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Teacher training in digital skills, independent learning, and equity in higher education

Formación docente en competencias digitales, aprendizaje autónomo y equidad en la educación superior

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Abstract

This article analyzed the scientific literature on teacher training in digital and pedagogical competencies aimed at promoting independent learning and educational equity in universities. Methodologically, the scientific literature in Scopus was analyzed for the 2020–2025 period, using a mixed-methods design that combines bibliometrics and a systematic review. Strategies for teacher training were explored, identifying validated models and emerging methodological approaches. Initially, 36 records were retrieved from Scopus. After an initial review, four articles were excluded because they did not align with the central focus of the research—topics related to basic education or purely technical engineering issues; the full texts of the remaining 32 articles were analyzed, and two documents were discarded because they were study protocols without final results, resulting in a final sample of 30 scientific articles for qualitative synthesis and discussion analysis. The results revealed an abundance of literature focused on technical and instrumental competence, contrasting with the scarcity of studies on digital equity and inclusion. The conclusions indicated that, for training strategies to be effective, it is not enough to simply teach how to use ICTs; it is also necessary to move toward models that connect with the reality of each context, encourage reflection, and have strong institutional support.

Keywords: Teacher training, digital skills, autonomous learning, educational equity.

Resumen

En el presente artículo se analizó la producción científica sobre la formación docente en competencias digitales y pedagógicas orientadas a la promoción del aprendizaje autónomo y la equidad educativa en universidades. Metodológicamente, se analizó la producción científica en Scopus durante el periodo 2020-2025, empleando un diseño mixto que combina bibliometría y revisión sistemática. Se exploraron estrategias para la formación docente, donde se identificaron modelos validados y enfoques metodológicos emergentes. Se recuperaron inicialmente 36 registros de Scopus. Tras una inspección inicial, se excluyeron 4 artículos que no se alineaban con el eje central de la investigación, temas relacionados a la educación básica o puramente técnicos de ingeniería; se analizaron a texto completo los 32 informes restantes y se descartaron 2 documentos por ser protocolos de estudio sin resultados finales, constituyendo una muestra final de 30 artículos científicos para la síntesis cualitativa y el análisis de discusión. Los resultados revelaron una saturación de la literatura orientada hacia la competencia técnica instrumental, contrastando con la escasez de estudios sobre la equidad e inclusión digital. Las conclusiones arrojaron que, para que las estrategias de formación puedan funcionar, no solo se debe enseñar a usar las TIC, también es necesario avanzar hacia modelos que conecten con la realidad de cada contexto, inciten a la reflexión y cuenten con un sólido respaldo institucional.

Palabras clave: Formación docente, competencias digitales, aprendizaje autónomo, equidad educativa.

Introduction

University education has undergone significant change in recent years, prompting a need to rethink teaching and learning strategies so that they keep pace with these transformations. Given the rapid advance of digital technologies and the worldwide digitalization of education systems, teacher training has taken on growing importance, since instructors must possess the digital competencies needed to adapt learning processes to the demands of today's digital educational environment (Kovalchuk et al., 2025). This means that teacher training cannot simply stop at learning how to use technological tools; it must also address how to apply them to better foster independent learning among students (Fernández-Batanero et al., 2021). Strengthening faculty digital competencies has become a key element in modernizing education (Duan & Ismail, 2025), particularly as recent research has shown that hybrid models and stronger teacher self-efficacy can prove fundamental to achieving genuine educational transformation (Pinto et al., 2021).

This study responds to the urgent need to rethink and strengthen teacher-training strategies so that they align with the challenges of today's digital transformation and with the ethical commitment to promoting a more equitable form of education (Celis Malatesta, 2024). Some initiatives and frameworks aimed at developing digital competencies have indeed been implemented, yet the evidence shows that many of these efforts remain scattered, poorly sustained, and in some cases disconnected from the concrete realities faced by teachers and students (Pirela Espina, 2022). The rapid pace of digital transformation in education demands effective training for future teachers, one that allows them to integrate technology into their pedagogy, particularly in contexts such as India, where such training tends to be scarce (Sheikh & Nath, 2026).

