RESEARCH PAPER

Effectiveness of ICT Integration in Classroom Teaching and Learning Practices in Teacher Education

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ABSTRACT

In teacher education, information and communication technology (ICT) is now being used increasingly in learning platforms, multimedia, online collaboration, simulations and digital assessment. But digital tools don't equal high-quality learning and teaching. This evidence-led critical narrative review explores the evidence regarding the integration of ICT into classroom teaching and learning practice related to teacher education with the following themes: teacher knowledge, digital competence, pedagogical use, reported learning outcomes, and conditions that influenced the implementation.

Relevant empirical research, systematic reviews, meta-analysis, theoretical work, and policy documents were gathered from targeted literature searches and verification of the sources up to 28 October 2026. The reviewed evidence reveals that structured technology integration courses can foster pre-service teachers' knowledge, yet knowledge and confidence does not necessarily lead to effective classroom use and better student achievement. As described in the literature, it is essential that technology is "synchronised" with its subject matter and the educational goals of the courses, that teachers have the chance to plan and implement technology-enhanced lessons, that teacher educators model good practice, and that feedback and institutional support is provided and sustained.

But implementation is affected by infrastructure, equitable access, teacher readiness, and quality of evaluation. ICT, overall, is not necessarily effective in all tools or all contexts and requires purposeful pedagogical integration, not technology use alone. The review highlights the need for in-curriculum professional learning and increased evaluation based on observed teaching practices and learning outcomes, as well as self-reported measures. More context-specific studies should be conducted to determine what techniques lead to lasting gains.

Keywords: ICT Integration, Teacher Education, Pre-Service Teachers, TPACK, Digital Competence, Teaching and Learning Practices

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1. INTRODUCTION

1.1 Background of the Study

In the educational context, ICT has found its place in learning platforms, digital content, online collaborative tools, simulations, mobile applications and digital assessment. In teacher education, it facilitates trainee learning and enables teachers to make sound professional decisions in relation to technology use. Confidence in use as a student is related, but not synonymous with the ability to choose an appropriate tool, predict learning problems or assess learning.

The Technological Pedagogical Content Knowledge (TPACK) model by Mishra and Koehler (2006) accounts for this problem, as it focuses on the relationship between technology, pedagogy and content. The European Framework for the Digital Competence of Educators also highlights the need for reflective use of digital technologies for learning, assessment, teaching and empowerment of learners (Redecker, 2017). The central question is not whether ICT is there, but whether it helps to support teaching and learning.

1.2 Problem Statement

While teacher preparation schools can provide courses on digital tools and technology, many are less effective than others. While some studies report improved knowledge, others find insufficient competence, limited transfer between training and classroom practice, or self-reported confidence. These positive attitudes do not equate to being able to explain concepts, evaluate learning, incorporate diverse learners, and manage a classroom. Additional barriers to implementation include inequities in connectivity, equipment, preparation time, and institutional support.

The question isn't "Adopt it?" it's "Does it work?". When evaluating, it is important to make a clear distinction between access and confidence and the outcomes of teaching and learning achieved. The value of technology also relies on the subject matter, the task or activity, the learners, how the teacher is prepared, and the conditions of implementation. The evidence available does not support the broad claim that technology automatically improves education (UNESCO, 2023).

1.3 Objectives of the Study

The objectives of this review are:

1. to examine how ICT is integrated into classroom teaching and learning within teacher education;
2. to synthesize evidence concerning teacher knowledge, digital competence, teaching practice, and learning-related outcomes;
3. to identify pedagogical, personal, and institutional factors that enable or constrain effective ICT integration; and
4. to identify evidence limitations and practical priorities for teacher education programmes and future research.

1.4 Research Questions

The review addresses four questions:

1. What ICT tools and integration approaches are used in teacher education?
2. What evidence is available on their influence on teaching practice, teacher competence, and learning-related outcomes?
3. Which factors facilitate or hinder effective ICT integration in teacher education?
4. What limitations and research gaps should guide practice and future investigation?

