

Reimagining Teacher Education in the Digital Era Emerging Pedagogies Professional Competencies and Future Directions

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Abstract

The rapid development of digital technologies, artificial intelligence (AI), immersive environments and generative AI is changing the knowledge, practices and professional judgements expected of teachers and teacher educators. Teacher education can therefore no longer be understood only as preparation for conventional classroom instruction. It increasingly involves preparing future teachers to design learning experiences with digital tools, interpret technology-mediated evidence, use AI responsibly, support diverse learners, and maintain professional and ethical judgement in increasingly complex learning environments. This thematic narrative review synthesises major conceptual and research trends concerning teacher education in the digital era. The review focuses on eight interconnected themes: digital transformation of teacher education; technology-enhanced pedagogies; artificial intelligence and generative AI; digital and AI professional competencies; personalised and learner-centred learning; ethical and human-centred practice; changing roles of teacher educators; and institutional conditions for sustainable transformation. Recent literature indicates [4, 5, 6, 7] that AI and digital technologies can support lesson planning, resource development, feedback, personalised support, professional learning and reflective practice, but their educational value depends on pedagogical purpose, teacher judgement, contextual fit and institutional support. Recent reviews also point to gaps in AI literacy, particularly in the practical and ethical dimensions of teachers' professional knowledge. On this basis, the paper proposes a Human-Centred Digital Teacher Education Framework connecting technological affordances with pedagogical judgement, professional competence, ethical responsibility and institutional support. The review argues that digital transformation should not be equated with the simple adoption of devices or platforms. Sustainable teacher education requires a shift from technology integration to pedagogical integration, in which teachers learn not merely how, but when, why and under what ethical conditions technologies should be used.

Keywords: Teacher education; digital pedagogy; artificial intelligence; generative AI; teacher competencies; teacher educators; personalised learning; educational technology; professional development

1. Introduction

Digital transformation has become a significant influence on contemporary education. Digital platforms, learning management systems, mobile devices, learning analytics, virtual and augmented reality, automated feedback systems and generative artificial intelligence are expanding the range of tools

available to teachers and learners. The important question for teacher education is therefore no longer whether technology will enter educational practice, but how teachers can be prepared to make professionally sound decisions about technology.

The emergence of generative AI has accelerated this question. Recent scholarship shows [4, 6, 7] that AI can contribute to resource development, tailored support, lesson design, feedback and professional learning, while simultaneously raising concerns about accuracy, bias, privacy, academic integrity, assessment, accountability and over-reliance. Tan's 2025 scoping review of teacher development research identified applications involving resource development, personalised support and learning environments, while noting that much of the empirical literature has focused on pre-service teachers and relatively short interventions. Similarly, Sperling et al. (2024) found that AI literacy in teacher education remains an emerging field and that practical and ethical dimensions of teachers' professional knowledge need stronger attention.

These developments challenge traditional assumptions about the knowledge base of teacher education. Teachers still need subject knowledge, pedagogical knowledge, classroom management skills and assessment literacy. However, they increasingly also need the capacity to evaluate digital tools, understand the limitations of AI-generated outputs, protect learner data, design inclusive technology-mediated activities, and exercise professional judgement when technological recommendations conflict with educational values.

The transformation also affects teacher educators. Teacher educators are not simply transmitters of information about technology; they model professional practice. If pre-service teachers are expected to use digital tools critically, teacher educators themselves need opportunities to experiment, reflect, collaborate and develop appropriate digital and AI literacy. Recent research on teacher educators highlights the importance of formal professional development as well as informal and collaborative learning opportunities.

Against this background, this paper examines the emerging contours of teacher education in the digital era through a thematic narrative review. Rather than presenting uncollected survey data or claiming causal effects, the paper synthesises established conceptual frameworks, international guidance and recent peer-reviewed literature to identify major themes and develop a conceptual framework for human-centred digital teacher education.

2. Purpose and Guiding Questions

The purpose of this review is to examine how digital transformation is reshaping teacher education and to identify the professional, pedagogical, ethical and institutional conditions required for meaningful technology use.