According to Wu et al. (2025), combining online or remote instruction with in-person teaching proves to be an innovative strategy that positively affects academic performance and student satisfaction, evidence that methodological flexibility is essential for pedagogical adaptation in university settings. Along similar lines, Tzoumpa et al. (2025) point to motivation as a crucial asset for independent learning, while cautioning that information-processing skills must be reinforced to avoid gaps in teaching performance. As Pérez-Escoda et al. (2025) put it, “improving teachers' digital competencies remains a crucial and urgent issue, despite the nearly two decades that have passed since their inclusion in education.”

Over the past decade, teaching practice has become increasingly shaped by the need to develop digital competencies capable of narrowing the digital divide, as numerous studies have shown (Cabero-Almenara et al., 2022; Moreno-Morilla et al., 2021; Pérez-Escoda et al., 2020), particularly since the COVID-19 pandemic. This reflects how deeply embedded technology has become in contemporary society, requiring teachers who are continuously trained in its use within teaching and learning processes (Roblizo Colmenero et al., 2025). Along the same lines, research such as that of Ivanchenko (2025) reveals the need to strengthen faculty digital competencies by training instructors in information-search methods and strategies, as well as building their proficiency with modern library and information tools and services

Demand for digitally competent teachers keeps growing, which means faculty must be able to use digital technologies effectively in the classroom to improve learning outcomes and foster students' own digital skills (Reisoğlu & Çebi, 2020; Siddiq et al., 2023). Here it is worth noting that while “skills” generally refer to technical proficiency, “competencies” are conceptualized as the integrated, functional use of knowledge, skills, and attitudes (Falloon, 2020).

Another important point concerns the fundamental role of digital pedagogy in post-pandemic inclusive education (Shi et al., 2025), which has emerged as a crucial response to persistent challenges. It encompasses a set of teaching practices that draw on digital technologies to enrich the educational experience of both teachers and students, fostering greater engagement and offering multiple avenues for learners to demonstrate what they have learned (Hamilton et al., 2021).

A program implemented by Alarfaj and Alrashidi (2025) proved its worth by equipping teachers with critical skills in areas such as artificial intelligence (AI), cybersecurity, big data, virtual reality, and digital content creation. The study successfully demonstrated that a specialized training program significantly improved teachers' digital competence, with lasting effects observed in subsequent evaluations, underscoring how essential this kind of initiative has become in contemporary education.

Teacher professional-development programs therefore need to be reoriented toward building equitable learning environments. Technology, in turn, must be positioned as a strategic resource that strengthens both the educational dimension and students' intellectual autonomy (Casamayou et al., 2025). This suggests that personalizing the educational process on the basis of a critical reading of student needs is a decisive factor for achieving favorable outcomes and for enhancing teachers' capacity to manage learning environments that balance direct instruction with student autonomy (Arizmendi Bernal & Carrillo Cruz, 2024).

From the standpoint of equity and inclusion, digital strategies open new paths toward democratizing access to knowledge (Hinojo & Leiva, 2022). One example worth mentioning is the development of gamified mobile applications specifically designed to support students with learning or visual disabilities. This illustrates how technology can personalize education and make it accessible, advancing both equity and inclusion while fostering autonomy among students who have traditionally been marginalized (Navas-Bonilla et al., 2025).

Teachers must nonetheless remain critical when using digital tools, since frequent use can reflect not only a stance of inclusion but also one of convenience, one that, if not handled properly, ends up reshaping how students work and undermining their critical and reflective thinking. Research has warned about the risks of digital capitalism and about the precarization or erosion of teaching quality that can accompany certain approaches to the digitalization of education, stressing that teacher training must be grounded in a critical pedagogy that questions commercial logics and prioritizes equity and well-being within educational institutions (Villao Salinas & Matamoros Dávalos, 2024).

