

**TEACHER TRAINING FOR TECHNOLOGICAL EDUCATION: COMPETENCIES,
CHALLENGES, AND INNOVATION**

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Abstract

This study aimed to analyze competencies, challenges, and innovation strategies in teacher training for technological education. It consists of an integrative literature review with a qualitative approach conducted between December 2025 and January 2026. The methodological process included defining the

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research problem, establishing inclusion and exclusion criteria, conducting a systematic search in the SciELO, ERIC, ScienceDirect, and SpringerLink databases, selecting and fully reviewing the studies, extracting data using a structured instrument, and performing thematic data analysis. Articles published between 2020 and 2025, available in full text and related to teacher training and digital competence, were included. The search identified 245 publications, of which 13 comprised the final sample. The results were organized into three axes: teachers' digital competencies, structural and institutional challenges, and innovative training strategies. Findings indicate that digital competence involves the integration of technological mastery, pedagogical knowledge, instructional contextualization, and ethical responsibility. Identified challenges included curricular fragmentation, weaknesses in continuing professional development, infrastructure limitations, and the absence of articulated institutional policies. The study also highlights training strategies grounded in the articulation between theory and practice, supervised experimentation, and continuous mentoring. In summary, the consolidation of technological education depends on the implementation of integrated and systematic training models supported by active methodologies, institutional support, and an organizational culture oriented toward innovation. Teacher education should be understood as a continuous process aligned with the demands of contemporary digital society, fostering critical, creative, and socially responsible pedagogical practices.

Keywords: Active Methodologies, Curricular Integration, Digital Competence, Institutional Culture, Professional Development.

INTRODUCTION

Technological education may be understood as a formative field that integrates scientific, technical, and pedagogical knowledge aimed at the critical understanding, reflective use, and production of technologies in educational contexts. Unlike a merely instrumental approach, it involves processes of pedagogical mediation, curricular innovation, and the development of digital competencies that enable individuals to act ethically, creatively, and transformatively in contemporary society. In this regard, Zhang

et al. (2025) argue that technological education is associated with the sustainable development of teacher education, linking digital competence, critical thinking, and social responsibility.

The expansion of digital technologies in educational environments has intensified the need to redefine teacher education processes. Kaminskienė, Järvelä, and Lehtinen (2022) argue that technological integration challenges traditional training structures by requiring articulation among pedagogical knowledge, content mastery, and technological competence, thereby overcoming the curricular fragmentation historically present in teacher education programs. Thus, technological education is not limited to the use of digital tools; rather, it implies methodological and epistemological reorganization.

The problem guiding this study stems from the following question: which competencies are essential for teacher training oriented toward technological education, and which challenges compromise its effective implementation?

Vanegas, Cifuentes, and Morrás (2025) show that effective training programs encompass technical, pedagogical, and collaborative competencies, supported by structured models and active methodologies. This finding reinforces the need for integrated approaches in initial and continuing teacher education.

In higher education, pedagogical innovation associated with digital technologies depends directly on the quality of teacher training. Riedner and Pischetola (2021) demonstrate that innovative practices emerge when there is consistent articulation between theory, practice, and technological experimentation, fostering the meaningful construction of knowledge. This perspective underscores that technological education requires pedagogical intentionality and institutional follow-up.

Nevertheless, challenges persist in the formative context. Bento (2024) highlights that gaps in continuing education, the absence of structuring policies, and insecurity regarding the pedagogical use of technologies limit the development of teachers' digital competencies. These factors indicate that the consolidation of technological education requires investment in ongoing professional development and an institutional culture favorable to innovation.

In addition, specific training strategies enhance the development of digital competence.

Momdjian, Manegre, and Gutiérrez-Colón (2025) point out that the combination of direct instruction, integrated practice, and pedagogical modeling supports the consolidation of technological knowledge applied to teaching, demonstrating that the training process must be experiential and reflective.

