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TEACHER EDUCATION IN THE AGE OF EDUCATIONAL TECHNOLOGY: INNOVATION, COMPETENCIES, AND EMERGING DIGITAL TOOLS

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Abstract Educational Technology (EdTech) has moved beyond "tools in classrooms" to a broader innovation ecosystem that reshapes **teacher education**, curriculum design, assessment, and professional identity. In computer- and computing-oriented education research, the central question is no longer whether technology should be integrated, but **how** teacher education can systematically develop the knowledge, skills, and ethics required for technology-rich teaching in rapidly changing contexts (AI, learning analytics, immersive environments, mobile learning, and open resources). This paper synthesizes 2023 scholarship on technology integration, digital competence, and innovation in teacher preparation, and proposes a practical framework that aligns teacher learning outcomes with evidence-based innovation design. Drawing on research on TPACK development through Lesson Study, teacher digital competence (e.g., DigCompEdu), online/blended professional development effectiveness, and emerging generative AI in schooling, the paper argues that impactful EdTech innovation in teacher education depends on (i) coherent competency models, (ii) authentic practice-based experiences, (iii) data-informed reflection, and (iv) strong governance for privacy, equity, and academic integrity. Two summary tables are included to support course redesign and research reporting.

Keywords: educational technology, innovation, teacher education, TPACK, digital competence, DigCompEdu, learning analytics, generative AI, metaverse, mobile learning, blended learning, professional development

1. Introduction

Teacher education is being reshaped by a dual pressure: first, the steady expansion of technology-mediated learning (LMS, mobile learning, simulation, learning analytics), and second, the sudden acceleration of **generative AI** that changes how learners produce text, code, media, and ideas. In computer-journal discourse, this shift is treated as a systems-level

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challenge: teacher education must prepare educators not only to "use" tools, but to design learning experiences, interpret data, ensure accessibility, and handle ethical issues such as privacy and academic integrity. Large-scale policy signals reinforce this direction; for example, the OECD emphasizes a "digital education ecosystem" lens where infrastructure, pedagogy, evidence, and governance co-evolve rather than operate as separate projects.

At the research level, measurement and conceptual clarity have become urgent. Studies in 2023 show that teacher readiness is not captured by a single variable (like "ICT skills"). Instead, readiness is multi-dimensional, mixing pedagogical decision-making, domain knowledge, assessment capability, and context-sensitive professional judgment. For example, the development of teachers' **TPACK** through structured collaborative models (like Lesson Study) is treated as a pathway to deeper integration than one-off tool trainings (Jiménez Sierra et al., 2023). Meanwhile, work on teacher digital competence highlights that competence is not only operational (how to click, configure, and upload), but also critical (how to evaluate information, manage data, design inclusive learning, and understand risks) (Smestad et al., 2023).

This paper is written in a "computer journal" style: it is conceptually grounded, evidence-linked, and design-oriented. It addresses two practical needs in teacher education:

1. a consolidated, 2023-only evidence base that can be cited in a journal manuscript, and
2. a course/program design map that translates evidence into implementable training structures.

