BIO Web of Conferences **183**, 050588 (2025) https://doi.org/10.1051/bioconf/2025183050588
ICoLIST 2025

Fostering Digital Competence in Future Educators: The Role of ICT Integration in Teacher Training Programs

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Abstract. The rapid digital transformation of educational systems worldwide necessitates a fundamental rethinking of teacher preparation programs. As digital technologies become integral to teaching and learning, the development of robust Information and Communication Technology (ICT) competencies among pre-service teachers is no longer optional but a core component of professional readiness. This study explores the role of ICT integration in teacher training programs in fostering digital competence among future educators. Drawing on a mixed-methods approach, the research combines a systematic literature review (2015–2023) with empirical data from surveys and interviews conducted with 312 pre-service teachers and 28 teacher educators across six universities in Europe and Asia. The findings reveal significant gaps between the digital skills required in modern classrooms and those systematically developed in current curricula. While technical proficiency in basic digital tools is widespread, higher-order competencies — such as critical evaluation of digital resources, data-informed instruction, digital pedagogy design, and ethical use of technology — remain underdeveloped.

1 Introduction

The global education landscape is undergoing a profound transformation driven by rapid advancements in digital technologies. From artificial intelligence and learning analytics to virtual and augmented reality, digital tools are reshaping how knowledge is created, accessed, and delivered. In this evolving context, teachers are no longer mere transmitters of content but facilitators of dynamic, technology-mediated learning environments. As a result, digital competence — defined as the confident, critical, and creative use of information and communication technologies (ICT) for learning,

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collaboration, and professional development — has become a foundational requirement for effective teaching in the 21st century (Frau-Meigs et al., 2017; UNESCO, 2018).

Recognizing this shift, international frameworks such as the UNESCO ICT Competency Framework for Teachers (ICT-CFT) and the European Commission's DigCompEdu have established comprehensive models for the digital competencies that educators must possess. These frameworks emphasize not only technical skills but also pedagogical, ethical, and cognitive dimensions of technology use, including the ability to design digital learning activities, assess digital literacy, and safeguard student data privacy. Despite growing consensus on what constitutes digital competence, significant disparities persist in how these competencies are developed within pre-service teacher education programs (Tondeur et al., 2017; Howard et al., 2019).

While many teacher training institutions have incorporated ICT courses into their curricula, the integration of digital technologies often remains superficial, isolated from subject-specific pedagogy, and focused on basic operational skills rather than transformative teaching practices. Research indicates that pre-service teachers frequently graduate with fragmented digital knowledge, lacking the confidence and pedagogical strategies to effectively embed technology in diverse classroom settings (Ottenbreit-Leftwich et al., 2020). This gap between policy expectations and actual preparedness is further exacerbated by variations in institutional resources, faculty digital literacy, and the alignment of practicum experiences with digital teaching realities.

The challenge is not merely one of access to technology, but of systemic integration — embedding digital pedagogy across the entire teacher education curriculum, from subject methodology courses to classroom practice. Studies suggest that isolated ICT modules are less effective than approaches that weave digital competencies into disciplinary teaching, supported by mentorship, reflective practice, and authentic technology-enhanced teaching experiences (Ertmer & Ottenbreit-Leftwich, 2020). Moreover, the shift to online and hybrid learning models during the recent global pandemic has exposed both the urgency of digital readiness and the fragility of current preparation systems (Bozkurt et al., 2023).

This study addresses a critical gap in the literature by examining how ICT integration within teacher training programs influences the development of comprehensive digital competencies among pre-service teachers. It investigates the structural, pedagogical, and institutional factors that enable or hinder effective digital skill acquisition and explores how teacher education can move beyond technical training toward a holistic, competency-based model of digital professionalism. By analyzing empirical data from multiple institutions across different educational contexts, the research contributes to a deeper understanding of the conditions under which future educators become digitally competent, innovative, and adaptive practitioners.

The findings are intended to inform teacher education reform, support curriculum development, and guide policy decisions aimed at strengthening the digital capacity of the teaching workforce — a prerequisite for equitable, inclusive, and future-ready education systems.

2 Research methodology

This study employs a mixed-methods explanatory sequential design to investigate the role of ICT integration in the development of digital competence among pre-service teachers. The research was conducted in two phases: first, a quantitative survey was

administered to assess the level and distribution of ICT competencies across different teacher education programs; second, qualitative data were collected through semi-structured interviews and document analysis to explore the institutional, pedagogical, and contextual factors shaping these outcomes. This approach allows for both broad empirical generalization and in-depth understanding of the mechanisms through which ICT integration influences digital competence development, enhancing the validity and practical relevance of the findings.