The review is guided by five questions:

1. What major technological and pedagogical changes are influencing contemporary teacher education?
2. What professional competencies are increasingly required for teachers and teacher educators in digitally mediated environments?
3. What opportunities and challenges are associated with AI and generative AI in teacher education?
4. How should ethical, inclusive and human-centred principles shape technology use in teacher preparation?
5. What conceptual and institutional directions can support sustainable digital transformation in teacher education?

3. Review Approach

This paper uses a thematic narrative review approach. It does not claim to be a systematic review or meta-analysis. Literature was selected purposively to represent foundational scholarship, international guidance and recent peer-reviewed research relevant to teacher education, digital pedagogy, AI literacy, generative AI, professional competence and teacher development.

The review proceeded through four broad stages. First, key conceptual foundations concerning technology integration and teacher knowledge were identified, including the Technological Pedagogical Content Knowledge (TPACK) framework. Second, recent literature on AI literacy and generative AI in teacher education and teacher development was examined. Third, recurring concepts were organised into thematic categories. Finally, the themes were integrated into a conceptual framework connecting technology, pedagogy, professional competence, ethics and institutional conditions. [1]

The review is interpretive rather than statistical. No primary participants were recruited, no questionnaire was administered, and no original numerical dataset was analysed. Consequently, the paper does not report percentages, significance tests or effect sizes. Claims about the field are based on published literature and conceptual analysis rather than newly collected empirical evidence. This methodological transparency is important for distinguishing a thematic review from an empirical research article.

4. Theme One Digital Transformation of Teacher Education

Digital transformation involves more than introducing computers or online resources into existing teacher education programmes. It can alter how teacher candidates access knowledge, collaborate, practise teaching, receive feedback and reflect on professional performance. Learning management systems, digital portfolios, video-based reflection, virtual simulations and online communities can extend teacher preparation beyond scheduled classroom sessions.

One important consequence is the expansion of learning spaces. A teacher candidate may learn through face-to-face seminars, asynchronous modules, recorded teaching demonstrations, online peer communities and practice-based digital tasks. Such environments can provide flexibility, but they also require stronger self-regulation and digital participation skills.

Digital transformation also changes the relationship between knowledge and access to information. Because information can be obtained rapidly through search engines, repositories and generative AI systems, teacher education must place greater emphasis on source evaluation, interpretation and professional judgement. Knowing where to find information is not equivalent to knowing whether information is accurate, pedagogically appropriate or ethically usable.

The transformation therefore requires curriculum redesign. Digital competence should not remain an isolated technical unit. Instead, it should be embedded across pedagogy, assessment, subject methods, classroom practice and professional reflection. This principle is consistent with the TPACK perspective, in which technology knowledge is understood in relation to pedagogical and content knowledge [1].

For teacher education institutions, digital transformation also raises questions about infrastructure and equity. A technology-rich programme can unintentionally disadvantage candidates who have limited connectivity, inadequate devices or less prior digital experience. Digital transformation should therefore be accompanied by inclusive access, technical support and opportunities for differentiated learning.

5. Theme Two Emerging Technology-Enhanced Pedagogies

Technology changes pedagogy when it changes what learners can do, how teachers organise learning and how evidence of learning is generated. Blended learning combines face-to-face and online learning; its value lies in deliberately allocating activities to the environment in which they are educationally useful. Flipped learning can use digital materials before class and reserve contact time for application, microteaching, discussion and feedback.

Collaborative digital learning can support peer feedback and professional communities. Digital portfolios can document lesson plans, teaching artefacts, reflections and revisions over time. Video-based reflection can help student teachers examine classroom interactions and connect practice with pedagogical concepts.

Immersive technologies such as virtual and augmented reality provide another emerging direction. Their potential is particularly relevant where authentic classroom experiences are difficult to reproduce safely or repeatedly. However, technological novelty alone does not guarantee learning value. Teacher educators need to identify the learning objective first and then determine whether an immersive environment adds educational value beyond a simpler method.