The relevance of this study lies in the need to strengthen theoretical and practical frameworks that guide teacher education policies and programs aligned with the demands of digital culture. By deepening the understanding of technological education, this work seeks to contribute to the construction of training models that promote innovation, criticality, and educational quality.

Therefore, the objective of this study is to analyze competencies, challenges, and possibilities for innovation in teacher training for technological education. The specific objectives are: (a) to identify essential digital competencies for teaching practice; (b) to discuss structural and pedagogical challenges in initial and continuing education; and (c) to examine innovative strategies that enhance educational practices mediated by technologies.

METHODOLOGY

This is an integrative literature review with a qualitative approach, exploratory and descriptive in nature, conducted between December 2025 and January 2026. The methodological pathway was structured according to the stages proposed by Whitemore and Knafl (2005), encompassing the definition of the research problem, the establishment of inclusion and exclusion criteria, the search and selection of studies, the critical appraisal of the material, the extraction and organization of information, and the interpretive synthesis of findings.

DEFINITION OF THE PROBLEM AND GUIDING QUESTION

The initial stage consisted of delimiting the research problem, considering the growing demand for teachers' digital competencies in light of the transformations imposed by digital culture and by the

integration of emerging technologies into educational systems. It is observed that, despite advances in incorporating technologies into educational contexts, challenges remain related to the consolidation of training practices that promote the effective development of competencies for technological education.

In this sense, the following guiding question was formulated: How are competencies, challenges, and innovation strategies articulated in teacher training for technological education?

DATABASES AND SEARCH STRATEGY

The search for studies was conducted in national and international databases recognized for their relevance in the educational and technological fields. The following databases were consulted: Scientific Electronic Library Online (SciELO), Education Resources Information Center (ERIC), ScienceDirect, and SpringerLink. The search strategy was developed using controlled descriptors drawn from the Health Sciences Descriptors (DeCS) and Medical Subject Headings (MeSH), combined using the Boolean operator AND. The following descriptors were used in Portuguese: formação docente, educação tecnológica, competência digital docente; and in English: teacher training, educational technology, and digital competence.

INCLUSION AND EXCLUSION CRITERIA

Articles published between 2020 and 2025 were included if they were available in full text, in any language that could be translated, and if they directly addressed teacher education, digital competence, pedagogical innovation, or technological integration in educational contexts. This time frame was chosen because discussions about digital transformation intensified in the post-pandemic period, when the topic gained greater centrality in scientific production. Duplicated articles, narrative reviews, theses, and dissertations were excluded, as were studies that addressed the descriptors only in isolation.

STUDY SELECTION PROCESS

The initial search yielded 245 studies identified in the consulted databases. After excluding 58 duplicate articles, 187 studies remained for title and abstract screening. At this stage, 142 articles were excluded for not meeting the established criteria, mainly because they did not directly address teacher education or because they dealt only with the instrumental use of technologies. Next, 45 studies were selected for full-text reading. After detailed analysis, 32 articles were excluded because they did not adequately respond to the research objective or because they presented a narrow focus on describing digital tools, without a consistent discussion of training. At the end of the selection process, 13 articles comprised the final sample of this review.

DATA EXTRACTION AND ANALYSIS

Information was extracted using a structured instrument containing author identification, year of publication, country of origin, study objectives, methodological design, main results, and contributions to technological teacher education. Data analysis was conducted through thematic content analysis, as proposed by Bardin (2011), involving the stages of pre-analysis, material exploration, categorization, treatment of results, and interpretation. From this process, analytical categories emerged related to teachers' digital competencies, structural and institutional challenges, and innovative training strategies. The discussion was developed interpretively, articulating empirical findings with contemporary theoretical frameworks on technological education and teacher professional development.

RESULTS AND DISCUSSION

The articles analyzed were organized in Table 1, containing information about the authors, titles, and main contributions of their studies.

