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Technology-Based Teacher Training and Enhancement of 21st-Century Competencies: A Systematic Review

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Abstract
The technological advancements of the 21st century have transformed educational paradigms, requiring teachers to shift from mere transmitters of knowledge to facilitators of dynamic, collaborative, and technology-driven learning environments. This article examines the role of technology-based teacher training in fostering the development of 21st-century competencies, including critical thinking, creativity, communication, collaboration (4Cs), and digital literacy. Employing a *Systematic Literature Review (SLR)* guided by the PRISMA framework, the study reviewed 27 empirical articles published between 2019 and 2025, sourced from Scopus, Google Scholar, ERIC, and DOAJ. The findings reveal that technology-based training enhances teachers' digital literacy through the Technological Pedagogical Content Knowledge (TPACK) framework, promotes innovative pedagogical transformations such as flipped classrooms and project-based learning, and strengthens professional collaboration through *Professional Learning Networks (PLNs)*. These outcomes underscore that practical training must go beyond technical proficiency to include pedagogical transformation and the cultivation of an innovative mindset. The article concludes that technology-based teacher training significantly enhances teachers' capacity for 21st-century education and recommends contextually designed, sustainable training that is supported by educational policies and adequate digital infrastructure.

Keywords: teacher training, educational technology, 21st-century competencies, TPACK, digital literacy.

INTRODUCTION

The technological advancements of the 21st century have precipitated a fundamental transformation in the educational landscape. Educators are now expected to evolve beyond the traditional role of information dispensers, stepping into the shoes of facilitators who foster dynamic, collaborative, and technologically integrated learning environments. This shift aligns with the core competencies required in the 21st century, encapsulated in the framework of Critical Thinking, Creativity, Communication, and Collaboration (often referred to as the "4Cs"), as well as embracing digital literacy and the concept of lifelong learning (Ayudhia et al., 2023; , Dewi et al., 2023; , Aini & Aini, 2023; , Junedi et al., 2020). Masters and contemporaries have asserted that this competency-based approach not only promotes deeper engagement but also enhances students' readiness for a rapidly changing world. They corroborate that 21st-century skills are imperative for academic achievement as well as preparation for professional success (Tuazon & Sumadsad, 2022; , Ponnusamy & Hassan, 2023; , Kareem & Hussein, 2023).

However, in various educational environments, particularly in Indonesia, a significant gap persists between the demands of 21st-century competencies and the actual skill set possessed by educators regarding the use of educational technology (Herlina & Kamila, 2023; , Pramasdyahsari et al., 2023; , Rizqillah et al., 2022). This

disparity necessitates a concerted effort toward teacher training that is firmly rooted in technological integration as a vital strategy to bolster educators' professional capabilities in the digital age. Research has illustrated that when teachers effectively incorporate technology into their pedagogical practices, students' engagement and learning outcomes improve markedly (Sari et al., 2023; , Agustin & Razi, 2023; , Mulyaningsih et al., 2024). Moreover, a focus on professional development for teachers will inevitably lead to enhanced instructional strategies that better equip students with the necessary skills to thrive in contemporary and future contexts (Tamela et al., 2024; , Novalinda et al., 2023; , Jupri et al., 2024).

Professional development initiatives centered around technology must extend beyond mere technical proficiency, as they should also prioritize a transformation of pedagogical approaches and the cultivation of an innovative mindset in educators (Handayani et al., 2023; , Purwasih et al., 2021). Evidence suggests that these pedagogical shifts not only enhance teachers' technology use but also promote an environment where critical thinking, creativity, and collaboration are integral to the learning experience (Muawiyah, 2024; , Susetyarini et al., 2022). In this vein, a systematic examination of current research between 2019 and 2025 will illuminate how technology-based training for educators contributes to the development of 21st-century competencies, thereby framing the discourse on educational reform in a rapidly evolving technological landscape (Anggraeni, 2020; , Theerathammakorn et al., 2024).