Teacher training must certainly advance in step with a more comprehensive vision, one in which the digital and the pedagogical complement each other harmoniously to ensure quality education and keep pace with today's digital and technological development. The use of learning analytics, or Learning Analytics, as it is commonly known, represents an essential step for monitoring the development of digital

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competencies, alongside the use of mobile tools that strengthen practical skills. This approach makes it possible to track teachers' progress once they are trained to integrate these resources from an inclusive, empowering perspective. In this way, universities can ensure an education that fosters the autonomy and equity that today's society demands. Against this backdrop, the present study seeks to analyze the scientific literature on teacher training in digital and pedagogical competencies aimed at promoting independent learning and educational equity in universities.

Methodology

Methodologically, the study applied a mixed-methods approach that combined bibliometric tools with a systematic literature review. This orientation made it possible to objectively measure the structure of the scientific field while simultaneously delving into the most significant theoretical contributions on the subject under investigation. Sources were retrieved through a search of the Scopus database, chosen to ensure the quality and impact of the selected works.

The information-selection process relied on an advanced Boolean search string: TITLE-ABS-KEY (autonomous learning AND education) AND PUBYEAR > 2020 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA, “SOCI”) OR LIMIT-TO (SUBJAREA, “ENGI”) OR LIMIT-TO (SUBJAREA, “COMP”)) AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (EXACTKEYWORD, “Students”) OR LIMIT-TO (EXACTKEYWORD, “Education”) OR LIMIT-TO (EXACTKEYWORD, “Artificial Intelligence”) OR LIMIT-TO (EXACTKEYWORD, “Higher Education”) OR LIMIT-TO (EXACTKEYWORD, “Artificial Intelligence Technologies”) OR LIMIT-TO (EXACTKEYWORD, “Educational Technology”) OR LIMIT-TO (EXACTKEYWORD, “Artificial Intelligence (ai)”)) AND (LIMIT-TO (LANGUAGE, “English”) OR LIMIT-TO (LANGUAGE, “Spanish”)) AND (LIMIT-TO (OA, “all”)).

The sample was limited to original research articles and reviews published between 2020 and 2025 in English or Spanish, studies centered on higher or university education, publications addressing technological innovation or transversal competencies, and studies available through open access. Excluded, in turn, were documents that did not focus on the university setting, letters to the editor or brief notes, and studies with undeclared methodologies or insufficient data.

The retrieved records were exported to specialized bibliometric tools and processed with the support of VOSviewer software (v. 1.6.20), which made it possible to examine indicators such as annual productivity, citation impact, and co-authorship networks, and to generate co-occurrence network maps. A synthesis matrix was used to extract key data, including author and year, subject area, methodology employed, and main findings or contradictions. The analysis followed a constant-comparison technique, grouping studies into thematic clusters: AI in education, hybrid models, and information literacy. This produced a trajectory that brings together the topics of interest and helps reinforce the theories and strategies applicable to the teacher training that is needed today.

