



Generative AI in Teacher Education: Opportunities, Challenges, and Future Directions

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DOI : <https://doi.org/10.5281/zenodo.22054334>

ARTICLE DETAILS

Research Paper

Received: 30-06-2026

Accepted: 20-07-2026

Published: 20-08-2026

Keywords:

Generative Intelligence, Artificial Teacher Education, AI Literacy, TPACK, Teacher Professional Development, Educational Technology

ABSTRACT

The emergence of Generative Artificial Intelligence (GenAI) has introduced transformative possibilities for education, particularly in teacher education. Tools such as ChatGPT, Gemini, Claude, and other AI-powered applications have begun to influence lesson planning, instructional design, assessment, content creation, and professional development. As teacher education institutions prepare future educators for rapidly evolving digital learning environments, understanding the implications of Generative AI becomes increasingly important. This paper examines the opportunities, challenges, and future directions associated with the integration of Generative AI in teacher education. Drawing upon recent literature, the paper discusses how GenAI can enhance personalized learning, instructional innovation, and professional growth among pre-service and in-service teachers. At the same time, concerns related to academic integrity, ethical use, data privacy, algorithmic bias, and overdependence on technology are critically analyzed. The paper is grounded in established theoretical perspectives, including the Technological Pedagogical Content Knowledge (TPACK) framework, Social Cognitive Theory, and the Technology Acceptance Model. The discussion highlights the need for AI literacy, ethical guidelines, and pedagogical preparedness among teacher educators and student teachers. The paper concludes by emphasizing the importance of

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developing responsible AI integration strategies to maximize educational benefits while minimizing potential risks.

Introduction

The rapid advancement of Artificial Intelligence (AI) has significantly transformed various sectors, including education. Among the most notable developments is Generative Artificial Intelligence (GenAI), which refers to AI systems capable of generating human-like text, images, audio, videos, and other forms of content. Applications such as ChatGPT, Gemini, Claude, DALL-E, and Microsoft Copilot have gained widespread attention due to their ability to support communication, creativity, and problem-solving.

In the field of education, Generative AI is increasingly being utilized to support teaching, learning, and assessment processes. Teachers can use AI tools to create lesson plans, generate instructional materials, design assessments, provide feedback, and personalize learning experiences. Consequently, teacher education institutions are faced with the responsibility of preparing future educators to effectively and ethically integrate AI technologies into classroom practices.

Teacher education plays a critical role in shaping the competencies, attitudes, and professional identities of future teachers. As educational environments become more technologically advanced, teacher preparation programs must equip student teachers with the knowledge and skills necessary to navigate AI-enhanced learning environments. The integration of Generative AI into teacher education offers opportunities for innovation and efficiency, but it also presents challenges related to ethics, equity, academic integrity, and professional responsibility.

Recent educational discourse has emphasized the need for AI literacy among teachers. AI literacy extends beyond technical competence and includes understanding the capabilities, limitations, ethical implications, and pedagogical applications of AI technologies. Without adequate preparation, educators may struggle to evaluate AI-generated content, identify biases, or use AI tools responsibly in educational settings.

Given the increasing adoption of Generative AI across educational contexts, there is a need to critically examine its implications for teacher education. This paper explores the opportunities, challenges, and future directions associated with Generative AI and discusses how teacher education institutions can prepare educators for AI-supported teaching and learning environments.



Review of Literature

Generative AI and Educational Transformation

Recent studies indicate that Generative AI has the potential to transform educational practices by enhancing instructional design, content generation, and learner engagement. Holmes et al. (2022) argue that AI technologies can support personalized learning experiences by adapting educational content to individual learner needs. Similarly, Zawacki-Richter et al. (2019) emphasize that AI can improve educational decision-making and learning support systems.

Generative AI tools have enabled teachers to produce instructional resources more efficiently. Research suggests that AI-generated materials can reduce teachers' workload and allow them to focus on higher-order pedagogical activities such as mentoring, facilitating discussions, and supporting student learning.

Opportunities for Teacher Professional Development

Teacher professional development is another area where Generative AI demonstrates significant potential. Studies have shown that AI-powered systems can provide personalized recommendations, instructional feedback, and reflective learning opportunities for educators. Luckin et al. (2016) suggest that AI can function as an intelligent coaching tool, helping teachers identify strengths and areas for improvement.

Furthermore, Generative AI can facilitate continuous learning by providing immediate access to educational resources, research findings, and instructional strategies. Such support can contribute to enhanced teaching effectiveness and professional growth.