Table 1

Summary of selected studies on teacher training and digital technologies

Author(s)/Year	Study title	Main contributions
Bento (2024)	Formação continuada de professores e tecnologias digitais: reflexões e desafios na prática de ensino [Continuing teacher education and digital technologies: reflections and challenges in teaching practice]	Analyzes the limits of continuing education for the pedagogical use of digital technologies, highlighting structural gaps and the need for systematic follow-up.
Kaminskienè; Järvelä; Lehtinen (2022)	Como a tecnologia desafia a formação de professores? [How does technology challenge teacher education?]	Highlights the need for curricular reorganization and integration between theory, practice, and technological competence in teacher education.
Medeiros; Wunsch (2023)	TPAC3K: conhecimento tecnológico-pedagógico dos conteúdos criativos, culturais e colaborativos do docente [TPAC3K: technological-pedagogical content knowledge of teachers' creative, cultural, and collaborative contents]	Proposes an expansion of the TPACK model by incorporating creative, cultural, and collaborative dimensions into teacher competence.
Momdjian; Manegre; Gutiérrez-Colón (2025)	Um estudo sobre o desenvolvimento da competência digital de professores em formação inicial [A study on the development of digital competence among pre-service teachers]	Shows that direct instruction, integrated practice, and pedagogical modeling foster consistent development of digital competence.
Oliveira; Mélllo; Franco (2020)	Práticas de ensino com o uso de tecnologias digitais: o papel da formação docente [Teaching practices using digital technologies: the role of teacher education]	Emphasizes the importance of pedagogical planning and institutional support for the effective use of technologies.
Riedner; Pischetola (2021)	A inovação das práticas pedagógicas com uso de tecnologias digitais no ensino superior [Innovation in pedagogical practices using digital technologies in higher education]	Emphasizes the importance of pedagogical planning and institutional support for the effective use of technologies.
Santos <i>et al.</i> (2025)	Processos de ensino e aprendizagem nos anos iniciais e as tecnologias digitais [Teaching and learning processes in the early years and digital technologies]	Highlights didactic intentionality in technological mediation in the early years.
Silva; Matta (2024)	Percepções docentes sobre o conhecimento tecnológico-pedagógico em formação continuada [Teachers' perceptions of technological-pedagogical knowledge in continuing education]	Identifies teachers' insecurities and the need for contextualized training practices.

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Theodorio; Wambua (2024)	Integração tecnológica na formação de professores: desafios e perspectivas na transformação digital [Technology integration in teacher education: challenges and perspectives in digital transformation]	Discusses institutional and cultural challenges in the digital transformation of teacher education.
Trujillo-Juárez <i>et al.</i> (2025)	Fortalecimento da competência digital docente no ensino superior: uma revisão sistemática [Strengthening teacher digital competence in higher education: a systematic review]	Systematizes effective models for strengthening digital competence in higher education.
Vanegas; Cifuentes; Morrás (2025)	Tecnologia educacional na formação de professores: revisão sistemática de competências, habilidades e modelos [Educational technology in teacher training: a systematic review of competencies, skills, and models]	Organizes competencies, skills, and integrated training models for technological education.
Wagner <i>et al.</i> (2024)	Desafios dos formadores de professores no contexto da transformação digital [Challenges faced by teacher educators in the context of digital transformation]	Analyzes challenges faced by teacher educators and their impacts on training quality.
Zhang; Yang; Zheng (2025)	Competência digital para a educação sustentável de professores em formação inicial [Digital competence for sustainable education of pre-service teachers]	Relates digital competence to sustainable education, emphasizing ethical responsibility and digital citizenship.

Source: Authors (2026).

From the thematic analysis of the thirteen selected articles, three structuring axes emerged: (1) teachers' digital competencies; (2) structural and institutional challenges; and (3) innovative strategies in teacher training for technological education. Below, an in-depth discussion of each category is presented.

TEACHERS' DIGITAL COMPETENCIES IN TECHNOLOGICAL EDUCATION

The analyzed studies indicate that teachers' digital competence cannot be reduced to the operational mastery of technological tools. Rather, it is a formative construction that involves articulation among pedagogical knowledge, content mastery, critical capacity, and ethical responsibility in the use of technologies. Zhang, Yang, and Zheng (2025), when examining teacher education oriented toward sustainable education, argue that digital competence is linked to digital citizenship and social responsibility. For the authors, the pedagogical use of technologies should be guided by ethical principles and by a critical understanding of their social impact. From this perspective, teacher education needs to

overcome instrumental approaches and promote continuous professional development aligned with broader educational purposes.

