. (2024) highlight the use of leadership with technological tools in Latin America to enhance collaborative teaching, although cultural resistance to change poses challenges for implementation.

While leadership models show significant potential in improving teacher competence, the research also reveals contextual limitations. Tzeni et al. (2019), focusing on Greece, noted a gap in perceptions between principals and teachers regarding effective administration, especially in physical education. This gap underscores the importance of aligning leadership practices with the teacher's perspective to ensure mutual understanding and effectiveness. Meneses et al. (2017) further highlight the influence of stress and leadership function in Spain, suggesting that stress can reduce the positive impact of leadership on teacher competence.

Setiawan et al. (2017) provide insights from Indonesia on the role of ICT-based school management, which increases leadership professionalism and improves teacher competence, especially in West Java. These findings are related to digital innovation theories such as TPACK (Koh, 2020), showing how leadership practices that integrate ICT can directly affect competency outcomes. However, focusing on specific regional contexts limits broader implementation. Chang (2023), in Taiwan, examines ecological knowledge leadership, which strengthens team competencies but requires strong institutional support for sustainability. Similarly, Caetano (2019) in Portugal emphasizes challenges in university governance, highlighting the structural and legal barriers that limit the potential impact of leadership on teacher competence.

The evidence presented in Table 1 is in line with the theoretical framework discussed in Section 3. Instructional leadership (Ismail et al., 2020; Soroño & Quirap, 2023) reinforces the importance of structured support for teachers, consistent with competency management theory (Namsone et al., 2024).

Transformational leadership (Khan et al., 2020) and leadership in a culture of change (Arendse et al., 2024) resonate with Fullan's adaptive leadership model, which emphasizes resilience and collaboration (Hanafi et al., 2022; Awang et al., 2022). Meanwhile, ICT-focused leadership (Setiawan et al., 2017) is connected to digital innovation theories such as TPACK and UTAUT (Xue et al., 2024), underlining how leadership and technology intersect to foster teacher competence.

The findings from Table 1 provide substantial evidence supporting the hypothesis that an integrated approach to leadership significantly improves teacher competence, which in turn improves student outcomes. By encouraging collaboration, providing instructional support, and integrating digital innovation, leaders create an environment conducive to teachers' professional growth. The limitations identified—such as accountability weaknesses, contextual resistance, and structural barriers—further highlight the need for adaptive leadership models tailored to specific educational contexts.

Professional Development Model

Professional development (PD) is the cornerstone for improving teacher competence and, ultimately, improving student outcomes. The studies presented in Table 2. The Professional Development Approach shows the diversity of PD strategies implemented across contexts, highlighting the impacts and limitations of each.

Table 2. Professional Development Approach

Author/ Year	PD Strategy	Target Group	Impact on Teacher Competence	Student Outcomes
Vehachart dkk., 2022	PLC + LMS (Schoology)	Math/Science Teacher	Improving 21C teaching skills	PISA readiness
Farrell et al., 2019	PD for OST staff	U.S. youth workers	Improved behavior management	Safer OST programs
Five, 2024	Customized PD through the main evals	Guru Pakistan	Addressing gender/age gaps	More effective PD
Holt & Ladwa, 2009	Mentoring/coaching	Teacher	Supported reflections	No student link
Namsone et al., 2024	Competency framework	Sekolah Latvia	Tools for PD & competency planning	Personalized PD
Boontonglek et al., 2023	PD art innovation	Thai art teacher	Expert competence enhanced	Strong cultural ties
Alabadan et al., 2020	Competency-based PD	Nigerian engineering teacher	T-shaped skills developed	Industry alignment

Loschiavo, 2023	Nursing PD Guide	School nurse	Practical competence	Safe student care
Carrera dkk., 2024	Technologically enhanced PD	University staff	Better teacher facilitation	Higher student engagement

Vehachart et al. (2022) explore the integration of PLCs with Learning Management Systems (Skoologi) for math and science teachers. Their studies show significant improvements in the teaching skills of 21st-century teachers, preparing students for international benchmarks such as PISA. This is in line with competency management theory (Namsone et al., 2024), which emphasizes a systematic framework for identifying skills gaps and addressing them through structured learning opportunities. The integration of PLCs with digital tools demonstrates how a collaborative environment, when supported by technology, can result in measurable improvements in teacher competence and student readiness.

Similarly, Carrera et al. (2024) examined technology-enhanced PD for university staff, finding that digital tools support facilitation skills and increase student engagement. This resonates with digital innovation theories such as TPACK (Koh, 2020), highlighting how combining pedagogy, content, and technology improves instructional quality. Positive results show that PD models that utilize technology not only strengthen teacher skills but also improve classroom interactivity and student motivation.