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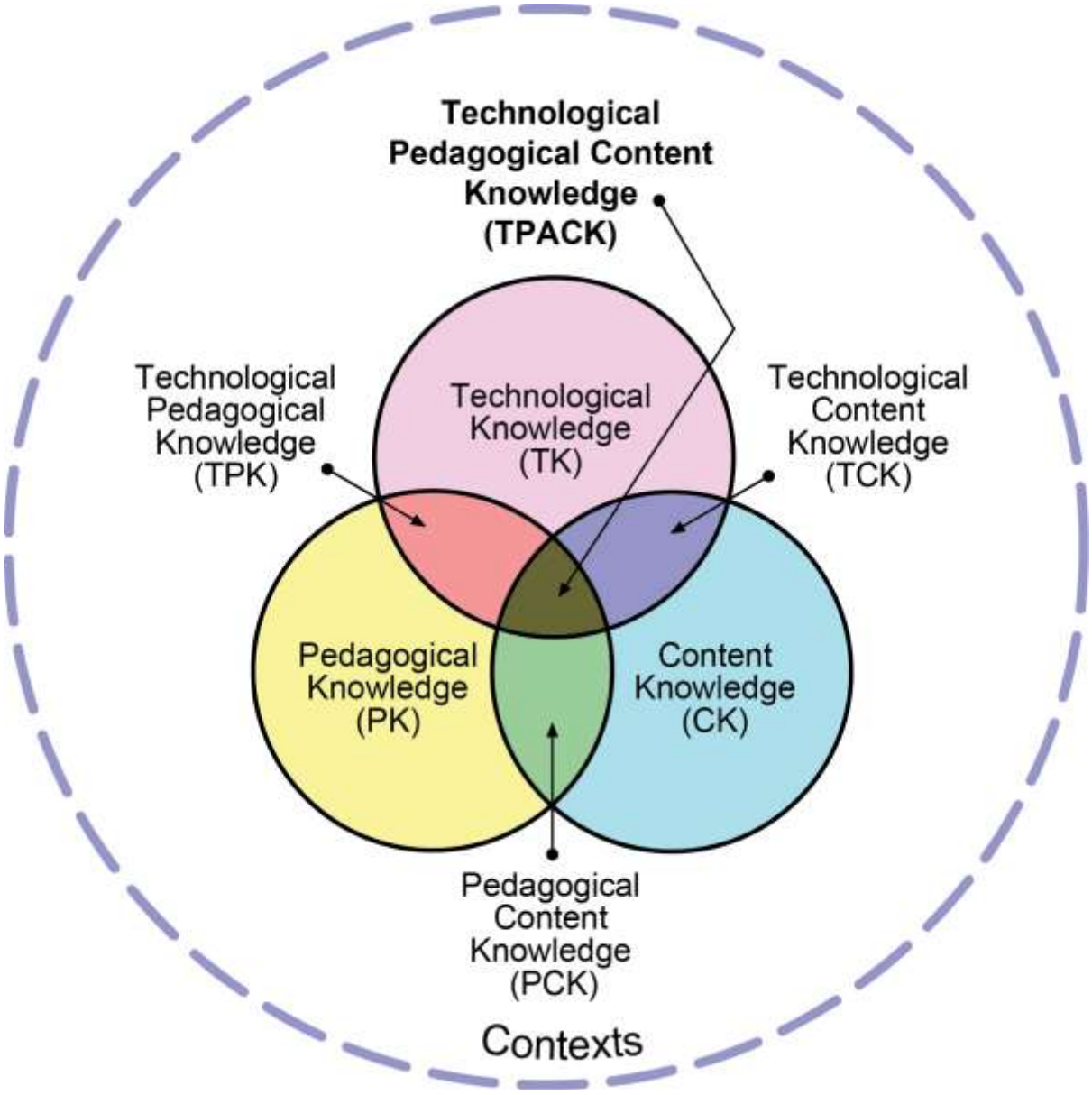

Figure 1.1 Conceptual Framework Linking Educational Technology Innovation and Teacher Education Competencies

2. Conceptual Foundations for Innovation in Teacher Education

Innovation in teacher education is often misunderstood as "adding new tech." In 2023 literature, innovation is better defined as **a measurable improvement in learning, teaching practice, or equity outcomes** achieved through systematic redesign of pedagogy, assessment, and support structures. This section summarizes the core frameworks most frequently used in 2023 to structure that redesign.

2.1 TPACK as a design-and-practice framework

TPACK remains central because it represents technology integration as a knowledge-in-action

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system: teachers coordinate content knowledge, pedagogy, and technology based on learners and context. A 2023 systematic review focusing on **Lesson Study** as a professional learning approach reports consistent TPACK growth when teachers collaboratively plan, teach, observe, and refine technology-enhanced lessons (Jiménez Sierra et al., 2023). The crucial point for teacher education is that TPACK is strengthened not by lectures about tools, but by **iterative cycles of design, enactment, feedback, and revision** in authentic settings.

2.2 Digital competence and DigCompEdu

Digital competence frameworks (including DigCompEdu) provide measurable domains for teacher education outcomes such as digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence (Cabero-Almenara et al., 2023). In 2023 studies, DigCompEdu is frequently used to diagnose baseline competence and to validate program impacts, especially in pre-service populations. A key contribution of digital competence research is its insistence that competence includes:
(1) **pedagogical orchestration** (how tools support learning processes),
(2) **assessment literacy** (how evidence is collected and interpreted digitally), and
(3) **ethics and governance** (privacy, bias, safety, academic integrity).