Across these approaches, the central principle is pedagogical alignment. Technology should be selected because it supports a defined learning purpose, not because it is new or sophisticated. The same tool may be useful for one learning task and inappropriate for another. Consequently, technology-enhanced pedagogy should be treated as a decision-making process rather than a catalogue of tools.

6. Theme Three Artificial Intelligence and Generative AI

Artificial intelligence is becoming increasingly visible in teacher education through automated feedback, recommendation systems, adaptive learning environments, AI-assisted content generation and generative AI applications. Generative AI systems can produce text, lesson ideas, examples, questions, rubrics and other educational materials. Recent reviews suggest [5, 7, 8] that teacher development programmes are beginning to explore these possibilities, but the evidence base is still developing.

A major opportunity is instructional design. A teacher candidate can use generative AI to produce alternative lesson structures, compare pedagogical approaches, generate differentiated examples and identify possible misconceptions. The educational value, however, comes from the candidate's evaluation and revision of the output rather than accepting generated material without scrutiny.

AI can also support personalised professional learning. Teachers may use conversational systems to obtain explanations, practise questioning, generate reflective prompts or receive alternative perspectives on a lesson plan. Such use can support self-directed learning when combined with critical evaluation. Tan (2025) reported that reviewed interventions associated generative AI with outcomes including learning, teacher knowledge, higher-order thinking, lesson design and AI literacy, while also identifying limitations in the current evidence base.

Assessment is another area of change. AI can assist in generating formative questions, feedback prompts and rubric drafts. At the same time, generative AI complicates traditional assumptions about take-home written assignments. Teacher education programmes may therefore need assessment designs that emphasise process, oral explanation, classroom performance, reflection, evidence of revision and authentic professional tasks.

The risks are equally important. Generative AI can produce plausible but incorrect information. It may reproduce biases present in training data or generate stereotyped representations. Privacy concerns arise

when users enter identifiable learner information into external systems. There are also questions about authorship, transparency and academic integrity. UNESCO guidance [3] therefore emphasises human-centred and responsible approaches to generative AI in education [3].

AI literacy should consequently include at least three dimensions: understanding what AI systems can and cannot do; developing practical competence in using and evaluating AI tools; and developing professional judgement about when AI use is educationally appropriate. Sperling et al. (2024) similarly identified gaps in the practical and ethical dimensions of AI literacy relevant to teacher education.

7. Theme Four Digital and AI Professional Competencies

Digital competence in teaching is broader than the ability to operate software. A professionally capable teacher must be able to connect technology with curriculum goals, learner characteristics, assessment purposes and ethical responsibilities.

The TPACK framework [1] provides a useful foundation because it conceptualises technology knowledge in relation to pedagogical and content knowledge. In the contemporary context, teacher education increasingly needs to extend this logic to AI. AI-related professional competence includes understanding the characteristics and limitations of AI systems, evaluating outputs, designing prompts where appropriate, checking generated information, recognising bias and protecting data.

A particularly important dimension is professional judgement. AI systems may provide multiple plausible options, but they cannot replace contextual knowledge of learners, relationships, classroom culture and professional responsibility. The teacher remains accountable for educational decisions even when technology contributes to decision-making.

AI literacy should therefore be developed through authentic professional tasks rather than only through technical demonstrations. Pre-service teachers can analyse AI-generated lesson plans, identify errors, compare human and AI-generated feedback, design technology-supported learning activities, and reflect on ethical dilemmas. Such activities make AI literacy part of professional formation rather than an isolated technological skill.

Professional competence also includes the ability to decide not to use technology. A digitally competent teacher should be able to justify technology use and non-use based on educational purpose, learner needs, accessibility, privacy, reliability and available resources.

8. Theme Five Personalised and Learner-Centred Teacher Education

Digital technologies can support more personalised learning pathways by providing flexible access to resources, differentiated tasks, feedback and learning analytics. For teacher education, personalisation can be applied to the development of individual professional competencies.

Digital portfolios can help student teachers identify areas of strength and development. Adaptive learning resources may provide additional practice where a candidate experiences difficulty. Online communities can offer peer support and access to diverse perspectives. Generative AI can also provide alternative explanations or examples, although outputs must be checked for accuracy and appropriateness.