Results and discussion

Figure 1. *Identification of studies through databases and registers.*

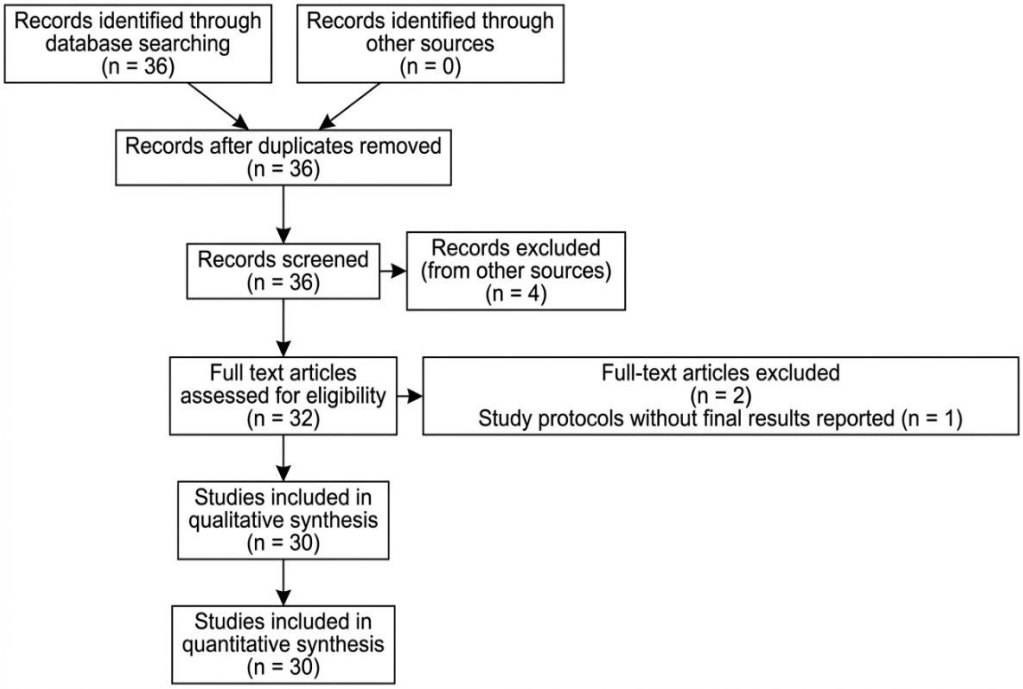
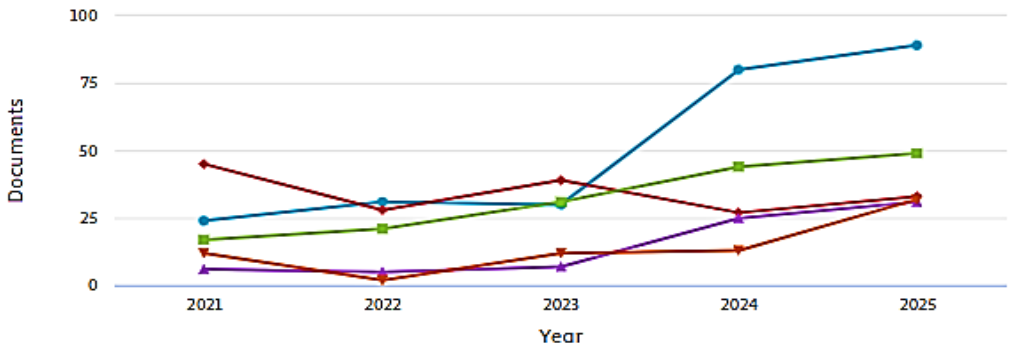


Figure 1, showing the PRISMA diagram, indicates that 36 records were initially retrieved from Scopus. After an initial inspection, the presence of duplicates was ruled out given the specificity of the search, and the 36 titles and abstracts were then screened. At this stage, four articles were excluded after a quick reading revealed they did not align with the central focus of the research, since they addressed basic education or purely technical engineering topics. The remaining 32 reports were analyzed in full text, and two documents were discarded for being study protocols without final results; the final sample for qualitative synthesis and discussion analysis therefore consisted of 30 scientific articles. The study revealed a steady increase in publications on digital teacher training from 2020 onward, driven mainly by the need to respond to the COVID-19 pandemic. It should be noted, however, that studies linking these competencies to the notion of equity were relatively scarce compared with those focused exclusively on educational technology.

Figure 2. *Annual evolution of scientific output on digital teacher training (2020–2025).*



Note. The figure shows a sustained upward trend, with publications concentrated most heavily in the last three years of the period analyzed.

Figure 2 shows that scientific output on digital teacher training has grown steadily since 2023. This increase reflects the rising academic interest in the topic, in step with the digital transformation education underwent after the pandemic and with policy efforts aimed at strengthening educational innovation.

The journals with the highest number of publications belong to the fields of education, educational technology, and management, most notably Scientific Reports, Heliyon, IEEE Access, Education and Information Technologies, and Computers and Education.