2. REVIEW OF LITERATURE

2.1 ICT Integration, Pedagogy, and Teacher Knowledge

The TPACK model is a conceptual framework that gives expression to the relationship between technology, pedagogy, and content. Teachers should think about what a tool does for a certain concept and learning activity, rather than how it works. A simulation might make the invisible visible, but the slides that mimic a textbook may contribute little. Value relies on design, involvement, feedback, and learning objectives (Mishra & Koehler, 2006).

Based on a review of the qualitative studies into the preparation of pre-service teachers, Tondeur et al. (2012) concluded that the three synthesised general strategies of modelling by teacher educators, learning technology through design, and scaffolded authentic experiences proved helpful in preparing pre-service teachers. They also pointed to institutional planning, leadership, collaboration and staff development. These results demolish the myth that a single technical course can equip future teachers for all classrooms.

2.2 Evidence on Knowledge and Teaching-Related Outcomes

A crucial quantitative result is given by Wilson et al. (2020). Their meta-analysis revealed that there was a positive overall effect of technology-integration courses on teacher knowledge (standardized effect size 1.057; 95% CI [0.836, 1.278]). It is a way of helping with structured preparation, but the actual measure of performance was only teachers' knowledge, not of the extent to which it was actually carried out across a school's classrooms or of the pupil achievement. Do not extend the findings beyond the measures evaluated.

Fabian et al. (2024) analyzed 163 primary TPACK intervention studies, qualifying 8 studies for a meta-analysis of TPACK performance outcomes. Technological knowledge was the most common target, and it was not explicitly targeted with more than one-fifth of the interventions. The meta-analysis failed to reveal a clear pattern in terms of which TPACK components in particular were found necessary and sufficient for good outcomes. Most programs teach tools and don't go into much detail on how trainees apply them with pedagogy and content.

Sofwan et al. (2024) examined 28 studies that touched on the assessment measures, interconnections between knowledge domains, and connections between technology integration and TPACK. The reviews as a group demonstrate that frameworks are helpful and some measures and intervention designs are different. Self-report improvement should be viewed in combination with lesson plans, teaching demonstrations, observation, and evidence of enacted competence.

2.3 Beliefs, Self-Efficacy, and Readiness

Confidence and beliefs influence ICT use. Ertmer and Ottenbreit-Leftwich (2010) state that knowledge, confidence, pedagogical beliefs, and institutional culture interact. If learning is predominantly a process of information transfer, digital tools can provide information more efficiently. Different tools and teaching decisions are needed for goals like inquiry, collaboration, or formative feedback.

A study with 155 pre-service teachers in Germany revealed different profiles in terms of ICT attitudes, students' self-efficacy, self-concept, and concerns in terms of the extent of prospective ICT integration. (Pozas et al., 2024) The study demonstrates that training for technology approaches vary, but such generalizability is limited to enacted practice when learning occurs within a single national setting and future use is self-reported. Li (2025) conducted a scoping review of 277 studies on pre-service teachers' ICT beliefs, revealing a strong interest in general beliefs and comparatively less research on regional differences and newer technologies. Further studies are required to link these perceptions to actual classroom practice.

2.4 Professional Learning and Institutional Conditions

Context is key in reviews of teaching practice and professional development. 14 studies on the competence, readiness, preparation, beliefs, environmental support, implementation and TPACK of pre-service teacher students were selected for review by Anwar et al. (2025). In a 2025 review of 23 professional-development studies between 2020 and 2024, Amemasor et al. found hands-on training, collaboration, mentoring, and institutional support. The latter review is on broader aspects of teacher development and should be seen as cautiously for initial teacher education.