2.3 Evidence-based professional development and modality effects

Innovation in teacher education is also shaped by modality: face-to-face, online, blended, and flipped formats. A 2023 meta-analysis comparing online learning and blended/flipped approaches reports that technology-supported professional development can be as effective as in-class delivery, with blended/flipped designs showing advantages under many conditions (Schmid et al., 2023). The design implication is that teacher education programs can adopt blended and flipped structures without sacrificing outcomes—provided the pedagogy is strong and practice opportunities are authentic.

2.4 Governance and risk: privacy, equity, integrity

2023 research and guidance treat governance as inseparable from innovation. The UNESCO guidance on generative AI stresses responsible adoption, protection of learner data, transparency, and equity-centered policy development (Miao & Holmes, 2023). For teacher education, governance becomes teachable content: pre-service teachers must learn what data are collected by platforms, how algorithmic bias can emerge, and how to design assessments that reduce AI-enabled misconduct while preserving learning goals.

3. Educational Technology Innovations Shaping Teacher Education in 2023

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Teacher education in 2023 is characterized by a portfolio of innovations. The strongest programs treat these innovations as **integrated design elements**, not isolated modules.

3.1 Mobile learning and ubiquitous professional learning

Mobile learning research emphasizes flexibility, contextual practice, and continuous reflection. Systematic reviews in 2023 describe mobile learning as effective when teacher education designs incorporate (i) short structured learning objects, (ii) reflective prompts aligned with teaching practice, and (iii) opportunities for collaboration and feedback (Tong et al., 2023a; Naveed et al., 2023). The innovation is not the phone; it is the **micro-architecture of learning**—how teacher candidates practice planning, teaching, documenting, and revising in small cycles.

3.2 Learning analytics for reflective teacher learning

Learning analytics in teacher education is increasingly used to support reflection: candidates review their participation traces, engagement patterns, concept mastery signals, and sometimes emotional/behavioral indicators in challenging learning tasks. Work published in 2023 demonstrates that analytics can support pre-service teachers' learning when it is framed as reflective inquiry rather than surveillance (Sointu, 2023). The design rule is simple: analytics must be paired with (1) interpretation scaffolds and (2) teacher-controlled action planning, otherwise dashboards become noise.

3.3 Immersive environments: VR/AR/metaverse and simulation

Immersive learning appears in 2023 as both a motivation booster and a practice environment—especially for scenarios that are rare, risky, or resource-intensive in real schools. Reviews and empirical studies show that VR/AR can support teacher preparation when aligned to clear teaching competencies such as classroom communication, spatial demonstrations, lab simulation, or inclusive pedagogy (Swanson, 2023). At the frontier, metaverse-oriented teacher education is discussed in 2023 literature as a new social-and-spatial classroom with identity, interaction, and community design challenges (Agrati et al., 2023; Chen et al., 2023; Kabilan, 2023). The main teacher education contribution is preparing educators to manage presence, participation norms, and well-being in immersive spaces.

3.4 Educational robotics and computational thinking

Computing-oriented teacher education increasingly includes robotics and computational thinking as both content and pedagogy. A 2023 empirical study in robotics-based learning for pre-service teachers reports gains in knowledge and self-efficacy under scaffolded intervention designs (Jaipal-Jamani et al., 2023). This supports a broader trend: teacher education is asked to prepare teachers for computationally enriched curricula, requiring design skills (tasks,

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rubrics, debugging pedagogy) and inclusion strategies (avoiding "elite STEM" participation patterns).

3.5 Generative AI as a disruptive innovation in teacher education

Generative AI moved from novelty to structural disruption. A widely cited 2023 commentary details benefits and risks of large language models for education, including opportunities for feedback, personalization, and productivity, while warning about reliability, bias, privacy, and misuse (Kasneci et al., 2023). In school contexts, evidence-based classroom experimentation in 2023 (e.g., structured lessons using ChatGPT) suggests both feasibility and strong need for teacher mediation, transparency, and task redesign (Jauhiainen & Guerra, 2023). For teacher education, generative AI therefore becomes both:
(1) a **tool domain** (planning, differentiation, feedback prototypes), and
(2) a **pedagogical challenge** (assessment redesign, AI literacy, integrity policies, equitable access).