The task of developing and implementing effective technology-based training programs for educators is critical. Such training initiatives must be comprehensive, focusing on enhancing teachers' abilities to foster critical thinking, engage students actively, enhance collaborative learning opportunities, and cultivate a culture of creativity within the classroom (Kousloglou et al., 2023; , Sotlikova, 2023; , Maulana & Sopandi, 2022). In this regard, multiple studies have highlighted the relationship between strong teacher competencies in these areas and enhanced student performance, underlining the necessity for continued investment in educator professional development (Rahmadhani et al., 2021; , Somphol et al., 2022; , Brata et al., 2023). Furthermore, as educational paradigms shift, the integration of 4Cs skills and creative pedagogy is essential to prepare educators and students alike for the demands of an increasingly complex societal landscape shaped by technology and innovation (Aini et al., 2020; , Inayah et al., 2023; , Brata et al., 2023). By establishing a robust framework for technology-based training, educators can not only meet contemporary challenges head-on but also contribute to the sustainable development of future educational frameworks (Mumtaza & Agustinaningsih, 2023; , Firda & Sunarti, 2022).

METHOD

This article employs a systematic literature review (SLR), conducted in accordance with the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). This methodological approach provides a comprehensive framework that effectively synthesizes existing research, offering a clear understanding of the relationships between teacher training, technology integration, and the development of 21st-century skills. The systematic

review process begins with data sources, wherein relevant literature was meticulously searched across several internationally recognized databases, including Scopus, Google Scholar, ERIC, and DOAJ. This search involved the use of meticulously chosen keywords such as "teacher training," "technology integration," "21st-century skills," and "digital pedagogy," which are central to the research topic Ghasya & Kartono (2022), Varghese & Musthafa, 2021; , (Wıbowo et al., 2022; , Çelik et al., 2024; , Bolat & Gençoğlu, 2024).

To ensure the relevance and quality of the studies included in this review, specific criteria for inclusion were established. Articles eligible for consideration had to be published between 2019 and 2024, focus directly on technology-based teacher training or digital pedagogy, examine the relationship between such training and the development of 21st-century competencies, and be empirical in nature, utilizing either quantitative, qualitative, or mixed-method approaches (Mertoğlu & AKMAN, 2020; , Almazroa & Alotaibi, 2023; , Dahri et al., 2023; , Dhakal, 2023; , Xu & Zhou, 2022). Initial searches identified 65 articles, of which 27 met these stringent inclusion criteria. Data from these articles were analyzed using thematic analysis to uncover key patterns and themes regarding the improvement of teacher competencies through technology-based training initiatives (Wıbowo et al., 2022; Cabahug et al., 2024; Septiana et al., 2023). This thematic approach enables a deep understanding of how educational technology not only enhances teaching practices but also prepares educators to foster essential 21st-century skills such as critical thinking, collaboration, creativity, and effective communication among their students (Yoke et al., 2020; , Djoeaeriah & Iskandar, 2024). Overall, the systematic review process facilitates a rigorous and structured synthesis of existing research, offering insights into the role of technology in modern teacher training and skill developme

RESULTS AND DISCUSSION

1. Key Findings

The analysis reveals that technology-based teacher training has a positive impact on the development of 21st-century competencies. This is evidenced by three primary findings distinguished within the literature. Firstly, an increase in digital literacy and pedagogical Technological Pedagogical Content Knowledge (TPACK) has been reported in several studies, such as those by Hidayat et al. Hidayat et al. (2024) and Fadil and Aryani (Fadil & Aryani, 2021). These investigations highlight how training that utilizes digital platforms enhances teachers' ability to effectively integrate TPACK into their instructional practices. Furthermore, research illustrates that a coherent framework for TPACK can facilitate better outcomes in teaching practices that align with the dynamic demands of contemporary education (Bentri & Hidayati, 2023; , Ramadhani et al. (2020). The emphasis on TPACK serves to refine teachers' technological skills while deepening their pedagogical and content knowledge critical for fostering student engagement (Li & Qian, 2025; , Yuliani & Heru, 2021).

