

THE EFFECTIVENESS OF USING AI IN ENHANCING PROSPECTIVE TEACHERS' TEACHING SKILLS: A SYSTEMATIC LITERATURE REVIEW

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Abstract

Background/Purpose: The rapid emergence of Artificial Intelligence (AI) necessitates an investigation into its impact on pre-service teacher (PST) competence. This systematic literature review (SLR) investigates AI's effectiveness in enhancing PSTs' teaching skills and professional competence. **Methodology:** Following PRISMA guidelines, a comprehensive database search yielded 68 initial studies, with 17 selected for synthesis. The analysis focused on AI tools, targeted teaching skills, and competence development, mediating factors like learning motivation (LM) and perceived usefulness (PU). **Findings:** AI interventions significantly enhance various teaching skills. AI-driven simulations and conversational agents improve responsive teaching, instructional dialogue quality, and nonverbal skills. AI-supported learning positively impacts Pedagogical Content Knowledge (PCK), TPACK, and deepens reflective patterns. The benefits are strongly mediated by enhanced LM and PU.

Conclusion: AI implementation is a scalable and ethical mechanism to bridge the theory-practice gap, significantly developing PSTs' teaching expertise. A focused approach integrating TPACK and PCK is crucial to maximize pedagogical benefits.

Keywords: Pre-service teachers; Artificial Intelligence; Teaching skills; Systematic Review; TPACK; Microteaching.

Introduction

Teacher education is a crucial foundation for preparing educators capable of adapting to the challenges of the 21st century. In line with digital acceleration, the integration of Artificial Intelligence (AI) into the education system has become an unavoidable issue, offering transformative potential in improving the quality of teaching and learning. AI, defined as a computational system capable of engaging in human-like processes such as learning and adaptation, is now transforming teacher training models, shifting away from traditional methods that are often passive and rigid.

Identification of Problems and Research Gaps

Although AI technologies, such as machine learning and generative AI (GenAI), have proven to support teachers' decision-making and provide personalized learning, traditional teacher training programs face significant challenges, namely:

1. **Limitations of Authentic Teaching Practice:** A lack of adequate and authentic teaching practice opportunities for pre-service teachers (PSTs) in a safe environment, which could bridge the gap between theory and practice.
2. **Feedback and Scalability:** The difficulty of providing timely, personalized, and detailed feedback on complex teaching aspects such as nonverbal teaching skills or reflection patterns, a process that is highly resource-intensive for teacher educators.
3. **Complex Knowledge Framework:** Challenges in comprehensively developing TEs' competencies within the context of Technology Pedagogical Content Knowledge (TPACK) and Pedagogical Content Knowledge (PCK) related to AI convergence.

A previous systematic review indicated that research remains focused on teachers' behaviors, perceptions, and digital competencies related to AI; however, there is a clear gap in understanding the mechanisms through which AI—particularly via generative conversational agents and virtual reality simulations—systematically influences the enhancement of core teaching skills and specific pedagogical knowledge frameworks, such as PCK and TPACK. AI interventions are often not yet tested within the context of structured pedagogical frameworks to measure significant impacts on complex teaching skills, such as responsive teaching skills and the quality of instructional dialogue.

Research Urgency

This research is of high urgency given the rapid acceleration of Generative AI (GenAI), which demands a redefinition of the educator's role. The use of AI, particularly in virtual classroom simulations, provides an ethical and measurable solution to address the limitations of real-world classroom practices. Furthermore, findings from preliminary studies indicate that learning motivation and perceived usefulness of CG are key mediating variables for the successful implementation of AI. Therefore, a comprehensive synthesis is needed to guide curriculum designers in integrating AI not merely as a tool, but as an effective pedagogical facilitator.

Novelty, Objectives, and Contributions

The novelty of this research lies in providing an in-depth qualitative synthesis of the effectiveness of AI interventions most of which are recent studies (2024–2025)—and linking them to a complex pedagogical framework.

The objectives of this study are to:

1. Identify the effectiveness of AI implementation in enhancing core instructional skills, including dialogue quality, responsive teaching skills, and nonverbal skills, among pre-service teachers.
2. Analyze the role of AI in facilitating the development of professional knowledge frameworks, particularly PCK and TPACK, among pre-service teachers
3. Identifying the driving mechanisms (such as motivation and perceived usefulness) that mediate the relationship between AI use and improvements in teaching skills.

The contribution of this research is to provide evidence based on a Systematic Literature Review (SLR) to curriculum developers and teacher educators regarding the most effective AI modalities (e.g., VR simulations, conversational agents) to be incorporated into training programs to bridge the theory-practice gap in a measurable and ethical manner.