After examining 38 research studies over the past 10 years (2014–2024), Zhang et al. (2026) found that pre-service teachers might have good everyday competencies and inconsistent competence in digital content creation, pedagogical integration, and problem-solving. They pointed to problems in transferring general skills to actual teaching. Furthermore, the competence in DigCompEdu is not limited to the technical component, but it also encompasses professional engagement, resources, teaching, assessment, digital learner empowerment, and the digital competence of learners (Redecker, 2017).

Factors that affect implementation include reliable devices and connectivity, inclusive resources, planning time, technical assistance, leadership and opportunities to practise. According to UNESCO (2023), the available evidence of the added value of educational technology is still weak, and the access is unequal. An assessment of digital integration should be conducted as part of teacher education, and should consider both resource context and use.

2.5 Research Gap and Analytical Focus

Research comprises meta-analyses of knowledge gains, belief review, TPACK studies, and professional development reviews. The main problem is between reported confidence, knowledge measured, actual classroom activity, and learner results. Additionally, some surveys report a lack of focus on authentic performance, region-wide variations, long-term transfer, and more recent technologies (Anwar et al., 2025; Li, 2025; Zhang et al., 2026). In this review, effectiveness is summed up in four dimensions: pedagogical alignment, demonstrated competence, learning-related outcomes and conditions for sustained implementation. There are no new models here; these are analytical categories.

3. RESEARCH METHODOLOGY

3.1 Research Design and Selection of Literature

This paper employs a critical narrative review with structured evidence searching and comparative synthesis. There are systematic reviews, meta-analyses, empirical research papers, conceptual models, and policy pieces; none of which can be directly equated to one another. The goal is to describe how strong and constrained these contributions were, rather than recompute a new pooled effect. No questionnaire, interviews or data collection for new data sets were used. Sources were prioritized when they were related directly to teacher education, preservice teachers, technology-integration knowledge or practice, or an existing framework. Where necessary the theory was explained using foundational sources. Studies did not merely fall out because they showed a positive impact; mixed impact, null impact and qualified impact were included where pertinent.

3.2 Search and Source-Verification Procedures

Searches and source checks were done on the web, specifically targeted, up to 28 October 2026. The keywords in search combinations included ‘ICT integration’, ‘technology integration’, ‘teacher education’, ‘pre-service teacher’, ‘TPACK’, ‘digital competence’, ‘professional development’, ‘teaching practice’, ‘meta-analysis', and ‘systematic review'. Official policy papers, academic archives, open-access journals, publishers' websites and lists of related reviews were also accessed.

The core collection was deliberately selected for relevance and traceability. This is not a systematic review by database, as a complete exportable record set and record-level exclusion log were not available, so no

PRISMA flow counts are claimed. Findings are a synthesis of selected research that is verifiable rather than an exhaustive listing of all possible research. Reported study (pub) details were checked against accessible publisher, journal, repository, or official records, when available.

3.3 Analytical Categories and Synthesis Procedure

Sources were compared across six categories:

1. the technology and instructional activity examined;
2. the teacher-education population and learning context;
3. the outcome measured, distinguishing self-report, knowledge tests, observed practice, and learner outcomes;
4. the main findings, including positive, mixed, null, or uncertain results;
5. pedagogical, personal, and institutional conditions influencing implementation; and
6. limitations affecting transferability or the strength of conclusions.

Findings were organized into four groups through narrative and thematic synthesis: knowledge and competence, pedagogical practice, beliefs and readiness, and institutional conditions. Wherever available, quantitative estimates were reported, but were not considered directly comparable with perception studies or implementation reports.

3.4 Scope, Reliability, and Ethical Considerations

The review is based on published sources found via web-indexed resources. It does not attempt to retrieve all studies, to perform duplicate screening of all studies by itself, nor to score all studies according to the formalized risk-of-bias, nor to statistically pool. Reported sample size and type of outcomes are maintained when available for synthesis in order to ensure reliability, and both source findings and interpretation are distinguished. There were no human subjects, nor personal information used.