Secondly, the transformation of learning practices through technology-based training has been confirmed to empower teachers to adopt innovative teaching methodologies such as flipped classrooms, gamification, and project-based learning aimed at fostering creativity and collaboration among students. Studies, including

the work of Gaite et al. Gaite et al. (2023) and Hermawan & Yuliani (Muvuti, 2023), demonstrate that these pedagogical shifts prompt active learning environments that encourage students' critical thinking and collaborative efforts. This transition toward more interactive learning models reflects a broader movement in education that highlights the integration of technology as a fundamental element for enhancing student engagement and achievement (Timalsina, 2024). Additionally, these innovative approaches are increasingly recognized for their effectiveness in nurturing essential 21st-century skills, such as creativity, collaboration, and communication (Denessen et al., 2023; , Wang et al., 2023).

Lastly, the enhancement of social and collaborative competencies among educators is a notable outcome of technology-based training. Through community-based online training initiatives such as Professional Learning Networks (PLNs), teachers cultivate professional networks that transcend geographical limitations, fostering the exchange of best practices (Nazim et al., 2024). Research emphasizes the significance of collaborative professional development, noting how these networks enhance communication skills and facilitate the sharing of pedagogical strategies among educators (Fitriah & Soehari, 2024). Such collaborative frameworks not only improve teacher morale and engagement but also create supportive environments conducive to shared learning, ultimately benefiting student outcomes in diverse educational settings (Zhao & Liu, 2022; , (Shongwe, 2023; . Thus, the evolution of teacher training through technology is pivotal in constructing a collaborative professional culture among educators, driving enhancements in educational quality (Zulaiha & Mulyono, 2020).

2. Theoretical Discussion

These findings substantiate the TPACK framework proposed by Koehler and Mishra Ramadhani et al. (2020) and the 21st Century Skills Framework established by the Partnership for 21st Century Learning (Wang & Li, 2024). Effective technology-based training does not merely focus on the application of technology; rather, it necessitates a transformational pedagogical approach that encourages adaptability, reflective learning, and continuous professional growth. Essential success factors identified include designing training programs that meet the actual needs of teachers, employing blended learning approaches combined with coaching, and ensuring ongoing support from school administration and educational policies (Hariyanti, 2023). Studies illustrate that tailoring training to address teachers' specific challenges can amplify the efficacy of professional development initiatives (Nseibo et al., 2022).

Conversely, several barriers thwart the effectiveness of these training programs, including limited digital infrastructure, low motivation among senior educators, and a lack of continuous assessment mechanisms to evaluate training effectiveness (Shongwe, 2023; , Rauteda, 2023). Research emphasizes that overcoming these hurdles requires a collaborative approach that incorporates sustained mentoring and the strengthening of professional communities of practice among educators. An ideal training model must integrate the concept of continuous support into its framework to ensure that trained skills lead to lasting improvements in teaching practices and student success (Ali et al., 2024; , Aminah et al., 2023). In this evolving educational landscape, the imperative to harness technology effectively in

teaching underscores the need for progressive training that aligns with the demands of 21st-century education.

Discussion

Findings from the literature indicate that technology-based teacher training plays a pivotal role in strengthening 21st-century competencies through three primary dimensions: enhancing digital literacy, transforming instructional practices, and reinforcing professional collaboration. Numerous studies underscore the positive impact of training on educators' digital literacy, particularly through the integration of Technological Pedagogical Content Knowledge (TPACK) Hidayat et al. (2024), Annan, 2020). Teachers participating in digital training programs have reported significant increases in their confidence and proficiency when utilizing online learning platforms, microlearning applications, and Learning Management Systems (LMS) (Gaite et al., 2023), (Bentri & Hidayati, 2023). Enhanced digital literacy not only enriches educators' teaching practices but also fosters a more engaging learning environment for students, facilitating active participation and deeper learning experiences (Yuliani & Heru, 2021), (Fadil & Aryani, 2021).

Moreover, technology-based training fosters the adoption of innovative pedagogies, such as flipped classrooms, gamification, and project-based learning, that are essential for cultivating creativity, critical thinking, and collaboration among students—core components of 21st-century education (Denessen et al., 2023), Husseini et al. (2022). Studies demonstrate that these pedagogical innovations lead to the creation of more student-centered learning environments, thus promoting active learning and enhancing students' problem-solving abilities (Masfufah et al., 2023), Ramadhani et al., 2020). Research shows that embracing such innovative teaching strategies equips students with essential skills required for success in a rapidly evolving global landscape (Akhter, 2023), (Quang & Minh, 2020). As educators become adept at integrating technology within their instruction, they are positioned to contribute to a more robust educational framework that prioritizes student engagement and competency development (Adhikari, 2023), (Fitriah & Soehari, 2024).