Convergently, Vanegas, Cifuentes, and Morrás (2025) show that effective training programs are those that integrate technical, pedagogical, and collaborative dimensions in an articulated manner. The systematic review conducted by the authors demonstrates that fragmented proposals—where technology appears dissociated from pedagogical practice—tend to produce limited effects on professional development. Digital competence becomes consolidated when technological learning is embedded in real teaching contexts, accompanied by collective reflection and curricular integration.

This understanding is deepened by Medeiros and Wunsch (2023), who, in proposing the TPAC3K model, broaden the scope of technological-pedagogical knowledge by incorporating creative, cultural, and collaborative dimensions. In this framework, technology ceases to be an accessory resource and becomes a structuring element of pedagogical practice, requiring from the teacher the capacity for creation, adaptation, and contextualization to students' sociocultural specificities.

However, the study by Silva and Matta (2024) reveals that the consolidation of this competence does not occur automatically. Although the investigated teachers recognize the relevance of technological integration, they report insecurity regarding practical application in everyday school life. This finding evidences a gap between conceptual understanding and effective pedagogical practice, indicating the need for more contextualized and closely supported training experiences.

In initial teacher education, Momdjian, Manegre, and Gutiérrez-Colón (2025) demonstrate that the consistent development of digital competence is associated with the combination of structured instruction, integrated practice, and pedagogical modeling. Guided observation of didactic strategies, followed by supervised experimentation and systematic feedback, fosters greater autonomy and professional confidence.

Complementarily, Santos et al. (2025) emphasize that, especially in the early years, technological integration requires didactic intentionality. Tool selection must be aligned with learning objectives,

avoiding superficial or decontextualized uses. Trujillo-Juárez et al. (2025) indicate that training programs with continuous follow-up and process-based assessment yield more consistent results, reinforcing the progressive and cumulative character of digital competence.

STRUCTURAL AND INSTITUTIONAL CHALLENGES IN TEACHER EDUCATION

Despite conceptual advances, significant challenges persist in the effective implementation of technological education. Kaminskienė, Järvelä, and Lehtinen (2022) highlighted that technology challenges teacher education by requiring curricular reorganization and the overcoming of fragmentation between theory and practice. The authors observed that many programs still maintain isolated pedagogy and technology courses, which hinders articulation between theory and practical application and compromises comprehensive teacher preparation. According to them, technological integration demands structural revision of training programs and institutional changes that promote alignment among pedagogical objectives, technological competence, and supervised practice.

Complementing these observations, Oliveira, Méllo, and Franco (2020) analyzed teaching practices using digital technologies across different educational institutions and found that the lack of institutional preparedness and technical support prevents teachers from consistently implementing digital strategies. The study showed that even when teachers have technical knowledge, barriers such as the absence of ongoing training, lack of structured pedagogical planning, and inadequate technological resources limit the effectiveness of technological education. It becomes evident that structural challenges are not restricted to curricular reorganization; they also include infrastructure, teacher development, and clear institutional policies.

In higher education, Riedner and Pischetola (2021) demonstrate that innovative practices emerge when there is articulation among theory, practice, and technological experimentation, but their implementation depends on consistent institutional support, such as laboratories, digital resources, and incentives for pedagogical experimentation.

Wagner et al. (2024) identify that teacher educators face challenges in their own digital upskilling, directly impacting the quality of the training they provide. Complementarily, Theodorio and Wambua (2024) emphasize that digital transformation in educational institutions requires cultural and organizational changes and is not limited to the acquisition of technological resources.