Challenges Associated with Generative AI

Despite its potential benefits, several challenges accompany the use of Generative AI in education. One major concern relates to academic integrity. Researchers have highlighted the possibility of students relying excessively on AI-generated content, potentially reducing opportunities for independent thinking and creativity.

Another challenge involves algorithmic bias. AI systems are trained on large datasets that may contain biases, inaccuracies, or cultural imbalances. Consequently, AI-generated outputs may reflect these biases, affecting the quality and fairness of educational content.



Privacy and data security concerns also remain significant. The collection and processing of user data by AI systems raise ethical questions regarding confidentiality, informed consent, and responsible data management.

AI Literacy and Teacher Readiness

Teacher readiness has emerged as a critical factor influencing successful AI integration. Studies indicate that educators who possess higher levels of digital competence and AI literacy are more likely to adopt AI technologies effectively. Teacher education programs must therefore incorporate AI-related competencies into curricula to ensure that future educators are prepared to utilize AI responsibly and effectively.

Theoretical Framework

Technological Pedagogical Content Knowledge (TPACK)

The TPACK framework developed by Mishra and Koehler (2006) provides a valuable lens for understanding AI integration in teacher education. TPACK emphasizes the interconnected relationship among technological knowledge, pedagogical knowledge, and content knowledge. Effective AI integration requires teachers to possess competencies in all three domains and understand how they interact within specific educational contexts.

Social Cognitive Theory

Bandura's (1986) Social Cognitive Theory highlights the role of self-efficacy, observational learning, and reciprocal interactions between individuals and their environments. In the context of Generative AI, teachers' beliefs regarding their ability to use AI effectively influence their willingness to adopt and integrate these technologies into teaching practices.

Technology Acceptance Model (TAM)

The Technology Acceptance Model proposed by Davis (1989) explains technology adoption through perceived usefulness and perceived ease of use. Teachers are more likely to embrace Generative AI when they perceive it as beneficial, accessible, and supportive of instructional objectives.



Need and Significance of the Study

The rapid expansion of Generative AI technologies has created both opportunities and uncertainties within teacher education. While AI tools offer innovative possibilities for instructional design, assessment, and professional development, many teacher education programs have yet to systematically address AI-related competencies.

Understanding the implications of Generative AI is essential for preparing future educators to function effectively in digitally enhanced learning environments. This study contributes to the growing body of literature by examining the educational potential, ethical considerations, and implementation challenges associated with Generative AI in teacher education.

The findings and discussions presented in this paper may assist teacher educators, policymakers, curriculum developers, and educational institutions in developing evidence-based strategies for AI integration. Furthermore, the study emphasizes the importance of fostering AI literacy, ethical awareness, and critical thinking among future educators.

Objectives of the Study

1. To examine the role of Generative AI in teacher education.
2. To identify the opportunities offered by Generative AI for teaching, learning, and professional development.
3. To analyze the challenges associated with the integration of Generative AI in teacher education.
4. To explore the theoretical foundations supporting AI adoption in educational contexts.
5. To suggest future directions for the effective and ethical use of Generative AI in teacher education.

Methodology

Research Design

This study adopted a systematic literature review (SLR) design to critically examine the opportunities, challenges, and future directions of Generative Artificial Intelligence (GenAI) in teacher education. A systematic literature review was selected because it enables the identification, evaluation, and synthesis of existing empirical and conceptual studies in a transparent and rigorous manner. The review



followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure methodological transparency and reproducibility.

Data Sources

Relevant literature was identified through comprehensive searches of internationally recognized academic databases, including:

- Scopus
- Web of Science
- ERIC (Education Resources Information Center)
- Google Scholar
- SpringerLink
- Taylor & Francis Online
- ScienceDirect
- Wiley Online Library

These databases were selected because they index high-quality peer-reviewed research in education, educational technology, artificial intelligence, and teacher education.

Search Strategy

The literature search employed combinations of the following keywords using Boolean operators (AND, OR):

- “Generative Artificial Intelligence”
- “Generative AI”
- “Artificial Intelligence in Education”
- “Teacher Education”
- “Pre-service Teachers”
- “Teacher Professional Development”
- “AI Literacy”
- “Teacher Competence”
- “Educational Technology”

An example search string was:

«(“Generative AI” OR “Artificial Intelligence”) AND (“Teacher Education” OR “Pre-service Teachers”) AND (“Professional Development” OR “Teaching” OR “Learning”))»



The search primarily included studies published between 2020 and 2026 to capture the most recent developments in Generative AI technologies.