Theoretically, these results reinforce the TPACK model proposed by Koehler and Mishra (Mbeba & Dares, 2020) and the 21st Century Skills Framework (Partnership for 21st Century Learning) (Zulaiha & Mulyono, 2020). Effective technology integration necessitates a paradigm shift in pedagogy, where technical mastery must be coupled with the development of reflective, adaptive, and innovative mindsets among educators to sustain technological integration (Darsinah & Purwatiningsih, 2020; , (Siddiqui et al., 2021). Emerging evidence suggests that teacher training must address not only the technical aspects of digital tools but also equip teachers with the necessary pedagogical strategies to engage effectively with diverse learning needs (Hulda, 2022). However, barriers such as limited digital infrastructure, low motivation among senior educators, and insufficient continuous evaluation persist, complicating the task of fostering a technologically adept teaching workforce (Wang & Li, 2024; , Nseibo et al., 2022). Hence, successful training models should implement blended learning, provide sustained mentoring, and ensure institutional support to overcome these barriers (Qing & Yang, 2023), Li et al., 2023). Therefore, technology-based teacher training should be conceptualized not merely as

technical upskilling but as an ongoing professional transformation aimed at fostering creative and future-oriented educational practices that benefit all students (Faudiah et al., 2023), (Li & Varakantham, 2024).

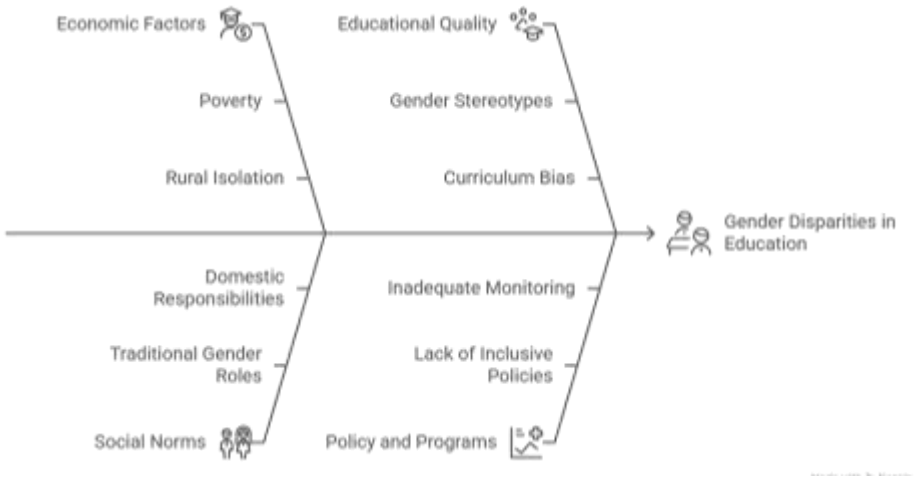

Figure 1. Enhancing Teacher Training with Technology

CONCLUSION

Technology-based teacher training has proven essential in enhancing 21st-century competencies, particularly in developing digital literacy, innovative pedagogical strategies, and professional collaboration. Well-structured training programs empower teachers to be more creative, adaptive, and reflective in utilizing technology for instruction. These findings highlight that advancing teacher capacity in the digital era requires not only skill development but also a transformative pedagogical mindset aligned with the goals of 21st-century education.

Recommendations

1. **Contextual Training Design:** Training programs should address teachers' actual needs, emphasizing TPACK integration and digital literacy relevant to local educational contexts.
2. **Sustainable Professional Development:** Implement *blended learning* models with continuous mentoring to ensure long-term competence and practice improvement.
3. **Policy and Infrastructure Support:** Governments and institutions must expand access to digital tools, support ecosystems for training, and ensure program continuity.
4. **Professional Learning Networks (PLNs):** Encourage collaborative professional communities that foster shared innovation, reflection, and sustained pedagogical improvement.

Through these initiatives, technology-based teacher training can effectively drive educational transformation and elevate the quality of learning in the digital age.

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