Table 1. Innovation-to-Competency Alignment for Teacher Education (2023 evidence synthesis)

Innovation strand	**Primary teacher-education competencies**	**Typical teacher-education learning design (high-yield)**	**Example 2023 evidence base**
Mobile learning	micro-planning, reflective practice, resource curation, contextual pedagogy	weekly micro-tasks + classroom try-outs + reflection prompts + peer feedback	Tong et al., 2023a; Naveed et al., 2023
Learning analytics	data-informed reflection, ethical data use, formative decision-making	dashboard interpretation scaffold + action plan + coaching conference	Sointu, 2023
VR/AR simulation	rehearsal of teaching moves, safe practice, multimodal explanation	simulation cycles: plan → teach → replay → coach feedback → reteach	Swanson, 2023
Metaverse/immersive social learning	managing presence, interaction norms,	scenario-based facilitation + identity/privacy	Agrati et al., 2023; Chen et

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	community building, safety	briefing + observation rubric	al., 2023; Kabilan, 2023
Robotics/CT	computational pedagogy, inclusive STEM facilitation, assessment of process	scaffolded build–test–reflect tasks + microteaching + rubric-based evaluation	Jaipal-Jamani et al., 2023
Generative AI	AI literacy, task redesign, integrity-by-design, bias/privacy awareness	prompt critique + rubric redesign + "AI-allowed/AI-not-allowed" task sets	Kasneci et al., 2023; Jauhiainen & Guerra, 2023; Adiguzel, 2023

4. Designing Teacher Education for Technology Integration and Innovation

This section translates 2023 evidence into implementable program design.

4.1 Program outcomes: specify competence, not tool exposure

A recurring 2023 finding is that "exposure to tools" does not guarantee classroom readiness. Teacher education must specify outcomes such as: designing technology-enhanced lessons, facilitating equitable participation, conducting digital assessment, and managing learner data responsibly. Studies highlight multi-dimensional competence structures—where competence includes both doing and judging (Smestad et al., 2023).

A practical outcomes structure is:
(1) **Design competence** (plan learning sequences with technology),
(2) **Enactment competence** (teach with technology under constraints),
(3) **Assessment competence** (collect and interpret evidence digitally), and
(4) **Governance competence** (privacy, equity, integrity, accessibility).

4.2 Practice-based preparation: "design → enact → revise" cycles

Practice-based preparation is repeatedly validated in 2023. The Lesson Study synthesis shows that collaborative inquiry cycles systematically improve teachers' TPACK (Jiménez Sierra et al., 2023). Similarly, computing-related innovations (robotics, simulation) work best when candidates must teach or rehearse teaching moves, not merely complete technical exercises. Therefore, teacher education should structure every EdTech module around cycles: *plan, teach/rehearse, receive feedback, revise, reteach*.

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4.3 Course architecture for blended and flipped teacher education

Evidence supports blended/flipped formats, but only when pedagogy is well designed. The 2023 meta-analysis indicates that blended/flipped approaches can outperform traditional delivery in professional development contexts (Schmid et al., 2023). In teacher education, the most practical architecture is: asynchronous conceptual grounding + synchronous practice + coached reflection. A common high-yield flow is: pre-class multimedia micro-lecture, in-class design studio, microteaching, analytics-informed reflection, and portfolio artifact submission.

4.4 Assessment redesign in the era of generative AI

Generative AI forces a shift from "product-only grading" to process-aware evaluation. In teacher education, candidates must learn assessment strategies such as:
(1) **authentic performance tasks** (teach, demonstrate, facilitate),
(2) **versioned artifacts** (drafts + reflection + revision rationale),
(3) **oral defense / teach-back** (explain choices and evidence), and
(4) **AI transparency protocols** (declare AI assistance and critique outputs).
This is consistent with 2023 guidance emphasizing responsible, transparent AI use and policy development in education systems (Miao & Holmes, 2023).

4.5 Inclusion and equity as design constraints

Innovation amplifies inequality if access, language, disability accommodations, and cultural context are ignored. For example, OER-focused teacher training includes attention to licensing literacy and IPR awareness—especially relevant in resource-constrained contexts (Saxena, 2023). Equity-by-design requires teacher candidates to learn: offline alternatives, universal design principles, multilingual resource strategies, and bias recognition in AI outputs.