4. SYNTHESIS AND DISCUSSION

4.1 Profile of the Comparative Evidence

Various types of evidence are included in the selected literature: a meta-analysis of knowledge gain; TPACK intervention and competence reviews; qualitative synthesis of preparation strategies; empirical studies of beliefs and prospective use; and policy-level evidence of equity. Table 1 provides a summary of representative sources and for each, the most significant boundary for interpretation.

Table 1. Characteristics and Principal Contributions of the Core Literature

Source and evidence type	Population or scope	Contribution to this review	Key interpretive boundary
Tondeur et al. (2012) Qualitative synthesis	19 studies on preparing pre-service teachers	Highlights modelling, learning by design, authentic experiences, and institutional support.	Older synthesis; technology contexts have evolved.
Wilson et al. (2020) Meta-analysis	38 studies; 3,271 pre-service teachers	Found a positive effect of technology-integration courses on teacher knowledge (ES = 1.057).	Knowledge gains do not by themselves establish classroom transfer or pupil achievement.
Pozas et al. (2024) Empirical study	155 pre-service teachers at two German universities	ICT attitudes, self-efficacy, self-concept, and concerns differed with reported prospective integration.	One national setting and self-reported future use.
Sofwan et al. (2024) Systematic review	28 TPACK-related articles from 2010–2022	Reviews TPACK measures, domain relationships, and links to technology integration.	Search relied on one platform; measures and contexts vary.
Fabian et al. (2024) Systematic review and meta-analysis	163 primary intervention studies; meta-analysis based on 8 performance-based studies	Technological knowledge was most often targeted; the meta-analysis found no clear link with intervention effectiveness.	Small performance-based meta-analysis limits precision.

Source and evidence type	Population or scope	Contribution to this review	Key interpretive boundary
Anwar et al. (2025) Systematic review	14 studies of teaching-practice integration, 2017–2022	Maps competence, readiness, preparation, beliefs, support, implementation, and TPACK.	Narrow teaching-practice scope and relatively small included set.
Li (2025) Scoping review	277 studies on pre-service teachers' ICT beliefs	Shows focus on general beliefs and gaps in regional comparison and newer technologies.	Beliefs are not equivalent to enacted classroom competence.
Amemasor et al. (2025) Systematic review	23 professional-development studies published 2020–2024	Emphasizes hands-on training, collaboration, mentorship, and support.	Broader teacher professional development, not exclusively pre-service education.
Zhang et al. (2026) Systematic review	38 studies on pre-service teachers' digital competence, 2014–2024	Reports uneven competence and a gap between daily digital skills and pedagogical application.	Competence frameworks and assessment approaches differ across studies.
UNESCO (2023) Global policy report	Global evidence on education technology	Highlights unequal access and limited robust evidence of added educational value.	Broad system-level evidence, not specific to teacher-education interventions.

4.2 Effectiveness Depends on What Is Measured

In support of this, a meta-analysis conducted by Wilson et al. (2020) concluded that there were significant increases in pre-service teachers' technology-integration knowledge. This helps with structured preparation, but it does not replace evidence from which trainees can design, deliver, and monitor technology-supported lessons within real classrooms.

Fabian et al. (2024) reiterate this separation: While there is already a considerable number of studies that have examined different interventions, only eight studies provided measures of student performance for use in the meta-analysis, and no consistent relationship emerged between the targeted TPACK components and the effect of the interventions. Similarly, Zhang et al. (2026) reported very uneven competence and difficulty in translating everyday digital skills into practice. So there is greater evidence of knowledge gains than of durable changes in practice or achievement in classrooms.

The effectiveness should be judged by the following outcomes: what teacher knows, what the teacher designs, what the teacher does, how learners participate, and what learners show. While self-efficacy and satisfaction can be useful, observed teaching and lesson artefacts, as well as feedback quality and valid learning assessment, offer additional evidence.