Research Methodology

The research method employed is a Systematic Literature Review (SLR). The SLR was applied to comprehensively identify, assess, and synthesize all relevant empirical evidence from primary

studies regarding the effectiveness of Artificial Intelligence (AI) implementation in enhancing the teaching skills of pre-service teachers (PSTs). This process adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and reliability.

Search Strategy and Inclusion Criteria

The literature search was conducted using the Publish or Perish software, targeting international academic databases such as Scopus, for the publication period from 2021 to 2025, with a focus on data recency.

Keywords (Search String): Keywords were combined using Boolean operators (AND/OR) to maximize coverage and relevance: (“Artificial Intelligence” OR “Machine learning” OR “Deep learning”) AND (“Pre-service teachers” OR “Student teachers” OR “Trainee teachers”) AND (‘Microteaching’ OR “Teaching Skills” OR “Teaching Practice” OR “Instructional skills” OR “Pedagogical skills”)

Selection Criteria: Included studies must be primary, empirical research that: (1) Focuses on interventions or the use of AI/GenAI/Machine Learning/Deep Learning; (2) Involve prospective teachers (PT) or novice teachers as research subjects; and (3) Aim to improve or measure Teaching Skills, Professional Competencies, or Pedagogical Knowledge Frameworks (such as PCK or TPACK).

Study Selection Process (PRISMA)

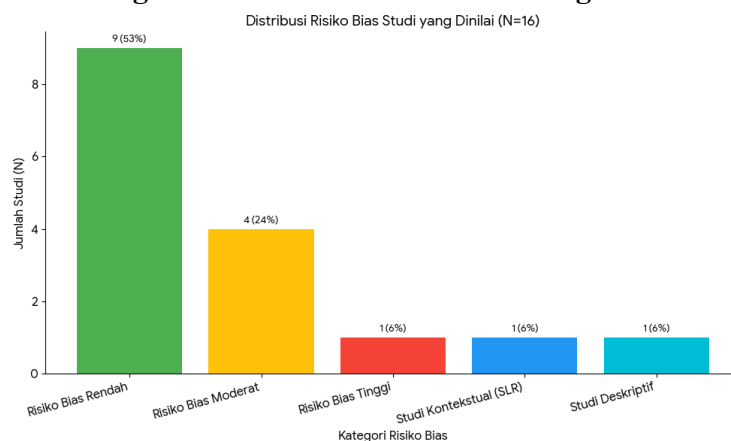
The study selection process was managed using Covidence software to facilitate the removal of duplicates and a systematic screening process.

1. Identification: The initial search yielded 68 studies for screening.
2. Screening: After removing duplicates and screening titles/abstracts, 32 full-text studies were assessed for eligibility.

Figure 1. Process for Research Selection (PRISMA) Flowchart Methodological quality assessment of 17 studies using the MMAT instrument (2018)

This figure indicates that the majority of studies had a low risk of bias (53%), supported by rigorous methodology in the AI interventions, which strengthens the reliability of this synthesis of findings. Studies with moderate or high risk of bias (such as Elgohary, 2022) were carefully considered in the discussion to avoid overly generalized conclusions. The distribution of bias risk categories is presented in Figure 2. Details of the bias risk assessment per study are further detailed in Appendix A.

Figure 2. Bias risk distribution diagram



Findings from the 17 analyzed studies are summarized in the following Table 1, grouped by type of AI intervention and the specific teaching skills enhanced in pre-service teachers.

Table 1. Study Synthesis Matrix (N=17)

