




Examining the use of artificial intelligence in pre-service teacher education

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ABSTRACT

This systematic review investigates the current state of artificial intelligence (AI) integration in pre-service teacher (PST) education, with an emphasis on PSTs' perspectives, attitudes, knowledge levels, and AI-related educational experiences. The review intends to uncover the characteristics that influence PSTs' intents to employ AI technology, as well as the success of AI training programs. A thorough search of academic databases turned up 33 research published between 2021 and 2024, which were examined using a theme framework. The findings show that PSTs have both positive and negative attitudes about AI integration, with initial AI knowledge and skills being restricted but improving with targeted training and hands-on experiences. Perceived utility, ease of use, social impact, and self-efficacy have all been proven to influence PSTs' propensity to employ AI. The review also emphasizes PSTs' favorable experiences using AI-based instruction, such as lesson planning, collaborative learning, and feedback/evaluation. However, issues and ethical concerns regarding data privacy, academic honesty, fairness, and the possible harmful impact on student learning were highlighted. The review recommends that teacher education institutes prioritize AI literacy development, address PSTs' concerns, and incorporate ethical considerations into AI courses. The findings add to the expanding body of literature on AI integration in education, providing useful insights for defining teacher education practice and policy in the AI era.

Keywords: artificial intelligence, pre-service teachers, AI literacy, perceptions, attitudes

INTRODUCTION

Artificial intelligence (AI) is transforming several industries, including education. Rapid advances in AI technology could change teaching and learning by enabling individualized learning, automated assessment, and data-driven decision-making (Hamal et al., 2022; Shoaib et al., 2024). As AI continues to affect education, it's important to assess how teacher education programs prepare future instructors to use AI.

Educational scholars and instructors are increasingly interested in AI integration. Research suggests that AI can alter educational administration, enhance student comprehension and competence, and improve school management (Srinivasan & Murthy, 2021; Xing, 2023; Yang & Xu, 2024). AI technologies have improved academic performance and learning outcomes (Chichekian & Benteux, 2022), language learning conversational practice (Zou et al., 2023), and educational assessment and student performance evaluation.

Teachers must be knowledgeable, skilled, and confident in employing AI technology to successfully integrate AI into education. Pre-service teacher (PST) education helps future teachers negotiate AI-enhanced education. To effectively incorporate AI into their education, educators must improve their AI literacy (Boscardin et al., 2024; Dai et al., 2023). PSTs must also understand the ethical implications of AI technology and critically analyze AI systems to ensure ethical application in education (Biagini, 2024; Grassini, 2023).

The application of AI in the training and development of PSTs is the subject of this systematic review, which gives a thorough overview. The study looks at how PSTs view, know, and have experienced AI in the classroom. The aims of PSTs to apply AI are investigated in this paper, together with the effectiveness of AI training courses. The intention is to give legislators and teacher training institutes insightful information to improve the future teachers' readiness for the incorporation of AI into the classroom.

The growing need for AI literacy as a skill for teachers emphasizes the need to closely examining the integration of AI in PSTs education (Rütti-Joy et al., 2023; Shen & Cui, 2024). AI education is part of teacher education initiatives to educate PSTs with the tools to properly employ AI technologies in their classrooms (Ayanwale et al., 2024b; Pu et al., 2021). PSTs have to critically evaluating AI systems and have a thorough awareness of the ethical consequences of AI technology to ensure their fair and responsible deployment in the field of education.

To augment the increasing corpus of knowledge, this systematic review synthesizes PSTs' education research on AI integration in education. Examining PSTs' viewpoints, attitudes, knowledge levels, and experiences helps this review highlight the factors influencing AI incorporation in teacher education initiatives. By evaluating AI training programs and the complexity and ethics of AI integration, this review proposes strategies for teacher education institutions and legislators to better equip future instructors for AI-enhanced classrooms.

This systematic review has major consequences for teacher education policy and practice. Teacher education schools can better serve PSTs' AI needs by understanding their viewpoints and experiences. Identifying PSTs' intention to utilize AI technology helps teacher education programs establish supportive environments that promote AI uptake and effectiveness in teaching. This review can also shape educational strategies that emphasize AI literacy among PSTs and provide teacher education institutions with the tools and support they need to integrate AI education into their curricula.

The main conclusions on PSTs' perspectives, attitudes, knowledge levels, and experiences with AI will be synthesized, together with their ramifications for teacher education practice and policy, in this systematic review underlining how it found and chose relevant studies. The review will also go over research constraints and make recommendations for next studies in this fast-growing field.

LITERATURE REVIEW

AI is increasingly being integrated into several aspect of education, offering a wide range of applications and benefits (Alier et al., 2024; Chen et al., 2020). Xing (2023) highlights the potential of AI to bring about a significant transformation in the field of educational administration. Further research has been conducted to improve students' comprehension and expertise in AI (Srinivasan & Murthy, 2021; Yang & Xu, 2024), address moral quandaries in primary and secondary school environments (Akgun & Greenhow, 2022), and enhance

the efficiency of educational management in schools (Çayir, 2023). Research has been studying the use of AI in education for more than three decades (Hamal et al., 2022). The research has mostly focused on personalized learning, automated assessment, and facial recognition systems (Hamal et al., 2022; Shoaib et al., 2024). These technologies are being developed to enhance academic performance and learning outcomes (Chichekian & Benteux, 2022), facilitate conversational practice in language learning (Zou et al., 2023), and transform educational assessment and student performance evaluation (Betaubun et al., 2023).