However, personalisation should not be equated with automation. Effective teacher education requires relationships, dialogue, mentoring and professional communities. A purely automated learning pathway could overlook emotional, social and contextual aspects of becoming a teacher.

The concept of learner agency is therefore central. Technology should create opportunities for student teachers to make choices, formulate questions, monitor progress and reflect on professional identity. Teacher educators remain important as mentors who help learners interpret experiences and connect theory with practice.

Personalisation also requires careful attention to data. Learning analytics can generate information about participation and performance, but data should not automatically be treated as a complete representation of learning. Quantitative indicators need to be interpreted alongside qualitative evidence and professional judgement.

9. Theme Six Ethical and Human-Centred Technology Use

The expansion of digital and AI technologies makes ethical competence an essential component of teacher education. The teacher's role includes safeguarding learners' dignity, privacy, inclusion and right to meaningful educational participation.

Privacy is particularly important because educational technologies can process personal information. Teacher candidates need to understand what information is being collected, where it is stored, who may access it and whether it is necessary for the educational purpose.

Bias is another concern. AI systems may reproduce patterns present in their training data. A teacher who uses AI-generated examples, images, feedback or recommendations therefore needs to examine whether outputs unfairly represent individuals or groups.

Transparency also matters. Learners should not be misled about the role of AI in an educational task. Teacher education programmes can develop norms for disclosure, citation, verification and responsible use.

Human-centred practice means that technology serves educational relationships rather than replacing them. Teaching involves empathy, interpretation, encouragement, moral responsibility and contextual judgement. These dimensions cannot be reduced to technical optimisation.

An ethical framework should consequently include four questions whenever a technology is introduced: Does it improve the intended learning process? Is its use fair and inclusive? Does it protect learners' rights and data? Does it preserve meaningful human agency and professional accountability?

10. Theme Seven Changing Role of the Teacher Educator

Digital transformation changes the role of teacher educators from primarily delivering content toward designing professional learning environments, modelling digital pedagogy and facilitating critical reflection.

Teacher educators increasingly need to demonstrate how technologies can be integrated into subject-specific teaching. A methods teacher, for example, may need to show how digital tools can support historical inquiry, language learning, scientific modelling or formative assessment rather than simply demonstrating the operation of a platform.

Teacher educators also become curators and evaluators of digital resources. Because the quantity of available materials is enormous, candidates need guidance in identifying credible, accessible and pedagogically appropriate resources.

Another role is that of ethical facilitator. Teacher educators can create structured discussions around privacy, algorithmic bias, academic integrity, authorship and responsible AI use. Such dialogue is

especially important because student teachers will later encounter diverse institutional policies and classroom contexts.

Professional learning among teacher educators should therefore be collaborative. Workshops can introduce tools, but sustained communities of practice are needed for experimentation, reflection and sharing successful and unsuccessful experiences. Research on teacher educators' engagement with GenAI has also identified needs for formal professional development and informal collaborative learning.

11. Theme Eight Institutional Challenges and Conditions

Individual teacher competence cannot by itself guarantee successful digital transformation. Institutional conditions strongly influence whether new practices become sustainable.

Infrastructure is a basic condition. Reliable connectivity, suitable devices, technical support and accessible digital platforms are necessary. Yet infrastructure alone is insufficient. Institutions also need clear policies concerning data protection, AI use, academic integrity, accessibility and procurement.

Time is another factor. Teachers and teacher educators need time to learn technologies, redesign lessons, experiment, evaluate outcomes and collaborate. When technology is introduced without workload planning, adoption may become superficial.

Leadership matters because digital transformation requires coordination across curriculum, assessment, infrastructure and professional development. Institutional leaders can create conditions for experimentation while avoiding a culture in which technology adoption is treated simply as compliance. Equity must remain central. Differences in access, prior digital experience and support can produce unequal outcomes. Teacher education institutions should therefore design programmes with accessibility and flexibility in mind.