Mentorship and coaching remain one of PD's most effective strategies for building reflective practices. Holt & Ladwa (2009) emphasize how mentoring and coaching support teachers' professional reflection, even though their research does not establish a direct relationship with student outcomes. Similarly, Rios-Ellis & Frates (2005) highlighted guidance for diversity among Latino students, pointing to better PD outcomes and greater inclusivity. These findings connect to a competency-based education model (Hariri et al., 2024), where targeted support encourages measurable skill development. In addition, tutoring is directly related to human resource theory, as investment in teacher mentorship results in long-term professional growth (Muazza, 2021; Sherly et al., 2022).

The benefits of coaching are also reflected in recent research, such as Altınay et al. (2020) and Crawford et al. (2021), which underscore how personalized coaching improves instructional strategies and professional adaptation. Together, these findings suggest that while tutoring and coaching may not always have direct student-related outcomes, their impact on teachers' confidence, adaptability, and inclusivity is critical to maintaining long-term competence.

Namsone et al. (2024) propose a competency framework for Latvian schools, offering tools for PD and systematic competency planning. Their findings illustrate how the framework provides a personalized pathway for teacher development, aligned with the Competency-Based Education paradigm (Hariri et al., 2024). Such a structured model is critical in ensuring that PD is not fragmented but rather strategically designed to meet the specified learning outcomes. This structured approach reinforces the hypothesis that context-sensitive PD contributes to measurable teacher growth.

In Nigeria, Alabadan et al. (2020) implemented a competency-based PD model for engineering teachers, focusing on T-shaped skills that integrate disciplinary expertise with cross-functional collaboration. This model aligns PD outcomes with industry requirements, ensuring teacher competencies translate into students' readiness for the professional field. This case illustrates the importance of connecting PD with real-world applications, resonating with human resource theory and competency-based frameworks (Shopia et al., 2022; Li et al., 2021).

Contextual PD models often produce stronger and more sustainable results compared to standard approaches. Kalim (2024) shows how tailored PD guided by principal evaluation addresses teacher gaps differentiated by gender and age in Pakistan, leading to more effective PD interventions. This contextual sensitivity is in line with the debate discussed in Section 3.4, where contextual PD argues is more impactful than the standard one-size-fits-all model (Piasta et al., 2020; Kadir et al., 2021).

Boontonglek et al. (2023) highlight the effectiveness of PD art innovation for Thai art teachers, improving expert competence while instilling cultural values. This case emphasizes the need for PD to incorporate cultural relevance, ensuring that professional growth resonates with teacher identities and local educational practices. Similarly, Loschiavo (2023) developed a nursing PD guide for school nurses, improving practical competencies and ensuring safe student care. These findings collectively underscore that PD models tailored to local needs are better suited for long-term teacher development and student outcomes.

The reviewed studies illustrate clear differences between standard and contextual PD approaches. Standard models, such as large-scale frameworks (Namsone et al., 2024), ensure equality and consistency but may be less responsive to local conditions. On the contrary, the contextual approach (Kalim, 2024; Boontonglek et al., 2023) result in greater relevance and adoption, although its scalability may be limited. The balance between these approaches is critical, as argued by Esch et al. in Section 3.4, highlighting the need for PD that combines broad consistency with local adaptation.

A recurring theme throughout the study was the relationship between PD and student outcomes. Vehachart et al. (2022) found that teachers engaged in PLCs with LMS integration showed improved skills that directly supported students' readiness for PISA assessments. Farrell et al. (2019) showed that PD for out-of-school time staff (OST) in the U.S. improves behavior management, creating a safer environment for youth programs. Alabadan et al. (2020) linked competency-driven PD with students' industry-aligned skills, while Loschiavo (2023) linked nursing PD to improved student care outcomes. These findings confirm the hypothesis that effective PD improves teacher competence, which in turn improves student performance and well-being.

Studies such as Moon et al. (2020) and Hu (2024) further strengthen this relationship, showing that increased instructional practice through PD correlates with higher levels of student engagement and achievement. Thus, PD not only serves as a mechanism for teacher growth but also as a strategic tool to advance educational equity and student success.

The evidence synthesized in Table 3 validates the hypothesis that professional development models are essential for improving teacher competence and positively impacting student outcomes. These findings highlight that PD strategies should be diverse, integrating culturally relevant mentorship, PLC, coaching, frameworks, and approaches. In addition, a balance between standard and contextual PD is critical to achieving contextual equity and relevance.