AI is transforming language education by integrating chatbots and natural language processing, leading to modifications in teaching methods and enhanced learner involvement (Gutiérrez, 2023). A recent bibliometric analysis of 3,623 publications revealed that following ChatGPT's launch in 2022, research output in this area increased dramatically, with annual growth rates reaching 41.38% in Scopus, signaling a paradigmatic shift in how researchers approach AI in education (Kuzu, 2025). Scientists are presently exploring the potential applications of AI in the realm of higher education. Their objective is to acquire novel perspectives on the potential applications of AI in academic settings and provide advice to institutions aiming to integrate AI technology (Ocaña-Fernández et al., 2019; Wang et al., 2023). The project is currently examining the use of AI in recognizing learning styles and facilitating customized learning experiences in online elementary education (Pardamean et al., 2022).

Incorporating AI into higher education in a responsible manner necessitates the examination of ethical concerns and the formulation of policies to effectively manage the complexities and advantages associated with AI technology (Qadhi et al., 2024). With the continuous advancement of AI, it is imperative for educational institutions to build ethical frameworks that will provide guidance for the use of AI and ensure that it has positive societal and economic effects (Eden et al., 2024; Kuleto et al., 2021). The latest trends and advancements in AI for higher education demonstrate a notable transition towards intelligent and informative learning environments, tailored learning experiences, and improved administrative procedures. The integration of AI technology in education is expected to have a lasting impact on the future of higher education, providing significant prospects for innovation and entrepreneurship education (Tan, 2020). This transition also extends to assessment practices, where AI-driven systems have been shown to streamline grading, reduce turnaround times, and provide timely personalized feedback, although concerns about algorithmic bias and the validity of automated evaluation in subjective domains remain (Mpolomoka, 2025).

AI literacy is becoming essential in education, necessitating educators to enhance their understanding of AI to effectively integrate it into their teaching approaches. To effectively negotiate the complexities of AI technology and ensure ethical and responsible use in educational settings, educators must develop a strong understanding of AI literacy (Boscardin et al., 2024). This involves the development of social responsibility and ethical awareness surrounding AI (Boscardin et al., 2024; Dai et al., 2023), as well as the promotion of inclusive and thoughtful engagement with AI technology (Almufareh et al., 2024; Biagini, 2024).

There is an increasing demand in K-12 education to provide AI learning experiences that include fundamental skills in AI literacy. This is done to assist educators in locating appropriate materials for their classes (Yim & Su, 2024). Furthermore, AI literacy encompasses not only computer science students but also primary and secondary school students, regardless of their proficiency in AI, machine learning, and programming (Voulgari et al., 2021).

In addition, the swift progress of AI necessitates the cultivation of AI literacy among teaching personnel in teacher education institutions. This will empower them to employ and instruct in AI in an ethical and responsible manner (Rützi-Joy et al., 2023). It is recommended that educators offer customized assistance in AI education, while institutions should provide specific courses to improve AI literacy (Shen & Cui, 2024). The evolving nature of AI literacy is also reflected in the theoretical frameworks guiding research in this domain. Kuzu (2025) notes that the field has witnessed a significant rethinking of the technological, pedagogical, and content knowledge (TPACK) model, with the emergence of AI-TPACK as a framework that extends beyond traditional technology integration to encompass AI's unique characteristics, including autonomous decision-making, learning capacity, and ethical considerations. This theoretical evolution underscores the need for teacher education programs to move beyond generic technology training toward AI-specific pedagogical preparation. To improve teachers' understanding and knowledge of AI, it is important to utilize a variety of training techniques and resources. By incorporating AI literacy into their continuous professional

development, individuals can guarantee its significance as a vital component (Nazaretsky et al., 2022). It is worth noting, however, that the relationship between AI literacy and actual classroom implementation is not straightforward. Yehya et al. (2025) found that even teachers who expressed positive attitudes toward AI frequently confused traditional information communication and technology (ICT) tools with advanced AI capabilities, suggesting that surface-level familiarity with technology does not equate to meaningful AI competence. This distinction carries important implications for how AI literacy is conceptualized and measured in teacher education research. Furthermore, educators must give utmost importance to the advancement of AI digital capabilities to learn the indispensable skills required for the post-pandemic environment (Ng et al., 2023).

AI integration into literacy instruction, advancement of students' technical literacy, and preparing of students for a future driven by technology are among the important obligations instructors play in the increase of student's AI literacy (Ciampa et al., 2023). Kitcharoen et al. (2024) argues that teachers will be able to enhance their teaching strategies and increase the academic achievement of their pupils if they can properly regulate problems and optimize AI. PSTs absolutely must have a strong awareness of AI and be competent in it. If PSTs have a thorough awareness of AI, they can incorporate AI technologies into their future classroom environments. Sanusi et al. (2024) and Zhang et al. (2023) show that giving PSTs AI literacy training courses greatly raises their professionalism in the area of AI education. Furthermore, it is quite crucial to make sure that PSTs have the required skills to effectively negotiate the always changing landscape of educational technology (Kitcharoen et al., 2024).

Furthermore, a thorough awareness of AI transcends simple technical expertise. It also entails having good socio-emotional abilities, knowing ethical issues, and being able to think critically (Biagini, 2024). PSTs should be deeply aware of the ethical ramifications of AI technology. It is crucial for them to be able to critically evaluate AI systems to ensure responsible and ethical use in educational settings (Grassini, 2023).

Having a strong understanding of AI and being competent in its use is crucial for PSTs (Söğüt, 2024; Xia & Zheng, 2020). This helps them to meet the demands of an educational environment concentrated on technology by means of their capacity to remain current with the most recent technical breakthroughs, guarantee ethical practices in AI, and enhance their teaching methods (AlKanaan, 2022; Çayir, 2023; Mohamed, 2023; Tomar & Verma, 2021). Providing future teachers with the tools required to become experts in AI would help educational institutions guarantee their complete readiness to use AI to enhance student involvement and learning (Ayanwale et al., 2024b).