Thus, the studies reveal that the consolidation of technological education depends on articulated institutional policies, an organizational culture favorable to innovation, and structured continuing education programs, as well as adequate infrastructure and consistent teacher development—evidencing that the effective implementation of technological education requires an integrated approach among resources, competencies, and institutional strategies.

INNOVATIVE STRATEGIES AND TRAINING MODELS

With regard to training strategies, the studies point to the need for active methodologies and contextualized practical experiences. Momdjian, Manegre, and Gutiérrez-Colón (2025), based on observation of teacher education programs, found that pedagogical modeling—when the trainer demonstrates strategies and participants practice under guidance—strengthens the internalization of digital competencies. In other words, learning becomes more concrete because teachers experience real digital teaching situations, reflecting on their decisions and adjustments. Santos et al. (2025) analyzed teaching practices in the early years and observed that when teachers plan the use of technologies with clear objectives and contextualized activities, students show greater engagement and achieve meaningful learning. The study shows that pedagogical mediation is decisive for technology to enhance learning rather than merely being an available resource in the classroom.

Vanegas, Cifuentes, and Morrás (2025) found that continuous follow-up, feedback, and process-based assessment yield more consistent results in acquiring digital competencies. Their study indicates that continuity and methodological support are essential to consolidate teachers' technological learning. Zhang, Yang, and Zheng (2025) argue that teacher education should include principles of sustainability

and digital citizenship. This indicates that technological education is not limited to technical mastery of tools but involves ethical and socially responsible application of technology in educational contexts. Medeiros and Wunsch (2023) show that creative and collaborative approaches expand the transformative potential of technological education. Silva and Matta (2024) emphasize that continuing education courses that provide opportunities for reflection, discussion of practices, and simulated experimentation enable teachers to consolidate technological knowledge. Bento (2024) highlights that isolated training sessions are not sufficient to internalize digital competencies. The research shows that training cycles, follow-up, and continuous support are fundamental for lasting results.

Riedner and Pischetola (2021) argue that pedagogical innovation requires articulation between technological experimentation and theoretical grounding. Without understanding the pedagogical principles that underpin technology, digital use becomes superficial and minimally transformative. Kaminskienė, Järvelä, and Lehtinen (2022) state that, for innovative strategies to be effective, curricular reorganization, integration among disciplines, and institutional support are required. The study shows that organizational barriers can prevent teachers from applying active methodologies even when they possess digital competence. Overall, the studies indicate that effective innovative strategies are those that articulate practice, reflection, and institutional support.

CONCLUSION

This study sought to analyze competencies, challenges, and possibilities for innovation in teacher training for technological education, aiming to understand how these elements are articulated in the contemporary context shaped by digital culture. It was possible to identify that training for technological education requires a multidimensional approach that goes beyond technical mastery of tools and involves integration among pedagogical knowledge, content mastery, critical thinking, and ethical responsibility.

The results show that teachers' digital competence constitutes a complex construct, supported by articulation among technical, pedagogical, collaborative, and sociocultural dimensions. The analyzed

literature converges in indicating that fragmented training proposals have limited impact, whereas structured models that combine theoretical grounding, supervised practice, pedagogical modeling, continuous follow-up, and process-based assessment tend to produce more consistent results. In addition, it was found that the consolidation of technological education depends not only on individual initiatives but also on favorable institutional conditions, including curricular reorganization, adequate infrastructure, permanent training policies, and an organizational culture oriented toward innovation.

As a contribution, this study systematizes recent evidence on teacher training for technological education, offering theoretical and analytical support for planning more integrated and sustainable training programs. By organizing the findings into structuring axes, the work broadens understanding of the factors that enhance or limit the development of teachers' digital competence, and it may guide institutional policies and pedagogical practices more closely aligned with contemporary educational demands.

Finally, empirical investigations are suggested in specific contexts of initial and continuing teacher education, especially regarding longitudinal evaluation of the impact of innovative training models. Comparative studies across different institutional realities may also help identify contextual variables that influence the effectiveness of technological education. In this way, it will be possible to advance the construction of more consistent frameworks for teacher education in a society increasingly mediated by digital technologies.

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