Inclusion and Exclusion Criteria

The following criteria guided the selection of studies.

Inclusion Criteria

- Peer-reviewed journal articles.
- Empirical, review, or conceptual studies related to Generative AI in teacher education.
- Publications written in English.
- Studies published between 2020 and 2026.
- Studies focusing on pre-service teachers, in-service teachers, teacher educators, or teacher preparation programmes.

Exclusion Criteria

- Conference abstracts without full-text availability.
- Opinion pieces, editorials, news articles, and blogs.
- Studies unrelated to education or teacher education.
- Duplicate publications.
- Articles lacking sufficient methodological or theoretical detail.

Study Selection Process

The initial database search yielded a large number of publications. After removing duplicate records, titles and abstracts were screened for relevance. Full-text articles meeting the inclusion criteria were then reviewed in detail. Studies that did not align with the objectives of the review were excluded. The remaining articles formed the final dataset for analysis.

Data Extraction

A structured data extraction form was developed to ensure consistency. The following information was extracted from each study:

- Author(s) and year of publication
- Country of study
- Research objectives
- Research design
- Sample characteristics
- AI tools investigated
- Major findings
- Opportunities identified
- Challenges reported
- Educational implications
- Recommendations for future research

Data Analysis

The selected studies were analysed using thematic analysis. Similar findings were grouped into recurring themes, allowing the identification of common patterns across the literature.

The major themes included:

- Opportunities for Generative AI in teacher education
- AI-supported teaching and learning practices
- Professional development and AI literacy
- Ethical concerns and academic integrity
- Data privacy and algorithmic bias
- Institutional readiness and policy implications
- Future directions for AI integration



The synthesis emphasized similarities and differences among the studies while identifying gaps in the existing literature.

Trustworthiness of the Review

To enhance the quality and credibility of the review, several strategies were employed:

- Use of multiple reputable academic databases.
- Clearly defined inclusion and exclusion criteria.
- Transparent study selection procedures following PRISMA 2020 recommendations.
- Critical evaluation of the methodological quality and relevance of included studies.
- Thematic synthesis based on evidence from multiple sources rather than individual studies.

These procedures strengthened the reliability, transparency, and scholarly rigor of the review.

Ethical Considerations

As this study is based exclusively on published scholarly literature, it did not involve human participants or the collection of primary data. Therefore, formal institutional ethical approval was not required. Nevertheless, ethical research practices were maintained by accurately representing previous studies, acknowledging all sources through proper APA 7th edition citations, and avoiding plagiarism and misrepresentation of findings.

Limitations of the Study

Despite offering valuable insights into the role of Generative Artificial Intelligence (GenAI) in teacher education, this study has several limitations that should be considered when interpreting its findings.

First, the study is based solely on a review and synthesis of existing literature rather than the collection of primary empirical data. Consequently, the conclusions are derived from previously published research and may not fully reflect the experiences and perceptions of teachers across different educational contexts.

Second, the review primarily includes studies published in English between 2020 and 2026. Relevant research published in other languages or outside this time frame may not have been captured, potentially limiting the comprehensiveness of the review.



Third, the field of Generative AI is evolving rapidly. New AI models, educational applications, and policy developments continue to emerge, meaning that some findings and recommendations may require revision as the technology advances and additional evidence becomes available.

Fourth, the implementation of Generative AI in teacher education varies considerably across countries, institutions, and educational systems. Differences in technological infrastructure, digital literacy, curriculum design, institutional support, and national policies may affect the generalizability of the findings presented in this paper.

Fifth, the reviewed studies employed diverse research designs, methodologies, sample characteristics, and AI tools. Such methodological diversity may influence the consistency and comparability of findings across studies.

Finally, while this paper discusses the educational opportunities and challenges associated with Generative AI, it does not provide a comprehensive evaluation of the technical performance, accuracy, or algorithmic architecture of individual AI systems. Instead, the focus remains on their pedagogical implications for teacher education.

These limitations highlight the need for further empirical, longitudinal, and cross-cultural research to generate stronger evidence on the effective, ethical, and sustainable integration of Generative AI into teacher education programmes.

Future Research Directions

The rapid evolution of Generative Artificial Intelligence (GenAI) presents numerous opportunities for advancing research in teacher education. As AI technologies continue to transform educational practices, future studies should move beyond conceptual discussions and provide robust empirical evidence on their effectiveness and long-term implications.