Since they will define the direction of instructional methods, PSTs' opinions and attitudes about AI are important. Kaplan-Rakowski et al. (2023), Nyaaba et al. (2024), and Lee et al. (2024c) have explored this field, pointing up various facets of PSTs' opinions on AI integration. Emphasizing their readiness to adopt new instructional approaches and preparedness to include AI tools into their teaching practices. Zakaria and Hashim (2024) underlines the need for knowing PSTs' attitudes about AI integration. Gatlin (2023) reveals three main areas of interest: PSTs' knowledge and self-efficacy in using AI, their opinions on AI in future classrooms, and their perspectives on the need for AI in teacher preparation programs. These studies help to clarify the several aspects of PSTs' opinions about AI.

Furthermore, Pokrivcakova (2023) notes as major determinants of PSTs' propensity to employ AI technology perceived utility and simplicity of usage. Given that AI is a necessary ability for upcoming teachers, Kim (2024) and Pu et al. (2021) underline the need for creating thorough educational programs and activities that successfully combine AI. AlKanaan (2022) and Hastomo et al. (2024), respectively highlight pre-service science and Indonesian teachers, respectively, so stressing the awareness and empowerment acquired by using AI-powered technologies in education.

PSTs' experiences and interactions with AI tools shape their points of view and attitudes towards AI. Lee and Yeo (2022) have shown that by using chatbots driven by AI meant to replicate the real classroom environment, aspirant teachers can develop useful teaching abilities including the capacity to pose challenging questions. This helps them then to properly clear student misunderstandings and support good learning results (Lee & Yeo, 2022). Nonetheless, teachers must be well-prepared and informed about its possible roles and constraints if AI is to be successfully included in K-12 education. This is because any misunderstandings could hinder its efficient application (Antonenko & Abramowitz, 2023). While some

educators focus on ethical concerns and the development of skills, others view AI education to overcome technical obstacles, ignite passion, and encourage intellectual growth (Yau et al., 2023). Although PSTs acknowledge the possible advantages of AI in improving instructional results, their attitudes and preparedness to include AI into their teaching are molded by their knowledge, confidence, and perceived significance of AI in the educational setting.

The ethical considerations surrounding AI in education for PSTs are complex and varied. It necessitates a thorough grasp of diverse principles and guidelines in this context. AI in education presents exciting possibilities for improving learning experiences and outcomes. But there are moral risks involved as well; issues of equity, accountability, openness, prejudice, independence, and involvement call for debate (Holmes et al., 2022). PSTs should understand the need for including humanistic and ethical values into the development and application of AI. This will help to address problems including supporting autonomous learning and safeguarding of personal data (Nguyen et al., 2023). Embracing an all-encompassing approach will help to ensure that AI can be a consistent and responsible colleague in the field of education (Sun & Ye, 2023). Regarding K-12 education, there are various ethical questions worth serious thought. PSTs should give these concepts some thought since they are important given the different needs and phases of development of young students (Adams et al., 2023). AI systems applied in educational settings create ethical conundrums and uncertainty about the possible replacement of human teachers by AI robots. Incorporating AI literacy and ethical values into teacher preparation courses will help to properly solve these issues. PSTs should be sufficiently ready to understand the ethical consequences of AI in the classroom. This is crucial for the responsible and successful inclusion of AI technologies into the classroom (Sanusi et al., 2024). PSTs who understand and apply these ethical issues will be able to properly manage the complexity of AI in the classroom and ensure that the application guarantees equitable and efficient learning environments for every student.

Including AI into PST preparation presents several difficulties that must be resolved if successful application is to be guaranteed. Dealing with AI models can provide major difficulties because of their complex and unknowable nature. The absence of transparency can lead to a decrease in trust and a restricted utilization of AI tools by PSTs (Wang et al., 2024a). Additionally, it is important to note that there is a notable difference in the level of AI-related content knowledge among teachers. This gap is made even more pronounced by the absence of clear rules in policy and curriculum, which makes it difficult for educators to acquire the fundamental components of TPACK in relation to AI (Velandar et al., 2024). Getting students to participate in meaningful interactions is yet another difficulty that AI systems need to find a solution for. It is possible that AI will be able to aid in a variety of educational domains. On the other hand, there have been few attempts made to fully immerse students in authentic and open-ended teaching scenarios, which are necessary for the development of responsive teaching abilities (Lee & Yeo, 2022). In addition, the effective use of ICT, including AI, continues to be a significant hurdle for PSTs, who frequently express a lack of readiness for this requirement (Jenßen et al., 2021). Implementing AI in teacher education poses significant challenges, including the need for better questioning techniques and addressing user perceptions (Zhang & Zhang, 2024). However, the potential benefits of AI in creating inclusive learning environments and improving digital skills cannot be overlooked. Beginning these challenges necessitates a well-rounded strategy, encompassing the creation of transparent AI to foster trust, extensive AI education initiatives to bridge knowledge disparities, and continuous design enhancements to promote meaningful interaction and successful teaching methods.