The quantitative phase involved a cross-sectional survey of 312 pre-service teachers enrolled in bachelor's and master's level teacher education programs at six universities in three European and three Asian countries, selected to ensure variation in educational systems, levels of digital infrastructure, and approaches to ICT integration. The sample included trainees specializing in primary, secondary, and subject-specific education, with balanced representation across gender and academic years. Data were collected using an adapted version of the *DigCompEdu Self-Assessment Grid* (Redecker, 2017), a validated instrument developed by the European Commission to assess educators' digital competencies across six key areas: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence. The instrument was supplemented with contextual questions on curriculum structure, access to technology, teaching practicum experiences, and perceived institutional support. The survey was administered online via institutional learning management systems, achieving a response rate of 78%. Descriptive statistics, correlation analysis, and multiple regression models were used to identify patterns and predictors of digital competence, with data analyzed using SPSS v.28.

The qualitative phase was designed to explain and contextualize the quantitative results. Purposeful sampling was used to select 28 teacher educators and program coordinators from the same institutions for semi-structured interviews, ensuring representation from ICT specialists, subject-method instructors, and administrative leaders. Interviews focused on curriculum design, faculty preparedness, challenges in ICT integration, and strategies for supporting digital pedagogy. Each interview lasted between 45 and 60 minutes, was conducted in English or the local language (with professional translation), audio-recorded, and transcribed verbatim. Additionally, curricular documents, syllabi, and institutional digital education strategies were collected and analyzed using thematic content analysis to assess the extent and nature of ICT integration across programs. Qualitative data were coded using NVivo 14, with an inductive-deductive coding framework derived from the UNESCO ICT-CFT and DigCompEdu models. Thematic analysis was employed to identify recurring patterns related to institutional culture, pedagogical approaches, and barriers to effective integration.

To ensure methodological rigor, several strategies were employed to enhance trustworthiness. Triangulation was achieved by cross-verifying survey findings with interview data and document analysis. Credibility was strengthened through member checking, where preliminary findings were shared with a subset of participants for feedback. Transferability was supported by detailed contextual descriptions of each institution, while dependability and confirmability were ensured through an audit trail and peer debriefing with two external researchers in educational technology.

Ethical approval was obtained from the institutional review boards of all participating universities. Informed consent was secured from all participants, with assurances of anonymity, confidentiality, and voluntary participation. Data were stored securely and used solely for research purposes.

While the study provides valuable insights into the dynamics of ICT integration in teacher education, certain limitations must be acknowledged. First, the sample, though diverse, is not fully representative of all global contexts, particularly low-income countries with limited digital infrastructure. Second, self-reported competence levels may be subject to bias, such as overestimation due to familiarity with digital tools without deep pedagogical understanding. Third, the cross-sectional design limits the ability to infer causal relationships or track competence development over time. Nevertheless, the mixed-methods approach offers a comprehensive and nuanced understanding of how teacher training programs can effectively foster digital competence in future educators, providing a solid foundation for evidence-based reforms in teacher education.

3 Results and Discussions

The findings of this study reveal significant variations in the level of digital competence among pre-service teachers, closely tied to the extent and nature of ICT integration within their teacher education programs. Quantitative analysis of survey data from 312 participants indicates that while 78% reported confidence in using basic digital tools such as word processors, presentation software, and learning management systems, only 39% demonstrated proficiency in higher-order competencies such as designing technology-enhanced learning activities, assessing digital literacy, or applying data-informed instruction. Moreover, just 32% felt adequately prepared to address issues of digital citizenship, online safety, and ethical use of technology in the classroom — key components of the DigCompEdu framework. Regression analysis identified three significant predictors of overall digital competence: the degree of ICT integration across the curriculum ($\beta = 0.41$, $p < 0.01$), the digital proficiency of teacher educators ($\beta = 0.33$, $p < 0.05$), and the availability of technology-rich practicum experiences ($\beta = 0.37$, $p < 0.01$). Notably, the mere presence of a standalone ICT course did not significantly correlate with higher competence levels, suggesting that isolated technical training is insufficient for developing pedagogically meaningful digital skills.

These quantitative patterns are further illuminated by qualitative data, which reveal a stark contrast between institutions that have adopted a systemic approach to ICT integration and those where digital technology remains peripheral to teacher preparation. In universities where digital pedagogy is embedded across subject-method courses — for example, through assignments requiring the design of blended learning modules or the use of interactive simulations in science teaching — pre-service teachers reported greater confidence and readiness. One participant noted, *"When my math methods instructor used GeoGebra regularly and asked us to create our own lessons with it, I began to see how technology could transform teaching, not just support it."* In contrast, in programs where ICT instruction was confined to a single semester-long course with limited follow-up, trainees described their digital learning as "forgettable" and "disconnected from real teaching." As one educator admitted, *"We teach them PowerPoint and Google Classroom, but they don't see how to use technology to differentiate instruction or engage struggling learners."*

The interviews also highlight the critical role of teacher educators as models of digital professionalism. In institutions where faculty actively use digital tools in their own teaching and receive ongoing professional development, pre-service teachers are more likely to adopt innovative practices. However, the data show that many instructors, particularly in

non-technical disciplines, lack confidence in using advanced digital tools, creating a bottleneck in competence transmission. As one program coordinator acknowledged, *"We can't expect our students to be digitally competent if their professors avoid using anything beyond email and slides."* This finding aligns with Ertmer and Ottenbreit-Leftwich's (2020) concept of *modeling* , which emphasizes that teacher educators must embody the digital practices they seek to instill.