Through citation mapping, the study identified the most significant academic contributions, which converge in highlighting the potential of educational analytics, or *Learning Analytics*. These studies point toward a paradigm shift in which artificial intelligence and data analysis become integrated to strengthen educational management and ensure more robust academic trajectories.

Using a co-occurrence technique, four core areas of interest emerged that structure the current academic debate, and the arrangement of these nodes within the network reveals the strength of the semantic associations involved, making it possible to identify which concepts function as bridges and which remain at the periphery of the field, an insight that further enriches the study's analysis.

Figure 3. *Co-occurrence of keywords on digital teacher training.*

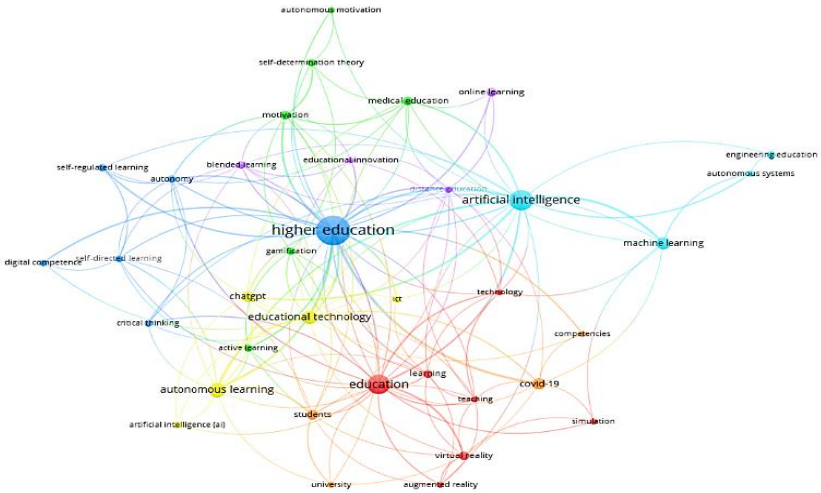
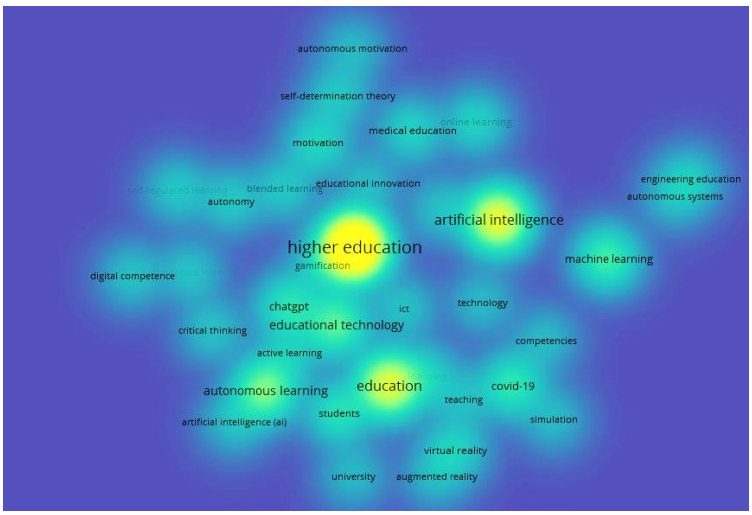


Figure 3 shows high density along with significant degree centrality at three main nodes: Higher Education, Artificial Intelligence, and Education. The first functions as a hub that concentrates most of the scientific output on technological innovation at the university level and captures the transformation of higher-education institutions. The second centers on the development of intelligent systems and process automation, areas that supply the tools driving change in educational science and engineering. The third shows how education is moving beyond the linear transmission model to become a complex, AI-mediated ecosystem; this node places the student at the center of the process and integrates technologies such as virtual reality and gamification to foster experiential learning, while also capturing the impact of COVID-19 as the phenomenon that accelerated this shift. Taken together, the map reflects an educational future situated at the convergence of artificial intelligence, student autonomy, and teacher mediation across emerging technological environments.