Author (Year)	Types of AI Interventions	Skills/Constructs Measured	Key Findings (Improving Teaching Skills)
C. P. Dai et al. (2024)	VR Simulation with AI-CA	Pedagogical Reasoning; Dialogic teacher talk; Emotion	AI-CA was assessed as authentic, promoting pedagogical reasoning, and orchestrating classroom discourse.
C.-P. Dai et al. (n.d.)	VR Simulation with Virtual Students	Teacher Emotions; Dialogic Speech Patterns	Cultivating positive emotions and supporting ambitious teaching practices.
Li et al. (2025)	ChatGPT-4o for Student Simulation	Instructional Dialogue Quality; Self-Efficacy	Significantly improves the quality of instructional dialogue, approaching the proficiency of experienced teachers.
Konakbayeva et al. (2025)	Lesson Study Microteaching with Chatbot GenAI	Lesson Plan Quality; Teaching Competence	Chatbots support significant improvements in the domain of instruction and the quality of lesson plans.
Li et al. (2025)	Hybrid Collaboration (GenAI-CG and Guru-CG)	STEM Teaching Knowledge; STEM Teaching Ability; Cognitive Load	GenAI Collaboration excels in teaching STEM knowledge and reducing cognitive load.
Mu et al. (2025)	Automated Feedback (AI) in Microteaching	Nonverbal Teaching Skills	AI-based feedback is a viable complement to human feedback in training nonverbal skills.
Meng (2025)	GenAI-Powered Teacher Feedback	Reflective Behavior Patterns (Bread and Depth)	GenAI optimizes reflective patterns, forming more logical and in-depth problem chains.
Lee (2025)	Responsive AI-Chatbot as a Virtual Student	Responsive Teaching Skills (Noting and Questioning)	Interaction with responsive virtual students promises to enhance CG's questioning and noticing practices.
He et al. (2025)	Mentoring AI Learners	Knowledge Acquisition; Mentoring Skills	AI mentoring practices significantly improve CG knowledge acquisition, especially procedural mentoring.
Blonder et al. (2025)	GenAI (ChatGPT) to Uncover PCK	PCK (Pedagogical Content Knowledge)	GenAI Dialogue can be used as a diagnostic tool to assess PCK and facilitate the application of theoretical knowledge.
Sahin (2025)	GenAI (ChatGPT, Diffit) for Historical Planning	Lesson Planning; Differentiated Assessment	GenAI enhances practice through lesson planning, differentiated assessment, and interactive simulations.
Al-Nofaie & Alwerthan (2024)	Various AI Tools (Chatbot, Quizizz)	Perception; Reflective Practice; Professional Development	AI is considered positive for personalized teaching and improving teaching initiatives.
Kim (2024)	AI Convergence TPACK Education Program	AI Convergence Teaching Competencies (PCK and TPACK)	The TPACK AI program significantly improved PCK and TPACK CG.

Shao et al. (2025)	AI Driving Mechanism Model	Perceived Usefulness (PU); Learning Motivation (LM); Teaching Skills Improvement (TSE)	Frequent use of AI improves PU and LM, which then has a positive impact on TSE.
O'Neill (2024)	AI for Science Lesson Plan Development	Effective Lesson Planning; Standards-aligned	AI helps new teachers create comprehensive, standards-aligned lesson plans.
Elgohary (2022)	AI-Based Educational Environment (Virtual Classrooms)	Training Development; Virtual Classrooms	AI-based educational environments have proven effective in training development.
Salas-Pilco et al. (2022)	SLR AI & Learning Analytics	(Background Study - SLR)	Identifying AI trends and challenges in teacher education (Used as context).

Discussion

The discussion of the synthesis results focuses on interpreting the key findings from Table 1, relating them to the theoretical framework, and comparing them with the existing literature, particularly studies from the past five years. The discussion is organized according to the three research objectives.

Effectiveness of AI in Improving Core Instructional Skills

Research findings consistently indicate that AI, particularly through simulation technology and conversational agents, is highly effective in training skills oriented toward classroom interaction.

Responsive Skills and Instructional Dialogue: Findings from Li (2025), Dai et al. (2024), and Lee (2025) indicate that interactions with virtual students and conversational agents (AI-CA) significantly improve the quality of instructional dialogue and CG's questioning practices. AI-CA-supported simulations are rated as authentic, promote pedagogical reasoning, and allow CG to practice responsive teaching (C. P. Dai et al., 2024; Lee, 2025). The quality of CG dialog in AI simulation conditions can even approach the proficiency of experienced teachers (Li, 2025). This aligns with the theory that deliberate practice in high-fidelity environments is crucial for mastering ambitious teaching practices (Windschitl, Thompson, & Braaten, 2018). The quality of real-time feedback provided by AI helps address the limitations of traditional microteaching models, which are often constrained by time and mentor availability.

Nonverbal Skills and Lesson Planning: AI also offers measurable solutions for training skills that are difficult to observe. Mu et al. (2025) found that AI-generated feedback during microteaching is an effective complement to human feedback, particularly in monitoring and refining nonverbal teaching skills. Meanwhile, GenAI tools such as ChatGPT and Diffit have proven superior in facilitating the preparation phase, including comprehensive, standards-aligned lesson planning and support for differentiated assessment (O'Neill, 2024; Şahin, 2025). GenAI facilitates generative tasks, allowing teachers to allocate their cognitive load to more important tasks—namely, designing effective pedagogy, not just content.

The Role of AI in Developing Professional Knowledge Frameworks (PCK and TPACK)

AI innovations have proven to make substantial contributions to the development of complex pedagogical knowledge frameworks, such as PCK (Pedagogical Content Knowledge) and TPACK. **Structured Enhancement of PCK and TPACK:** Kim's (2024) study provides strong evidence that educational programs explicitly integrating the TPACK framework with AI convergence education significantly enhance teachers' instructional competencies, with the most notable improvements observed in the PCK and TPACK dimensions. These findings underscore

the importance of pedagogically informed AI integration, rather than merely the use of technology. This aligns with Shulman’s (1986) concept, which states that PCK is the core of effective teaching. An understanding of TPACK (as illustrated in Figure 3) is fundamental because it integrates three forms of knowledge: content, pedagogy, and technology. AI-based programs ensure that CG not only possesses Technological Knowledge (TK), but also understands how that technology can transform teaching practices for specific content (TPACK).