The implications for policy and practice are significant. Policymakers should prioritize investments in PD that combine a structured framework with flexibility for contextual adaptation. Education leaders should encourage mentorship and collaborative learning models while ensuring that digital tools are integrated into PD strategies. In addition, equity considerations demand that PD opportunities be accessible to teachers across socio-economic and cultural contexts, addressing gaps that may perpetuate educational inequalities.

Digital Innovation in Teaching and Training

Digital innovation is increasingly becoming a transformative force in education, offering new avenues to improve teacher competence and student learning outcomes. As outlined in Table 3: Digital Innovation and Teacher Competencies, technologies such as artificial intelligence (AI), gamification, mobile learning, flipped classrooms, immersive virtual environments, and high-performance computing have been used to drive teacher development.

Table 3. Digital Innovation and Teacher Competence

Author/Year	Technology Used	Context	Influence on Competence	Reported Challenges
Numa-Sanjuán dkk., 2024	AI in education	Global	Enhanced innovative teaching	Infrastructure gaps
Parody dkk., 2022	Gamification (Classroom Craft)	Spanish, engineering	Increase motivation & creativity	Limited to techniques
Amjad et al., 2025	Gamification Society 5.0	Pakistani primary schools	Increased motivation when trained	Funding, curriculum gaps
El-Sofany & El-Haggar, 2020	Mobile learning	Egypt higher education	Better collaboration & skills	The digital divide
Azeta et al., 2018	Reverse vs question/project	Nigeria	Reverse > engagement & accountability	Resource limits
Sáiz-Manzanares et al., 2021	Digital game-based learning	Spanish health sciences	Improved LMS usage & results	Varies by degree
Reimann et al., 2009	VR/Second Life yang Imersif	Australia	Fostering innovation	Infrastructure issues
Davis et al., 2007	High-performance computing	United States	Altered simulation pedagogy	Expensive & complex
Bhuiyan et al., 2017	Model e-learning PST	Global	Enabled teacher-student-parent collaboration	Slow implementation
Wang, 2022	AI network communication	Chinese	Increased virtual engagement	Requires training
Ogea-Pozo, 2025	Digital co-evaluation	Spain	Higher translation/ teaching skills	Niche fields

Numa-Sanjuán et al. (2024) emphasize the global role of AI in education, demonstrating how AI-powered platforms enhance innovative teaching practices and empower teachers to design personalized learning experiences. Similarly, Wang (2022) reports how AI-powered network communication in China facilitates virtual engagement, improving teachers' digital competence. These findings resonate with the UTAUT model (Xue et al., 2024), which highlights the role of performance expectations and social influence in driving technology adoption. However, limited infrastructure and training gaps remain significant barriers, confirming previous debates about the digital divide (Said et al., 2022).

The incorporation of AI in the classroom also supports real-time data analytics, allowing teachers to tailor teaching to diverse learners (Ghamrawi et al., 2023). However, as warned by Mahligawati et al. (2023), inadequate

preparation and a lack of AI-specific PD can limit effective integration. These challenges emphasize the importance of linking AI adoption with structured professional development to maximize its potential.

Gamification has been widely recognized for its capacity to improve teacher competence and student engagement. Parody et al. (2022) investigated gamification through Classcraft in Spanish engineering education, finding an increase in motivation and creativity among teachers and students. Amjad et al. (2025) show that gamification in the context of Society 5.0 in Pakistan improves the competence of elementary teachers in motivational strategies, provided they receive adequate training. These results are in line with TPACK theory (Koh, 2020), illustrating how gamification tools require teachers to balance pedagogical knowledge, technology, and content to be effective.

Nevertheless, challenges remain. Limited application outside of engineering (Parody et al., 2022), funding constraints, and curricular misalignments (Amjad et al., 2025) highlight that the impact of gamification is highly context-dependent. Despite these limitations, the integration of game elements such as the point system and leaderboard has been shown to increase collaboration, creativity, and reflection in teaching (Kim et al., 2022).

Mobile learning is another important innovation. El-Sofany & El-Haggar (2020) report that mobile learning in Egypt's higher education sector facilitates teacher collaboration and improves digital skills. These findings connect with competency management theory (Namsone et al., 2024), showing how mobile access to resources supports the continued growth of teachers. However, the digital divide, especially in developing regions, continues to hinder scalability and equitable access (Park & Kwon, 2023).