Figure 4. *The most relevant core.*



In Figure 4, the heat map identifies higher education as the central and most prominent node in the current academic landscape, revealing a critical convergence with artificial intelligence and educational technology. The intensity of the heat highlights a strong interconnection between the development of digital competencies and emerging tools such as ChatGPT and machine learning, oriented toward strengthening independent learning and pedagogical innovation.

Figure 5. *Co-authorship network.*

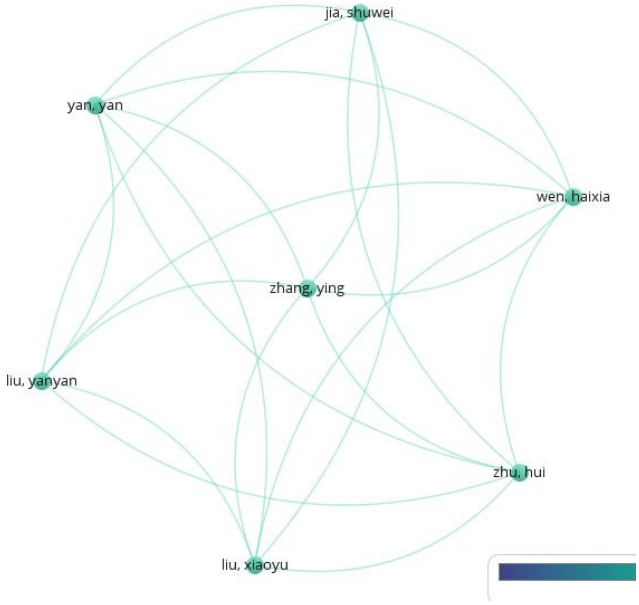


Figure 5 illustrates a highly integrated and collaborative research cluster made up of seven principal authors, among whom Zhang Ying, Liu Yanyan, and Jia Shuwei stand out. The dense web of connections reveals a tightly knit, robust working structure in which direct, reciprocal collaboration exists among all members of the group, a pattern characteristic of a well-established research team.

Table 1. *Synthesis of factors and proposed model for teacher training.*

Dimension	Facilitating factors	Hindering factors	Foundations of the proposed training model
Methodological	Implementation of hybrid models combining in-person and virtual instruction. Use of gamification and virtual reality for experiential learning.	Saturation of literature and training with a purely technical focus. Teaching strategies disconnected from teachers' realities.	Evolve toward models of pedagogical reflection that incorporate the management of hybrid environments. Balance direct instruction with the promotion of intellectual autonomy.
Psychosocial	Strengthening teacher self-efficacy and beliefs about the importance of competencies. Fostering student motivation and autonomy.	Teacher training limited to technological literacy. Lack of focus on student agency within the digital ecosystem.	Transform teachers' digital identity, giving it a more human and community-oriented meaning. Design experiences that spark motivation and guide learners toward mindful learning.
Ethics and Equity	Development of gamified mobile applications for students with disabilities. Personalization of the educational process according to student needs.	Risks of digital capitalism and the precarization of teaching work. Scarcity of studies addressing digital inclusion and equity.	Adopt a critical pedagogy that questions commercial logics and prioritizes well-being. Position technology as a social equalizer to help close gaps in inequality.
Institutional	Use of learning analytics and AI to monitor academic progress. Policies driving post-pandemic educational innovation.	Scattered training initiatives lacking solid institutional support. Lack of coordination between theoretical frameworks and vulnerable contexts.	Build comprehensive teacher-professionalization models instead of isolated workshops. Ensure solid institutional support and pedagogical leadership for long-term sustainability.

The results of the bibliometric analysis confirm that, although scientific output on digital competencies has grown rapidly since 2020, a critical disconnect persists between technical training and

pedagogical reality within universities. Findings from earlier research on educational management are consistent with this picture; it is worth noting, in this regard, that adopting technology on its own does not guarantee improved learning unless it is underpinned by pedagogical leadership (Alba Pastor et al., 2015).