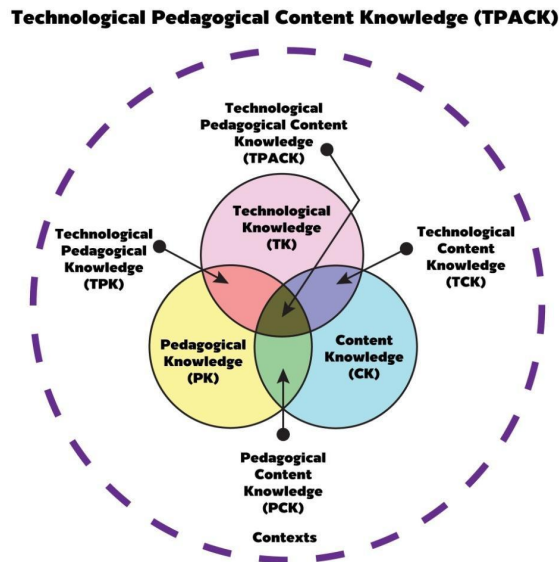


Figure 3. TPACK Diagram

AI as a Diagnostic Tool and for Deep Reflection: Blonder (2025) hypothesizes that interactive dialogue with GenAI can be used as a diagnostic tool to uncover and assess CG PCK. By analyzing prompts and interactions, educators can personalize training based on the identified level of PCK. Additionally, Meng et al. (2025) found that GenAI-supported teacher feedback during microteaching significantly optimized teachers’ reflective patterns. Reflection patterns became deeper, more logical, and encompassed complex chains of issues (e.g., content □ process □ classroom atmosphere), shifting from superficial reflection to diagnostic and transformative reflection.

Driving Mechanisms and Inclusive Collaboration Issues

The success of AI implementation depends not only on the tools but also on the psychological and social factors of teachers. Mediating Factors (Motivation and Perceived Usefulness): Findings from Shao et al. (2025) confirm the AI driving mechanism model: the frequency of AI use positively influences Perceived Usefulness (PU) and Learning Motivation (LM), which in turn enhance Teaching Skill Enhancement (TSE). The mediating role of LM is the strongest, indicating that AI must be designed to enhance teachers’ autonomy and sense of competence to be effective. This is consistent with Self-Determination Theory (SDT), where support for basic psychological needs (autonomy and competence) triggers intrinsic motivation (Li, 2025).

Inclusive Collaboration and Cognitive Load Reduction: In the STEM context, Li’s (2025) study shows that AI-based collaboration (CSPL and iHMCL) outperforms traditional collaboration (TSPL) in enhancing STEM teaching knowledge and, crucially, reducing teachers’ cognitive load. This supports the perspective of the updated Cognitive Load Theory, where AI can manage extraneous cognitive load (e.g., searching for curriculum resources or organizing foundational materials), allowing prospective teachers to focus on germane cognitive load—

namely, the process of assimilating and constructing complex pedagogical schemas (Ouweland et al., 2025).

Overall, these findings validate the hypothesis that AI is not merely an add-on but a transformative pedagogical tool capable of providing authentic practice, measurable personalized feedback, and facilitating the development of prospective teachers' professional knowledge frameworks in the digital age.

Conclusions and Recommendations

This Systematic Literature Review concludes that the implementation of Artificial Intelligence (AI), particularly through Virtual Reality simulations and generative conversational agents, has proven to be highly effective and plays a transformative role in bridging the theory-practice gap in pre-service teacher (PG) training. This success is clearly evident through significant improvements in core instructional skills, including dialogue quality, responsive questioning practices, and nonverbal abilities, facilitated by measurable and personalized feedback. Furthermore, AI serves as a catalyst for the development of pre-service teachers' professional knowledge frameworks, specifically strengthening Pedagogical Content Knowledge (PCK) and TPACK, while simultaneously fostering a transition from descriptive reflection to deep, logical, and structured diagnostic analysis. This effectiveness is also strongly mediated by psychological factors, where AI supported by Learning Motivation and Perceived Usefulness (PU) among teachers results in optimal improvements in Teaching Self-Efficacy (TSE). Therefore, it is recommended that teacher education institutions adopt the integration of AI strategically and ethically, by designing a curriculum focused on TPACK to maximize pedagogical benefits, as well as ensuring that the use of AI is directed toward enhancing teacher autonomy, reducing unnecessary cognitive load, and fostering inclusive collaboration.

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