5. Research and Evaluation Framework for Computer-Journal Publication

A computer-journal paper typically demands clarity on variables, instruments, and evaluation logic. 2023 studies also highlight the need for more consistent measurement in teacher education technology research (Consoli et al., 2023).

5.1 Recommended research questions (numbered, adaptable)

1. What is the effect of an innovation-focused teacher education intervention on **TPACK/digital competence**?
2. How do candidates transfer competencies into authentic teaching tasks (microteaching, practicum, simulation)?
3. What learning analytics indicators correlate with competence growth, and how do candidates interpret them?

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4. How do equity variables (device access, language proficiency, disability, gender) moderate outcomes?
5. Under generative AI conditions, which assessment designs preserve validity and integrity?

5.2 Methods design consistent with 2023 evidence

High-quality teacher education studies in 2023 commonly use mixed methods: pre/post scales (TPACK, DigCompEdu), artifact analysis (lesson plans, rubrics), teaching observation rubrics, platform analytics, and interviews/focus groups to interpret candidate reasoning. The most publishable designs include: comparison groups (or at minimum interrupted time series), validated instruments, and explicit fidelity reporting (what exactly was implemented, for how long, and with what coaching).

5.3 Measurement and reporting: practical instrument map

Table 2 offers a compact reporting aid for manuscripts.

Table 2. Evaluation Measures and Data Sources for Teacher Education EdTech Innovation Studies

Construct (dependent / mediator)	Operationalization options	Data sources	Notes for reporting
TPACK growth	validated TPACK survey; TPACK lesson-plan rubric	pre/post survey; artifact scoring	align rubric criteria with learning design
Digital competence (DigCompEdu)	DigCompEdu-based scale or performance tasks	self-report + performance evidence	triangulate self-report with artifacts
Teaching enactment quality	observation rubric; simulation scoring	microteaching video; VR/AR rehearsal logs	add inter-rater reliability
Reflective practice	coded reflection journals; action-plan quality	portfolios; learning logs	link reflections to evidence (analytics/artifacts)
Learning analytics use	dashboard interpretation accuracy; intervention response	LMS logs; analytics	ensure ethics: informed consent, transparency

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		dashboards; interviews	
AI literacy / integrity	prompt critique tasks; AI disclosure compliance	assignments; oral defense; policy quiz	define allowed vs disallowed AI use clearly
Equity outcomes	access index; participation distribution	surveys; logs; demographic variables	avoid deficit framing—report structural constraints

5.4 Discussion synthesis: what 2023 evidence suggests

Across 2023 studies, three patterns appear consistently:

- **Competence grows through practice cycles** more reliably than through tool demonstrations (Jiménez Sierra et al., 2023).
- **Modality is not destiny**—online/blended can be highly effective when pedagogy is strong and feedback loops exist (Schmid et al., 2023).
- **Emerging technologies demand governance literacy**: AI, analytics, and immersive learning increase capability while increasing risk, making ethics and policy teachable essentials (Miao & Holmes, 2023; Kasneci et al., 2023).

6. Conclusion and Recommendations

EdTech innovation in teacher education in 2023 is best understood as a competency-building enterprise rather than a hardware/software adoption problem. The strongest evidence supports programs that:

1. define outcomes using integrated competence models (TPACK + digital competence),
2. organize learning around iterative design–enact–revise cycles,
3. leverage analytics for reflection (not surveillance),
4. adopt blended/flipped structures with strong pedagogy and coaching, and
5. treat generative AI as both a toolset and an assessment redesign driver.

Actionable recommendations for teacher education programs (numbered):

1. Build one **capstone "technology-enhanced teaching portfolio"** that integrates lesson design, assessment, inclusion, and governance artifacts across the program.
2. Implement **Lesson Study-inspired cycles** (plan–teach–observe–revise) as the default structure for EdTech modules.

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3. Introduce **AI literacy and integrity-by-design**: transparent AI use policies, redesigned assessments, and prompt critique activities.
4. Make **equity and accessibility** explicit grading criteria in every technology-enhanced lesson plan and microteaching rubric.
5. Publish with computer-journal rigor: validated instruments, clear fidelity reporting, and triangulation of survey + performance evidence.

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