METHODOLOGY

This study focused on how AI might be used in PST preparation using a systematic review approach. A systematic review is a methodical, open way to combine current research on a certain issue, therefore enabling a thorough awareness of the present situation of knowledge (Liberati et al., 2009). This method was chosen for its ability to combine findings from numerous studies as well as for providing a logical, replicable way for recognizing, selecting, and evaluating relevant research (Moher et al., 2015). Since it allows a thorough investigation of the several ways AI is being included into PST education, the opinions and attitudes of PSTs toward AI, and the factors influencing AI adoption in teacher preparation programs, this study would be especially appropriate for the methodical review approach. By means of a thorough and transparent

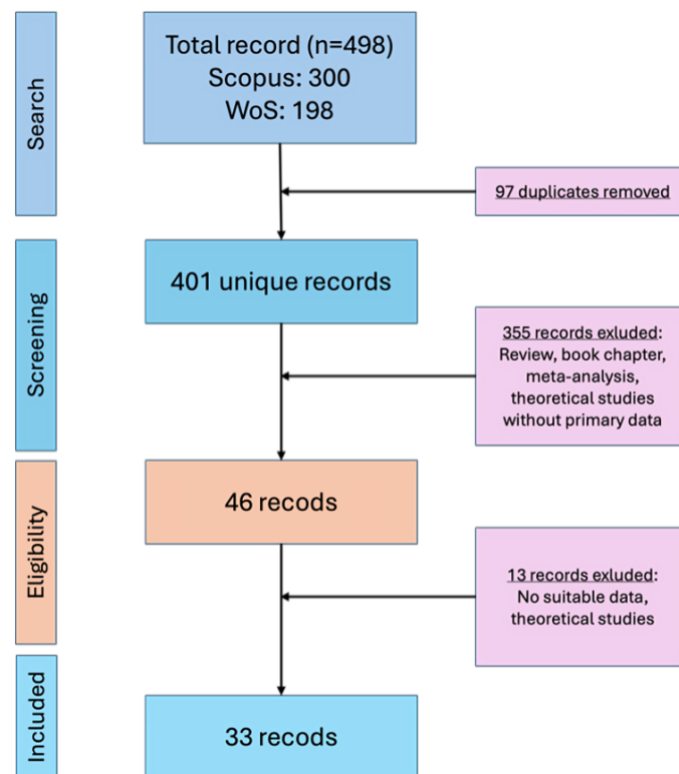


Figure 1. Data collection process (Source: created by the authors)

approach, this evaluation aims to provide a good basis for understanding the present position of AI in PST education and to highlight knowledge gaps that might drive next research and practice. created by the authors

Data Collection Process

The data collection process involved a comprehensive search of two major academic databases: Scopus and Web of Science (WoS). The search was conducted in July 2024, covering articles published up to this date. **Figure 1** shows the data collection process. To ensure a thorough coverage of relevant literature, we developed the following search queries for each database.

Search query for the Scopus databases: TITLE-ABS-KEY (("artificial intelligence" OR "AI") AND ("pre-service teacher*" OR "preservice teacher*" OR "student teacher*" OR "teacher candidate*" OR "teacher education") AND ("education" OR "training" OR "learning" OR "teaching")). Search query for the WoS databases: TS = (("artificial intelligence" OR "AI") AND ("pre-service teacher*" OR "preservice teacher*" OR "student teacher*" OR "teacher candidate*" OR "teacher education") AND ("education" OR "training" OR "learning" OR "teaching")).

The first search turned up 498 papers in all: 198 from WoS and 300 from Scopus. We found and eliminated 97 duplicate entries after aggregating the data from both databases, therefore producing 401 original publications.

The choosing procedure then followed these phases: We looked over the titles and abstracts of every 401 distinct article. This first screening sought research directly pertinent to the application of AI in PST preparation. 46 publications were chosen for additional examination following this level.

Examined closely were the whole texts of the 46 chosen works. We used the following inclusion criteria at this level:

- Studies must center on teacher applicants or PSTs.
- Research has to include using AI in teacher preparation.
- Studies must include the main data.

Exclusion standards included:

- Theoretical investigations devoid of primary data

- Meta-analyses and methodical studies
- Research unrelated to direct use in PSTs education

Following the whole text review and application of inclusion/exclusion criteria, 33 papers in total were chosen for the systematic review. Two independent reviewers evaluated the papers to guarantee dependability and reduce prejudice over the choosing process. Every conflict was settled by consensus and conversation. This thorough selection method guaranteed that the last collection of 33 papers satisfied the quality criteria needed for inclusion in the systematic review and were quite pertinent to our study issue.

Data Analysis

Thirty-three papers that fit the inclusion criteria came out of the methodical review procedure. Using a thematic analysis technique, these papers were examined to find recurrent themes and patterns across the corpus (Braun & Clarke, 2006). The study procedure consisted of many phases (Table 1):

- To fully grasp the material, the researchers carefully read and reread every included study.
- Key ideas and conclusions from every study were first coded using an inductive technique, therefore enabling themes to surface from the data instead of fitting the data into pre-existing categories.