First, there is a need for large-scale empirical studies involving pre-service teachers, in-service teachers, and teacher educators from diverse educational settings. Such studies can examine how the integration of Generative AI influences teaching competencies, instructional quality, classroom practices, and student learning outcomes.

Second, longitudinal research is essential to understand the long-term impact of Generative AI on teacher professional development, self-efficacy, pedagogical decision-making, and technology adoption.



Tracking teachers over extended periods would provide valuable insights into how AI-related competencies evolve and how sustained AI use shapes professional practice.

Third, comparative studies across countries, educational systems, and institutional contexts are recommended to identify contextual factors that influence the successful implementation of Generative AI. Cross-cultural research can contribute to the development of globally relevant yet locally adaptable AI integration strategies for teacher education.

Fourth, future research should focus on the development and validation of reliable instruments for measuring AI literacy, AI pedagogical competence, ethical AI awareness, and teachers' readiness to integrate Generative AI into classroom instruction. Standardized assessment tools would strengthen the consistency and comparability of research findings.

Fifth, experimental and quasi-experimental studies are needed to evaluate the effectiveness of AI-supported instructional interventions in teacher education programmes. Such studies can compare AI-assisted teaching approaches with conventional instructional methods to determine their impact on teaching performance, critical thinking, creativity, reflective practice, and learner engagement.

Sixth, researchers should investigate the ethical, legal, and social implications of Generative AI in greater depth. Areas such as academic integrity, data privacy, algorithmic bias, transparency, accountability, intellectual property, and responsible AI governance require continued scholarly attention to ensure the ethical use of AI in educational environments.

Seventh, future studies should explore the integration of Generative AI with established pedagogical frameworks such as TPACK, SAMR, Universal Design for Learning (UDL), and competency-based teacher education. Examining these relationships may provide evidence-based guidance for curriculum design and teacher preparation.

Finally, interdisciplinary collaborations among education researchers, computer scientists, psychologists, policymakers, and teacher educators are encouraged to develop comprehensive frameworks for the responsible and sustainable use of Generative AI. Such collaborations can contribute to evidence-informed policies, innovative teacher education programmes, and professional development initiatives that prepare educators to effectively leverage AI while upholding ethical and pedagogical standards.



Collectively, these research directions will strengthen the evidence base for Generative AI in teacher education and support the development of inclusive, ethical, and learner-centred educational practices that meet the demands of rapidly evolving digital learning environments.

Conclusion

Generative Artificial Intelligence (GenAI) has emerged as a transformative force in teacher education, offering innovative opportunities to enhance teaching, learning, assessment, and professional development. AI-powered tools have the potential to support teacher educators and pre-service teachers by facilitating personalized learning, improving instructional planning, generating high-quality educational resources, providing timely feedback, and promoting reflective teaching practices. When integrated thoughtfully, Generative AI can contribute to more engaging, efficient, and learner-centred teacher education programmes.

Despite these promising opportunities, the integration of GenAI also presents significant challenges. Concerns related to academic integrity, data privacy, algorithmic bias, ethical decision-making, overreliance on AI-generated content, and unequal access to digital technologies must be addressed to ensure the responsible use of AI in education. These challenges highlight the importance of equipping future teachers with not only technical competencies but also critical thinking skills, ethical awareness, and AI literacy.

The theoretical perspectives discussed in this paper, including the Technological Pedagogical Content Knowledge (TPACK) framework, Social Cognitive Theory, and the Technology Acceptance Model (TAM), provide valuable insights into understanding teachers' readiness and capacity to integrate Generative AI into educational practice. These frameworks underscore that effective AI integration depends on the interaction of technological competence, pedagogical expertise, positive beliefs about technology, and supportive institutional environments.

Teacher education institutions have a crucial responsibility to prepare future educators for AI-enhanced classrooms. This requires the redesign of teacher education curricula to incorporate AI literacy, digital pedagogy, ethical AI practices, and opportunities for hands-on experience with Generative AI tools. Continuous professional development, institutional support, and evidence-based policies will also be essential for enabling teachers to use AI confidently, responsibly, and effectively.

As Generative AI technologies continue to evolve, ongoing research and collaboration among educators, researchers, technology developers, and policymakers will be critical for ensuring that these innovations are used to strengthen educational quality while safeguarding human values and professional



integrity. Rather than replacing teachers, Generative AI should be viewed as a powerful instructional partner that complements teachers' expertise, creativity, and professional judgment. By embracing a balanced, ethical, and learner-centred approach, teacher education can harness the full potential of Generative AI to prepare competent, reflective, and future-ready educators for the rapidly changing educational landscape.

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