4.3 Pedagogical Alignment and Authentic Practice

One constant theme is the need to link technology to instruction. The trainee should explain why the tool is used for the topic, learner group, and assessment goal. Authentic tasks could involve making learning materials, developing formative assessments, practicing lessons, considering students' answers, and adapting lesson plans following feedback given on them.

Alongside preparation, implementation, readiness and contextual support, Tondeur et al. (2012) focus on teachers' modelling and scaffolded learning. The integration of ICT into subject methods and practicum experiences should not be left to one ICT class. It's not about the novelty of the tool, but about making good decisions about teaching.

4.4 Beliefs, Professional Learning, and Institutional Support

Attitudes, confidence, and concerns influence technology use, but context and opportunity make a difference. Pozas et al. (2024) concluded that affective-motivational profiles were related to prospective ICT integration. Training must be able to adapt to varying needs while recognizing that low use does not mean resistance due to lack of access, time, mentoring or reference to the subject.

Amemasor et al. (2025) cite hands on training, collaboration, mentorship, and institutional support as key, similar to Tondeur et al.'s (2012) focus on leadership and cooperation. Institutions require a coherent programme design, appropriate use of devices and connectivity, technical support, time to experiment, and the opportunity to observe teaching with technology support. A short workshop might introduce a tool, but ongoing support is more effective for maintaining practice.

Equity is an ingredient of effectiveness. Any method that requires constant fast internet or individual devices

or paid software may not be portable to a resource-poor context. UNESCO (2023) emphasizes inequitable access and the lack of independent evidence. Teacher education programmes should provide readily available, low bandwidth, offline and locally relevant alternatives, and consider the possibility of increasing access.

4.5 Overall Interpretation

Evidence is not enough to say that integration of ICT is always successful. The most promising is blend of technological knowledge with pedagogical and content knowledge, genuine practice, feedback and institutional support. Effectiveness should be evaluated at multiple points and across time. This interpretation is consistent with TPACK, DigCompEdu and reviews that have highlighted perceived skills and actual use (Mishra & Koehler, 2006; Redecker, 2017; Zhang et al., 2026).

5. CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

5.1 Conclusions

This review discussed research findings regarding ICT in teacher training. Classroom implementation requires more than technical knowledge, and structured courses can enhance pre-service teachers' knowledge. Pedagogical alignment, authentic practice, beliefs, self-efficacy, modelling, reflective feedback, professional learning, infrastructure and institutional support are important. There is more supporting evidence for knowledge gains, but less for sustained effects in classroom practice and learner achievement.

Information and communication technology (ICT) should be integrated into the subject matter pedagogy classes and practice classes, and trainers should be asked to plan and run technology-supported lessons, with competence being independently validated through observation as well as self-report. Learning goals and learner needs should drive decisions, not the availability of tools. Integrating ICT works when it effectively underpins good teaching, active involvement, open participation, and evidence of learning.

5.2 Limitations of the Study

This critical narrative review employs targeted searching and a purposively selected body of verifiable sources. It does not represent a full systematic review, lacks a full database export, a record-level screening log, a full appraisal of each study or a new meta-analysis. Sources were not uniformly rich in populations, settings, technologies, measures, or quality. Some evaluate beliefs or knowledge, others focus on observed teaching or student learning, and a few focus on in-service development or system-level issues. These differences make direct comparison and broad generalisation difficult.

5.3 Future Research

Future research should investigate whether competence gained during coursework remains during practicum and the early years of teaching. Research should engage a mix of materials and tasks in self-report, lesson plan analysis, classroom observation, student work, and suitable learning outcomes. To facilitate replication the description of intervention should include technologies, pedagogical purpose, duration, feedback, context, and support.

Accessible low-bandwidth and resource-intensive approaches should then be compared and additional study should focus on under-represented regions and institutions of different infrastructure. A study is needed to see if mentoring and collaborative design can affect transfer, along with using authentic teaching practices. Clear definitions of outcomes and transparent reporting are required to differentiate confidence from gains in teaching and learning.

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