Table 1. Descriptive for selected publications

Authors	Title	Journal	C	D
Adelana et al. (2024)	Exploring pre-service biology teachers' intention to teach genetics using an AI intelligent tutoring-based system	Cogent Education	3	S, W
AlKanaan (2022)	Awareness regarding the implication of artificial intelligence in science education among pre-service science teachers	International Journal of Instruction	16	S, W
Alrishan (2023)	Determinants of intention to use ChatGPT for professional development among Omani EFL pre-service teachers	International Journal of Learning, Teaching and Educational Research	1	S
Ayanwale et al. (2024a)	Examining artificial intelligence literacy among pre-service teachers for future classrooms	Computers and Education Open	3	W
Ayanwale et al. (2024b)	Exploring factors that support pre-service teachers' engagement in learning artificial intelligence	Journal for STEM Education Research	2	S
Zhang et al. (2023)	Acceptance of artificial intelligence among pre-service teachers: A multigroup analysis	International Journal of Educational Technology in Higher Education	45	S, W
Lee and Yeo (2022)	Developing an AI-based chatbot for practicing responsive teaching in mathematics	Computers and Education	72	S, W
Wang et al. (2024a)	Using explainable AI to unravel classroom dialogue analysis: Effects of explanations on teachers' trust, technology acceptance and cognitive load	British Journal of Educational Technology	0	S, W
Dahri et al. (2024)	Extended TAM based acceptance of AI-powered ChatGPT for supporting metacognitive self-regulated learning in education: A mixed-methods study	Heliyon	5	S, W
Lee and Zhai (2024).	Using ChatGPT for science learning: A study on pre-service teachers' lesson planning	IEEE Transactions on Learning Technologies	4	S, W
Lee et al. (2024a)	Collaborative learning with artificial intelligence speakers: Pre-service elementary science teachers' responses to the prototype	Science and Education	2	S
Hur (2025)	Fostering AI literacy: Overcoming concerns and nurturing confidence among preservice teachers	Information and Learning Science	0	S, W
Wang et al. (2024b)	Pre-service teachers' GenAI anxiety, technology self-efficacy, and TPACK: Their structural relations with behavioral intention to design GenAI-assisted teaching	Behavioral Sciences	0	S, W
Karahan (2023)	Using video-elicitation focus group interviews to explore pre-service science teachers' views and reasoning on artificial intelligence	International Journal of Science Education	2	S, W
Kartal (2024)	The influence of ChatGPT on thinking skills and creativity of EFL student teachers: A narrative inquiry	Journal of Education for Teaching	3	S, W
Kim (2024)	Development of a TPACK educational program to enhance pre-service teachers' teaching expertise in artificial intelligence convergence education	International Journal on Advanced Science, Engineering and Information Technology	2	S

Table 1 (Continued).

Authors	Title	Journal	C	D
Lim (2023)	The effects of pre-service early childhood teachers' digital literacy and self-efficacy on their perception of AI education for young children	Education and Information Technologies	11	S, W
Lim (2024)	Metaphor analysis on pre-service early childhood teachers' conception of AI (artificial intelligence) education for young children	Thinking Skills and Creativity	7	S, W
Lozano and Blanco Fontao, (2023)	Is the education system prepared for the irruption of artificial intelligence? A study on the perceptions of students of primary education degree from a dual perspective: Current pupils and future teachers	Education Sciences	24	S, W
Ma and Lei (2024)	The factors influencing teacher education students' willingness to adopt artificial intelligence technology for information-based teaching	Asia Pacific Journal of Education	3	S, W
Markos et al. (2024)	Pre-service teachers' assessment of ChatGPT's utility in higher education: SWOT and content analysis	Electronics	1	S, W
Martono et al. (2023)	Intertextuality in pre-service teachers' argumentative essay in raising AI: Practices and beliefs	Register Journal	1	W
Mnguni (2025)	A qualitative analysis of South African pre-service life sciences teachers' behavioral intentions for integrating AI in teaching	Journal for STEM Education Research	0	S
Okulu and Muslu (2024)	Designing a course for pre-service science teachers using ChatGPT: What ChatGPT brings to the table	Interactive Learning Environments	2	S
Pokrivcakova (2023)	Pre-service teachers' attitudes towards artificial intelligence and its integration into EFL teaching and learning	Journal of Language and Cultural Education	3	W
Pu et al. (2021)	Improvement of pre-service teachers' practical knowledge and motivation about artificial intelligence through a service learning-based module in Guizhou, China: A quasi experimental study	Asian Journal of University Education	13	S
Lee et al. (2024b)	Enhancing pre-service teachers' global Englishes awareness with technology: A focus on AI chatbots in 3D metaverse environments	TESOL Quarterly	1	S, W
Sailer et al. (2023)	Adaptive feedback from artificial neural networks facilitates pre-service teachers' diagnostic reasoning in simulation-based learning	Learning and Instruction	47	S, W
Sămărescu et al. (2024)	Artificial intelligence in education: Next-gen teacher perspectives	Amfiteatru Economic	4	W
Sanusi et al. (2024)	Investigating pre-service teachers' artificial intelligence perception from the perspective of planned behavior theory	Computers and Education: Artificial Intelligence	9	S
Sun et al. (2024)	Pre-service teachers' inclination to integrate AI into STEM education: Analysis of influencing factors	British Journal of Educational Technology	0	S, W
Uzumcu and Acilmis (2024)	Do innovative teachers use AI-powered tools more interactively? A study in the context of diffusion of innovation theory	Technology, Knowledge and Learning	6	S, W
Younis (2024)	Effectiveness of a professional development program based on the instructional design framework for AI literacy in developing AI literacy skills among pre-service teachers	Journal of Digital Learning in Teacher Education	0	S

Note. C: Citations; D: Databases; S: Scopus; & W: WoS

- Codes were categorized into possible themes and sub-themes under continual comparison between the data, codes, and developing themes.
- Reviewing and improving themes helped to guarantee they were unique from one another and fairly reflected the data.
- Every topic has a specific name and meaning meant to represent its core.

There were five main themes found from the study; some topics were further split into categories. Two independent researchers coded a selection of the papers to guarantee the accuracy of the analysis; any differences were examined and settled upon consensus (Miles, 2014). An extensive review of the results was given by synthesizing quantitative data taken from the investigations. For instance, the analysis of publication years revealed that the majority of the studies—22 out of 33—were published in 2024, implying a recent rise in this sector of academic activity. To enable one to perceive the connections between themes and categories, a thematic map was generated. Using this exacting analytical approach, we were able to identify gaps in the literature, synthesize the current state of knowledge on AI in PST education, and derive important conclusions to direct further research and practice in this fast evolving field.