The analysis further shows that the centrality of nodes such as Artificial Intelligence and Higher Education in the co-occurrence map demonstrates that higher-education institutions are moving toward AI-mediated ecosystems to transform administration and academic trajectories. This process of digitalization, however, also carries the risk of being driven primarily by market logic or digital capitalism, which could ultimately weaken teachers' working conditions unless it is grounded in a critical pedagogy that places human dignity and meaning at the center of education (Fareed et al., 2025).

The findings of this bibliometric analysis confirm a critical tension within higher education: as scientific production becomes saturated with literature focused on technical and instrumental competence, a significant gap remains regarding how technology can function as a social equalizer. This gap shows that university digitalization tends to be guided by digital capitalism, in which teacher training is reduced to basic tool handling without regard for its true pedagogical mission, or else simply reflects the absence of a structured training system for that purpose (Villar et al., 2025).

These results help clarify that teacher training in digital competencies must be understood as a comprehensive professional-development process oriented toward pedagogical reflection, instructional decision-making, and the design of inclusive learning experiences, one that adds to the quality of education rather than being reduced to the operational mastery of platforms or technological resources, which should instead be seen as a complement. Recent literature on the use of artificial intelligence in higher education likewise indicates that its impact will depend less on the availability of tools than on the existence of institutional policies, academic leadership, and curricular redesign capable of guiding its implementation according to the ethical and pedagogical criteria teachers bring from their own training.

Similarly, evident is the gap between technological access and the meaningful use of technology. This stems from the fact that resource availability varies across settings and teacher training does not develop uniformly, which makes it necessary to distinguish between instrumental digital literacy and pedagogical digital competence. The former centers on the operational handling of tools and applications, while the latter involves the selection, adaptation, and critical evaluation of technologies according to specific training objectives, the student profile, and the equity conditions of the university context.

This distinction matters because student autonomy does not emerge automatically from virtualization or the incorporation of artificial intelligence, but rather from teaching praxis that promotes self-regulation, critical thinking, meaningful interaction, and ongoing formative support. Research, in this sense, should not simply celebrate the growth of scientific output; it must also point to the need for studies that dig deeper into teacher-training models capable of bringing together technological innovation, educational justice, and the humanization of learning, a dimension that has declined in recent years.

The risk is clear: quality declines alongside the precarization of teaching work, and the emphasis falls on consuming platforms rather than cultivating critical thinking, which is why a shift toward critical pedagogy is needed, one capable of questioning these market logics and placing human dignity and the well-being of the historically marginalized at its center (Cruzado Llanos et al., 2024). Educational leadership that reaches beyond the merely technical could help close these equity gaps and open up space for students to develop genuine intellectual autonomy (Golec et al., 2025).

This study has limitations tied to its information source, having relied exclusively on the Scopus database. This may mean that relevant contributions indexed in other repositories, such as Web of Science or SciELO, were omitted. It should also be noted that, while the 2020-2025 period offers an up-to-date perspective, the literature included from 2025 is based on advance publications, which calls for a cautious reading of that year's final trends.

Closing this gap requires more than simply teaching instructors how to operate a tool; what truly matters is supporting them in designing experiences that spark motivation and help them guide students toward autonomy while cultivating more mindful, meaningful learning (Wang et al., 2025). The focus, ultimately, should rest on people and their capacity to grow, rather than on technique alone.

Conclusions

Scientific output on digital teacher training has grown steadily; the focus, however, has remained exclusively technical and instrumental, leaving a gap in the relationship between ICT use and students' capacity to decide, act, and build their own autonomy, since few studies attempt to connect digital competencies with the idea of equity and educational justice

The teacher-training process needs to move toward spaces for pedagogical reflection that strengthen faculty confidence in their own abilities and enable them to strategically manage hybrid teaching environments.

More comprehensive teacher-training models are needed, ones that incorporate the responsible use of educational data analytics alongside a critical, inclusive outlook centered on people and equity.

Ultimately, genuine student autonomy in the twenty-first century depends on a profound transformation of teachers' digital identity. What is needed is a shift toward a more human, community-oriented, and reflective sense of practice, that connects technology with the social realities of each educational context.

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