Reverse learning also shows promise in reconfiguring the role of teachers. Azeta et al. (2018) found that flipped classrooms in Nigeria improve teacher accountability and increase student engagement compared to inquiry and project-based models. These results mirror the Diffusion of Innovation Theory (Oestreich & Guy, 2023), which explains how innovative practices are spreading among educators. However, the adoption of reverse learning remains constrained by limited resources, insufficient PD, and resistance to change (Mutohhari et al., 2021; Novita, 2022).

Reimann et al. (2009) demonstrated the potential of immersive virtual environments such as Second Life in Australia to drive innovation among teachers, while Davis et al. (2007) report how high-performance computing in the US is transforming simulation pedagogy, expanding teachers' instructional capacity. These findings are in line with human resource theory (Muazza, 2021; Sherly et al., 2022), as they show how investment in advanced technology can result in substantial returns in teaching quality. However, both studies highlight

cost, infrastructure, and complexity as important barriers to sustainable adoption.

Sáiz-Manzanares et al. (2021) examined digital game-based learning in Spanish health science education, showing an increase in the use of learning management systems (LMS) and positive student outcomes. However, effectiveness varies by discipline, illustrating the importance of contextual alignment in digital innovation strategies. Similarly, Ogea-Pozo (2025) found that digital co-evaluation tools in Spain improve translation and teaching skills but are limited to specific areas, underscoring scalability challenges.

Throughout the reviewed studies, several barriers to digital innovation emerged. These include a lack of infrastructure (Numa-Sanjuán et al., 2024), funding gaps (Amjad et al., 2025), and limited teacher training (Wang, 2022; Novita, 2022). Cultural resistance to change and a deep-rooted reliance on traditional pedagogy also slows adoption (Herfina, 2022). On the other hand, enablers such as targeted PD, institutional support, and strong leadership (Setiawan et al., 2017; Cloud et al., 2023) facilitate the successful integration of digital tools. These findings reinforce the debate in Section 3.4, which emphasizes the importance of addressing the digital divide to ensure equitable development of teacher competencies.

The findings from Table:3 are clearly related to the theoretical framework AI integration reflects the UTAUT factors of performance expectations and effort expectations (Xue et al., 2024). The gamification study is aligned with TPACK by showing how teachers should integrate technology with pedagogy and content (Koh, 2020). The adoption of reverse learning reflects the Diffusion of Innovation Theory, describing diverse levels of readiness among educators (Oestreich & Guy, 2023). Immersive and high-performance computing environments reinforce the theory of human resources, as investments in high-level technologies increase competence but require significant resources (Sherly et al., 2022). These connections validate the hypothesis that digital innovation directly improves teacher competence, but the outcome depends on context, resources, and institutional readiness.

For policymakers and institutions, these findings underscore the need for strategic investments in digital infrastructure, targeted PD programs, and adaptive policies that drive technology adoption. In addition, the issue of equality demands that digital tools be accessible in various educational contexts to avoid exacerbating existing gaps.

Digital innovation is both an opportunity and a challenge to improve teacher competence. The studies in Table 3 highlight the transformative potential of AI, gamification, mobile learning, and immersive technologies while pointing to persistent barriers such as cost, infrastructure, and cultural resistance. By

linking these findings with theoretical frameworks such as TPACK, UTAUT, Diffusion of Innovation, and human resource theory, this review shows that digital innovation is an important pillar of teacher competence in the 21st century. Overcoming barriers and scaling drivers will be critical to ensuring that digital innovation contributes fairly and sustainably to the improvement of global education.

Cross-Contextual Insights and Equity Issues

Teacher competency development varies substantially across global contexts, influenced by the availability of resources, policy frameworks, cultural norms, and systemic inequalities. As presented in Table 4: Contextual Comparisons in Teacher Competency Development, the study reveals critical gaps between developed and developing countries, highlighting the ongoing successes and challenges in achieving equitable professional growth for educators.

Table 4. Cross-Contextual Comparison in Teacher Competency Development

Author/ Year	Region	Intervention	Competency Results	Equity/Access Issues
Day, 2024	Chinese	STEM competency evaluation	Competence in predicting work	Differences by qualification
Juharyanto et al., 2023	Indonesia	Distance school leadership	Climate builds competencies	Rural inequality
Meneses et al., 2017	Spain	Admin stress survey	Stress impacts leadership competencies	Generalization issues
Carrera dkk., 2024	America Latino	Learning technology	Higher engagement	Access & resistance
Chang, 2023	Taiwan	Sustainability knowledge	Improve team competencies & learning	Need policy support
Caetano, 2019	Portugal	Legal analysis of the role of teachers	Legal/ career obstacles revealed	Structural inequality
Alabadan et al., 2020	Nigeria	T-shaped competencies	Interdisciplinary skills	Regulatory gaps
Sáiz et al., 2021	Spain	Digital game PD	Enhanced competencies	Varied adoption
Vehachart dkk., 2022	Thailand	PLC in distance schools	Higher science/ math competencies	Equality
Amjad et al., 2025	Pakistan	Gamification	Motivational potential	Teacher unpreparedness
Boontonglek et al., 2023	Thailand	Art pedagogy	Building moral/ ethical competence	Limited scaling