Table 2. Methodology data collection tools, major, and sample size of selected publication

Authors	Method	Data collection tools	Major	Sample
Adelana et al. (2024)	Quantitative	Survey	Biology teachers	90
AlKanaan (2022)	Qualitative	Interview	Science teacher	43
Alrishan (2023)	Quantitative	Questionnaire	English language teaching	280
Ayanwale et al. (2024a)	Qualitative	Scale	Mixed	529
Ayanwale et al. (2024b)	Quantitative	Survey	ICT	35
Zhang et al. (2023)	Quantitative	Questionnaire	Mixed	452
Lee and Yeo (2022)	Qualitative	Questions asked to chatbot, questionnaire	Elementary mathematics	23
Wang et al. (2024a)	Qualitative	Questionnaire	Mixed	59
Dahri et al. (2024)	Mixed	Questionnaire	Mixed	300
Lee and Zhai (2024)	Qualitative	Survey, lesson plan	Elementary teachers	29
Lee et al. (2024a)	Quantitative	Questionnaire	Elementary science teachers	15
Hur (2025)	Quantitative	Survey	Mixed	46
Wang et al. (2024b)	Quantitative	Survey	Mixed	606
Karahan (2023)	Qualitative	Focus group interviews	Science teacher	45
Kartal (2024)	Qualitative	Narrative, interview	English language teaching	12
Kim (2024)	Quantitative	Scale	History, mathematics, informatics	39
Lim (2023)	Quantitative	Test	Early childhood education	212
Lim (2024)	Qualitative	Survey	Early childhood education	137
Lozano and Blanco Fontao, (2023)	Quantitative	Questionnaire	Primary Education	118
Ma and Lei (2024)	Quantitative	Questionnaire	Mixed	359
Markos et al. (2024)	Quantitative	Questionnaire	Department of primary education and education sciences in early childhood	257
Martono et al. (2023)	Qualitative	Essay, interview	English language teaching	16
Mnguni (2025)	Qualitative	Interview	Life sciences teacher	10
Okulu and Muslu (2024)	Qualitative	Course plan	Science teacher	
Pokrivcakova (2023)	Mixed	Questionnaire	English language teaching	137
Pu et al. (2021)	Quantitative	Questionnaire, scale	Primary education	60
Lee et al. (2024b)	Mixed	Questionnaire, focus-group interviews	English language teaching	97
Sailer et al. (2023)	Qualitative	Questionnaire	Primary education	178
Sămărescu et al. (2024)	Quantitative	Questionnaire	Social sciences, psychology	270
Sanusi et al. (2024)	Quantitative	Questionnaire	Mixed	796
Sun et al. (2024)	Quantitative	Survey	STEM teachers	239
Uzumcu and Acilmis (2024)	Qualitative	Scale, lesson plan	Classroom teaching	32
Younis (2024)	Quantitative	Scale	Mixed	37

FINDINGS

A total of 33 publications were selected for review. When the years of the studies are examined, the distribution is as follows: 2024: 22 publications, 2023: 8 publications, 2022: 2 publications, and 2021: 1 publication. In terms of database distribution, there are 9 studies unique to Scopus, 4 unique to WoS, and 20 studies present in both Scopus and WoS. Examining the journals in which the studies were published, there are two publications each in the “Journal for STEM Education Research” and the “British Journal of Educational Technology,” while there is one publication from each of the other journals. When considering the number of citations, there are 7 publications with 10 or more citations. Twenty publications have a citation count between 1 and 10, while 6 publications have not received any citations yet.

Table 2 offers a thorough summary of 33 studies emphasizing the application of AI in PST preparation. Across many educational specializations, this varied collection of studies uses several approaches, data collecting instruments, and sample sizes.

Regarding research techniques, one finds a fair diversity of approaches. Of the 17 investigations, quantitative approaches predominate; 13 papers use qualitative methodologies. The three studies left use mixed methodologies, mixing qualitative and quantitative methods. This distribution points to a thorough investigation of the issue as scholars look at AI in PST preparation via several methodological lenses.

The diverse methodological techniques utilized in these studies are reflected in the several data collecting instruments applied in them. employed in 22 investigations, surveys and questionnaires are the most often

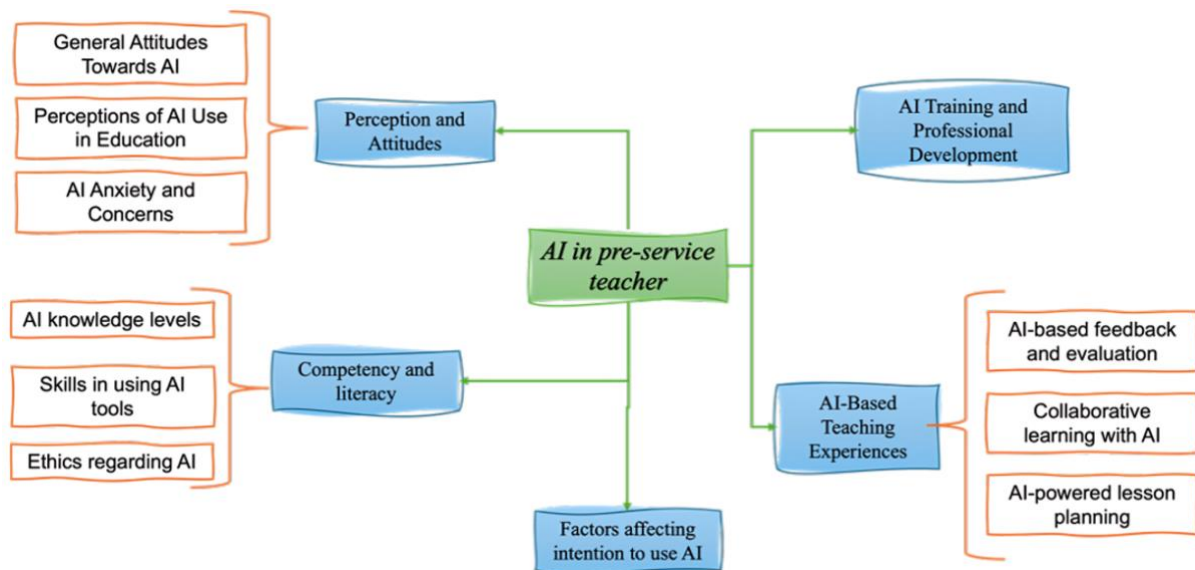


Figure 2. Themes and categories (Source: created by the authors)

employed tools. This inclination for questionnaires shows a concentration on obtaining broad, generally applicable information from bigger samples. Providing both quantitative data and in-depth qualitative insights, other instruments include scales, interviews, focus groups, and study of course or lesson plans.