Finally, evaluation should focus on educational outcomes rather than technology adoption alone. The number of platforms used, devices purchased or digital activities completed does not demonstrate improved teacher preparation. Evaluation should examine whether candidates demonstrate stronger pedagogical reasoning, digital judgement, reflective capacity and ethical decision-making.

12. From Technology Integration to Pedagogical Integration

The thematic synthesis suggests an important distinction between technology integration and pedagogical integration. Technology integration can occur when a digital tool is added to an existing activity without substantially changing the learning purpose. Pedagogical integration occurs when technology is deliberately selected because its affordances improve a particular learning process.

A useful sequence is: educational purpose → learner/context analysis → pedagogical strategy → technology selection → implementation → evidence and reflection → revision. This places pedagogy before technology and makes reflection a necessary stage. A teacher should examine whether the technology supported the intended learning and whether unexpected consequences emerged.

For AI, the sequence can be extended: educational purpose → learner/context analysis → pedagogical strategy → AI/tool selection → task or prompt design → output verification → ethical and privacy check → implementation → evidence and reflection → revision. This model discourages technology-first teaching and supports professional agency.

13. Proposed Human-Centred Digital Teacher Education Framework

Based on the thematic synthesis, this paper proposes a Human-Centred Digital Teacher Education Framework consisting of five interconnected dimensions.

Dimension 1—Technological affordances: digital platforms, AI systems, learning analytics, immersive technologies and other tools available to teacher educators and student teachers.

Dimension 2—Pedagogical judgement: decisions about why a technology should be used, how it aligns with learning objectives, and how it can support particular learners.

Dimension 3—Professional competence: digital literacy, AI literacy, assessment literacy, instructional design, information evaluation and reflective practice.

Dimension 4—Ethical and human-centred responsibility: privacy, fairness, inclusion, transparency, academic integrity, learner agency and professional accountability.

Dimension 5—Institutional support: infrastructure, policy, leadership, professional development, technical support, time and communities of practice.

The framework assumes that effective teacher education emerges from interaction among all five dimensions. Strong technology without pedagogy can produce superficial adoption. Strong pedagogy without technological awareness can limit opportunities. Competence without ethics can create harmful practices. Individual competence without institutional support can be difficult to sustain. The framework can therefore be used as a conceptual tool for curriculum review, teacher educator development and future empirical research.

14. Discussion

The thematic synthesis indicates that digital transformation is simultaneously technological, pedagogical and professional. A narrow technology-adoption perspective is insufficient because teacher education is fundamentally concerned with professional judgement.

First, the literature points to a movement from tool competence toward integrated professional competence. Teachers need to understand technologies, but they also need to evaluate their educational value and limitations. This supports the continuing relevance of TPACK while suggesting the need for stronger treatment of AI-specific knowledge and ethical judgement.

Second, AI is altering the meaning of instructional design. Generative systems can produce first drafts of lesson plans, questions and learning materials, but this does not remove the need for teacher expertise. Instead, it increases the importance of checking, contextualising, adapting and improving generated content.

Third, teacher education must address the ethical dimension of digital practice. AI literacy should not be reduced to prompt writing or tool familiarity. Teachers need to understand privacy, bias, transparency, authorship and the consequences of automated recommendations.

Fourth, institutional support is essential. Teacher educators and student teachers cannot be expected to transform practice without adequate infrastructure, time, policy clarity and professional learning opportunities.

Finally, the review identifies a research opportunity. Existing studies increasingly examine AI literacy, adoption and professional development, but there remains a need for context-sensitive research that connects technological competence with actual pedagogical decision-making, professional identity and ethical judgement. Research in diverse educational systems and resource conditions is particularly important.

15. Implications for Teacher Education Programmes

The review suggests several practical implications. Curriculum design should embed digital and AI competence across teacher education rather than isolating it in a single technology course. Subject-method courses can include technology-supported lesson design, evaluation of digital resources and critical analysis of AI-generated materials.

Practicum and internship programmes can include structured digital reflection. Student teachers can document technology-supported lessons, analyse evidence of learning, identify limitations and propose revisions.