He (2024) shows that STEM teacher competencies in China strongly predict work performance, although differences in qualifications create unequal opportunities within the same national system. In Indonesia, Juharyanto et al. (2023) find that supportive school leadership builds teacher competence, yet rural inequalities persist, mirroring broader disparities in developing contexts where infrastructure and PD access remain uneven (Derder et al., 2023; Díaz, 2021). These findings reveal how competency management frameworks operate differently depending on economic and geographic conditions.

In developed contexts, challenges also exist. Meneses et al. (2017) report that administrative pressure in Spain undermines leadership competence, while Sáiz-Manzanares et al. (2021) show that digital game-based PD improves teacher competence but varies by discipline. Technology-based interventions further reflect both opportunities and inequalities: Carrera et al. (2024) highlight increased engagement through collaborative learning in Latin America despite resistance and access issues, while Vehachart et al. (2022) show that PLCs improve competence in remote Thai schools despite island–mainland gaps, consistent with digital divide debates (OECD, 2021; Ofosu-Asare, 2024). Amjad et al. (2025) similarly find that gamification under Society 5.0 in Pakistan is promising but constrained by inadequate training and curriculum alignment.

Institutional structures also shape equity in competency development. Caetano (2019) shows how legal and career barriers in Portugal create structural inequalities, resonating with human resource theory (Muazza, 2021). Alabadan et al. (2020) demonstrate that competency-based PD fosters T-shaped engineering skills in Nigeria but is weakened by regulatory limitations. Chang (2023) in Taiwan and Boontonglek et al. (2023) in Thailand further illustrate that while sustainability and culturally rooted PD can enhance competence, scaling remains limited without supportive policies. Studies on marginalized groups show that diversity mentoring improves competencies but cannot overcome broader socioeconomic disparities, echoing arguments for contextual PD in Section 3.4.

These findings reinforce competency management frameworks (Namsone et al., 2024) while highlighting the need for local adaptation, especially for rural or under-resourced teachers (Adeleye et al., 2024; Amirova et al., 2023). Theoretical perspectives also manifest differently across contexts: competency management explains China's STEM evaluations (He, 2024); human resource theory shapes outcomes in Nigeria and Portugal (Alabadan et al., 2020; Caetano, 2019); and the Diffusion of Innovation Theory is evident in Thai PLCs and Pakistani gamification (Vehachart et al., 2022; Amjad et al., 2025). The tension between contextualization and standardization (Esch et al., 2023) further illustrates that equity requires tailoring interventions to local realities.

Cross-context findings show that while structured PD, leadership, and digital innovation consistently enhance teacher competence, inequalities arise from resource gaps, structural constraints, and cultural resistance. Policymakers must therefore address not only training but also infrastructure, policy barriers, and socio-cultural factors. Equity-focused approaches—such as rural PD initiatives, inclusive mentoring, and legal reform—are essential, and global frameworks like TALIS should be adapted to ensure alignment with local capacities and challenges.

CONCLUSION

This literature confirm that effective leadership plays a catalytic role in driving teacher growth by creating a supportive and adaptive school environment. Professional development models—such as mentorship, coaching, and professional learning communities—have proven to be highly effective, especially when contextualized with local needs and supported by structured competency frameworks. Digital innovations, including artificial intelligence, gamification, mobile learning, and flipped classrooms, provide transformative opportunities to improve teacher competencies, although their impact remains dependent on adequate infrastructure, professional training, and institutional support. Cross-contextual analysis reveals persistent equality challenges, with rural settings and limited resources facing greater barriers to competency development compared to well-resourced urban and resource systems.

This review shows that teacher competencies are multidimensional and context-dependent, requiring integrative strategies that combine leadership, professional development, and digital innovation. This underscores the need for policies that prioritize equality in access to training and resources, alongside local adaptation of global frameworks. Future research should explore the longitudinal impact of digital innovation on teacher competence, investigate equity-driven interventions in low-resource contexts, and further examine how policy frameworks can sustain teacher growth.

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