The studies address a broad spectrum of instructional specialties. The studies involve pre-service instructors from numerous disciplines, while some concentrate on certain topics as English language instruction, science education, or mathematics. This variety in majors enables a thorough knowledge of AI integration in several learning environments.

The studies have quite different sample sizes: from as few as 10 participants (Mnguni, 2025) to as many as 796 (Sanusi et al., 2024). While some large-scale studies reach 500 participants, most studies have sample counts between 30 and 300 people. From in-depth qualitative inquiries to more general quantitative surveys, this range in sample sizes reflects varied study designs and goals. Especially, the research center on several educational levels—early childhood, elementary, and secondary school. This extensive coverage implies that integration of AI in teacher education is under investigation the whole range of K-12 education.

This set of studies offers a wide and varied body of evidence on AI in PST preparation. The diversity in approaches, instruments for gathering data, educational specializations, and sample sizes offers a multifarious perspective of the topic, therefore enabling a thorough knowledge of how AI is being included into teacher preparation programs in many fields and circumstances.

Using AI in PST Education

The integration of AI in education is a topic of growing interest and debate among PSTs. While many see potential benefits, there are also significant concerns about its impact on teaching and learning. The study yielded 5 main themes and 9 categories (Figure 2). Categories were not formed under some themes. Firstly, the data of the studies examining PSTs' general perceptions and attitudes towards AI were analyzed. Then, the findings related to PSTs' AI competency and AI literacy were presented. In the next theme, the findings of the studies examining the factors affecting PSTs' use of AI were synthesized. Then, the findings of studies examining PSTs' experiences of AI-based teaching are presented. In the last theme, studies related to the trainings developed for PSTs' use of AI are presented.

Perception and Attitudes

General attitudes towards AI

13 studies out of 33 had findings in "general attitudes towards AI" category. There are studies with positive attitudes and opinions. PSTs typically hold favorable opinions regarding the utilization of AI in the field of education. Numerous studies have supported this. One study stated that "PEC teachers had positive

perspectives about AI education for young children” (Lim, 2024). Another study reported that “nearly all the mean scores of the structures for the entire sample were higher than the mid-point” (Zhang et al., 2023). A different study observed that teachers’ attitudes improved after training, noting that “PSTs have pleasing attitudes toward the use of AI before participating in the professional development program (PDP), mean = 2.942, which increased to 4.471 after completing the program” (Younis, 2024). PSTs showed “generally favorable perceptions” towards AI tools like ChatGPT (Dahri et al., 2024). PSTs in the treatment group (who received AI explanations) showed significantly higher trust in the AI-powered models compared to the control group (Wang et al., 2024a). Also, many PSTs want to learn more about AI. One study found “high interest among 76% of the respondents in taking further training in the field of AI” (Sămărescu et al., 2024). In addition to this, there are some studies that state that it is at a medium level. For example, Markos et al. (2024) used the statement “the results indicate a moderately positive view of ChatGPT’s benefits, with both strengths and opportunities being recognized.” These findings suggest that PSTs see potential in AI for education and are eager to learn about it.

Perceptions of AI use in education

In 15 studies, findings related to the category “perceptions of AI use in education” were obtained. PSTs see many potential benefits of AI in education. They believe AI can help with various aspects of teaching. Lim (2024) found that AI “has the potential to play an important role in expanding and deepening young children’s play and their educational experiences.” PSTs think AI can help them save time. They say “ChatGPT can help you save time while planning classes because it generates content more quickly and effectively than conventional techniques” (Kartal, 2024). According to a study by Markos et al. (2024), students [PST] see opportunities for ChatGPT in academic research experimentation, improving collaborative projects, and enhancing accessibility to educational resources. Wang et al. (2024a) indicate that [pre-service] teachers reported that the AI explanations contributed to their understanding of talk moves and classroom dialogue analysis. Many teachers see AI as a useful tool, not a replacement. Sămărescu et al. (2024) reported that “the vast majority of the respondents value the use of AI as a teaching tool or virtual teacher assistant to enhance the student learning experience.” PSTs also think AI can make learning more personal. They believe it can offer “individualized learning support for each student, a task that a single teacher cannot fulfill independently” (Lee & Zhai, 2024). Some teachers are excited about using AI to create better lessons. In Dahri et al. (2024), teachers said ChatGPT helped with “improving lesson clarity (96.7%), enhancing content quality (93.3%), and aligning with learning objectives (86.7%).” These findings show that many PSTs see AI as a helpful tool for their future teaching work. Besides, there are also PSTs who are not certain about using AI technologies in their future professions.

AI anxiety and concerns

In 11 studies, findings related to the category of “AI anxiety and concerns” were obtained. PSTs have several concerns about AI in education. They worry about how AI might change teaching and learning. Hur (2025) found that [pre-service] teachers are concerned about “the potential replacement of teachers and the negative impacts of incorporating generative AI on students’ development of critical learning skills.” Some PSTs think AI might make students depend excessively on it too much. For example, in Lee and Zhai (2024), it is stated that “the PSTs were also worried that students might be overly dependent on ChatGPT, given its feasibility and high accessibility.” There are also worries about cheating and plagiarism. Lozano and Blanco Fontao (2023) noted that a major concern was “the greater capacity for plagiarism.” Markos et al. (2024) stated that students worry about the misuse of ChatGPT, including the generation of fake academic content, plagiarism, impact on traditional teaching methods, weakening of critical thinking, and reduction in human interaction.