Assessment should include authentic professional tasks. Instead of relying exclusively on conventional written assignments, programmes can assess lesson design, microteaching, portfolios, reflective commentary, oral defence and evidence of revision.

Teacher educator development should include sustained professional learning. Short workshops can introduce technologies, but collaborative communities of practice can support longer-term experimentation and reflection.

Institutions should develop transparent guidance on responsible AI use. Policies should address acceptable use, verification, disclosure, privacy, assessment and academic integrity without treating all AI use as either automatically acceptable or automatically unacceptable.

Finally, equity should be treated as a design principle. Programmes should consider device access, connectivity, accessibility, language, prior experience and technical support when introducing digital learning activities.

16. Research Gaps and Future Directions

Several directions emerge for future research. First, more longitudinal research is needed. Much emerging AI research in teacher development involves short interventions; longer studies could examine whether competencies developed during teacher education are sustained during early teaching careers.

Second, research should move beyond self-reported confidence and intention. Performance-based measures can examine whether teachers actually demonstrate effective digital and AI-supported pedagogy.

Third, more attention is needed to teacher educators. Their professional learning, beliefs, institutional constraints and pedagogical practices influence what student teachers experience.

Fourth, research should investigate ethical competence. Studies could examine how teachers recognise bias, protect data, communicate AI use to learners and make decisions when technology conflicts with educational values.

Fifth, comparative research across contexts is important. Digital teacher education cannot be designed around assumptions that all institutions have the same infrastructure, policy environment or learner population.

Sixth, future studies can empirically test the Human-Centred Digital Teacher Education Framework proposed here. Possible designs include mixed-methods studies, design-based research, intervention studies and longitudinal investigations of pre-service teachers' professional competence.

Finally, future research should distinguish between technology adoption and educational transformation. Adoption measures whether a tool is used; transformation research asks whether professional practice, learning processes or teacher decision-making have meaningfully changed.

17. Limitations

This paper has several limitations. It is a thematic narrative review rather than a systematic review with a reproducible database search and formal risk-of-bias assessment. The literature was purposively selected to illuminate major conceptual and contemporary themes, so the review should not be interpreted as an exhaustive census of all research. The field of AI and teacher education is changing rapidly; consequently, new empirical findings may modify some themes identified here. The proposed framework is conceptual and requires empirical validation before it can be treated as an established model.

18. Conclusion

Digital transformation is changing what it means to prepare teachers for professional practice. The central challenge is not simply to increase teachers' exposure to digital technologies but to develop their capacity to make informed, pedagogically justified and ethically responsible decisions about those technologies.

The review identified eight interconnected themes: digital transformation, technology-enhanced pedagogies, AI and generative AI, professional competencies, personalised learning, ethical and human-centred practice, changing teacher educator roles, and institutional conditions. Together, these themes suggest a shift from technology integration toward pedagogical integration.

The Human-Centred Digital Teacher Education Framework proposed in this paper places technological affordances within a wider system of pedagogical judgement, professional competence, ethical responsibility and institutional support. Its central proposition is that technology should strengthen—not displace—teacher agency, professional relationships and educational judgement.

The future of teacher education is therefore unlikely to be defined by a single platform or technology. It will depend on whether institutions can prepare teachers and teacher educators to work critically and creatively with changing technologies while preserving the human purposes of education. This requires curriculum renewal, authentic assessment, sustained professional learning, ethical guidance, equitable access and research that examines actual professional practice rather than technology adoption alone.

Table 1: Dimensions of the Human-Centred Digital Teacher Education Framework

Dimension	Core focus	Illustrative question
Technological affordances	Digital and AI tools	What can the technology enable, and what are its limitations?
Pedagogical judgement	Alignment with teaching and learning	Why is this technology appropriate for this learning goal and learner group?
Professional competence	Digital/AI literacy and reflective practice	Can the teacher evaluate, adapt and justify technology-supported practice?
Ethical responsibility	Privacy, fairness, inclusion and agency	Is the use transparent, equitable, safe and professionally accountable?
Institutional support	Infrastructure, policy and	What conditions are needed

	professional learning	to sustain responsible practice?
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