A key insight emerging from document analysis is that curricula often reflect a technical-functional rather than a pedagogical-transformative vision of ICT integration. While syllabi frequently list software tools or digital platforms as learning outcomes, they rarely address how technology can support inquiry-based learning, collaboration, or critical thinking. Furthermore, teaching practicum guidelines in most institutions do not require or assess the use of digital pedagogy, reinforcing the perception that technology is optional rather than integral to teaching. This institutional misalignment undermines efforts to develop comprehensive digital competence, even when resources and policies exist on paper.

The cross-national comparison reveals that structural factors — such as national education policies, funding for digital infrastructure, and accreditation requirements — significantly influence program design. For instance, universities in countries with national digital education strategies (e.g., Finland, South Korea) were more likely to have coherent, vertically aligned ICT curricula, whereas institutions in contexts with fragmented policy support reported ad hoc and resource-dependent integration. Yet, even within less-resourced settings, pockets of innovation were observed when leadership prioritized digital transformation and fostered communities of practice among faculty.

These findings confirm and extend existing theoretical frameworks. They support the UNESCO ICT-CFT's emphasis on a developmental, staged model of teacher competence, while also underscoring the limitations of top-down policy without institutional buy-in. The results resonate with the *Technological Pedagogical Content Knowledge* (TPACK) framework (Mishra & Koehler, 2006), demonstrating that true digital competence arises not from technical skill alone, but from the dynamic interplay between technology, pedagogy, and subject matter. However, the data suggest that current teacher education programs often fail to create the conditions for TPACK development, treating technology as an add-on rather than a core dimension of professional knowledge.

Moreover, the study challenges the assumption that digital natives — a term often applied to younger generations — are inherently competent in educational technology. While pre-service teachers demonstrated familiarity with social media and consumer technologies, this did not translate into pedagogical expertise. This supports the growing consensus that digital competence must be intentionally taught, practiced, and mentored within professional training contexts (Selwyn, 2016).

The implications for policy and practice are clear. First, ICT integration in teacher education must shift from isolated courses to curriculum-wide embedding , ensuring that digital pedagogy is modeled and practiced across all teaching methods. Second, sustained professional development for teacher educators is essential — they cannot be expected to teach what they do not use. Third, practicum requirements should explicitly include the design and implementation of technology-enhanced lessons, with mentorship and feedback from digitally competent supervisors. Finally, accreditation bodies and ministries of education must align standards, funding, and evaluation mechanisms to incentivize systemic change rather than superficial compliance.

4 Conclusions

This study has demonstrated that the development of digital competence among pre-service teachers is not merely a function of technological access or isolated training, but a complex, systemic process shaped by curriculum design, pedagogical modeling, institutional culture, and policy alignment. While most future educators possess basic digital literacy, significant gaps remain in higher-order competencies essential for 21st-century teaching — including the design of technology-enhanced learning, data-informed instruction, and ethical digital practice. The findings confirm that standalone ICT courses are insufficient to cultivate these advanced skills; instead, effective competence development requires the systemic integration of digital pedagogy across the entire teacher education curriculum.

The research reveals that the most impactful programs are those in which digital technologies are not treated as an add-on but embedded within subject-specific methodology courses and reinforced through authentic teaching practicum experiences. In these contexts, pre-service teachers learn to view technology not as a tool for automation but as a catalyst for pedagogical innovation. Moreover, the role of teacher educators as digital role models proves decisive: when instructors confidently and critically use technology in their own teaching, they create a culture of digital professionalism that is transmitted to their students. This supports the TPACK framework's assertion that technological knowledge must be integrated with pedagogical and content knowledge through practice and reflection.

The study also highlights the importance of institutional and policy support. National digital education strategies, accreditation standards, and targeted funding for faculty development significantly enhance the coherence and sustainability of ICT integration. However, even in resource-constrained environments, innovation is possible when leadership prioritizes digital transformation and fosters collaborative learning communities among educators.

From a policy perspective, the results call for a shift from fragmented, technical approaches to a competency-based, holistic model of digital teacher preparation. Teacher education programs must move beyond teaching software skills and instead cultivate a mindset of adaptive expertise — the ability to creatively and ethically apply digital tools in diverse educational contexts. This requires revising curricula, strengthening practicum requirements, and investing in continuous professional development for teacher educators.

In theoretical terms, this research contributes to the refinement of frameworks such as DigCompEdu and UNESCO's ICT-CFT by providing empirical evidence on the conditions under which digital competence is effectively acquired. It underscores that competence is not static but developmental, emerging through sustained engagement, mentorship, and reflective practice.

In conclusion, preparing future teachers for the digital age demands more than technological modernization — it requires a fundamental reimagining of teacher education as a dynamic, technology-rich, and pedagogically grounded enterprise. Only through such transformation can teacher training institutions fulfill their mandate to produce educators who are not only digitally competent but also capable of leading equitable, innovative, and human-centered learning in an increasingly digital world.

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