The quality of AI-generated material concerns teachers as well. They said, “the lack of depth and authenticity in the comments produced by the program” (Kartal, 2024). Furthermore, according to Lee and Zhai (2024) state that “primarily, they were concerned about the precision of ChatGPT’s responses and its dependability.” Some teachers fear that AI might make teaching less personal. Pokrivcakova (2023) found that “42.33% cumulatively feared that AI would make EFL teaching less personal.” Some PSTs were concerned about technical issues and the challenges of implementing AI tools in large classes. For instance, Uzumcu and

Acilmis (2024) state that “big class sizes leading to unindividualized learning and insufficient infrastructure were also among the mentioned disadvantages.” These issues highlight how PSTs have serious reservations regarding the application of AI in the classroom even when they find advantages in it.

Competency and Literacy

AI knowledge levels

In 13 studies, findings related to the category of “AI knowledge levels” were obtained. PSTs generally have limited knowledge about AI, but this can improve with training. Many studies show that teachers start with low AI literacy. Younis (2024) found that “PSTs had low level of AI literacy skills” before training. AlKanaan (2022) noted that “PSTs’ awareness of employing AI in science education is low.” Mnguni (2025) found that “... pre-service life sciences teachers had varied perceptions regarding their perceived behavioral control for integrating AI in teaching.” According to Hur (2025), “the analysis of online discussion also confirmed students’ lack of understanding of AI before AI lessons.” However, training can help. After a program, Younis (2024) saw that “participants had high levels of AI literacy skills.” Some PSTs know more about AI in their specific subjects. For example, “respondents rated their knowledge of AI-based applications for EFL teaching significantly higher” than general AI knowledge (Pokrivcakova, 2023). Many PST would like further knowledge about AI. Pokrivcakova (2023) revealed that “64.24% of respondents agreed that AI training should be included in the university curriculum.” Teachers who understand AI will be more adept in their instruction. Research indicated that “SLBM-TAIS could improve PSTs’ practical knowledge more than the educational practice training module” (Pu et al., 2021). These results reveal that although PSTs frequently have little AI expertise, they are eager to learn, and that training can greatly advance their knowledge and abilities.

Skills in using AI tools

Results on the “skills in using AI tools” category came from eleven studies. While PSTs’ skills with AI technology differ, they typically improve with experience and instruction. Many start with little experience but show development after AI training. Based on Younis (2024) tracking a PDP, teachers attained “high score levels” in employing AI teaching and learning technologies. Results of Hur (2025) show that following the courses, over forty percent of participants said they felt confident in teaching AI. Another study showed that “86.7% of the lesson plans were clear in outlining their objectives, underscoring the effectiveness of ChatGPT in assisting PSTs” (Dahri et al., 2024). Uzumcu and Acilmis (2024) show that preservice teachers can include AI-powered tools in a lesson plan, both in teaching and evaluation. However, teachers often need more support. Some expressed a need for “hands-on workshops and specialized and comprehensive training” (Mnguni, 2025). Experience with AI tools increases confidence. A particular research study indicated that “self-confidence about the ability to use AI... significantly increase the likelihood that a future teacher will use AI in his/her career” (Sămărescu et al., 2024). The use of AI does not necessarily indicate the creation of AI. Ayanwale et al. (2024a) discovered that “UAAI negatively affected ‘creating AI’, emphasizing a potential trade-off between adopting existing AI applications and engaging in the creative process of AI creation.” Even though PSTs are continuing to improve their AI capabilities, there is a definite need for additional training and hands-on experience in order to strengthen their confidence and ability.

Ethics regarding AI

Results on the “ethics regarding AI” category came from five studies. PSTs have many ethical concerns about using AI in education. They worry about student privacy and data security. One study found that students have “ethical concerns about privacy and data security when using ChatGPT in academic settings” (Markos et al., 2024). Academic honesty and cheating raise more questions as well. According to Hur (2025), teachers worried about “the potential for increased student cheating, the accuracy of AI-generated data, and the presence of AI bias.” Fairness and equal access to AI worry some teachers. One teacher said, “there’s the risk of widening the educational gap. Which is not fair. AI won’t be cheap” (Mnguni, 2025). Many PSTs think AI could be dangerous. In one study, “more than half of the students (a total of 71 = 51.82%) agreed with the statement that AI will become a threat to humanity” (Pokrivcakova, 2023). The majority of educators, which accounts for 67.15 percent of the total, are in agreement with the statement that “teachers should be careful when using AI tools in their classrooms” (Pokrivcakova, 2023). The potential risks associated with algorithmic

bias and malicious AI applications demonstrate the necessity of incorporating an ethical dimension into the education of future educators, as stated by Ayanwale et al. (2024a). This is despite the fact that it is essential to have a foundational understanding and competence in some aspects of AI. It is clear from these data that PSTs appreciate the potential benefits of AI, but they also acknowledge the significant ethical concerns that must be addressed.

Factors Affecting Intention to Use AI

The theoretical frameworks used in the studies were examined to determine the influencing factors for teacher candidates' use of AI technologies. These framework or models offer a methodical way to grasp the intricate interactions among the several elements influencing the acceptance of AI in learning environments.

Across the examined studies like Alrishan (2023), Dahri et al. (2024), Ma and Lei (2024), and Zhang et al. (2023), the technology acceptance model (TAM) shows to be the most often used paradigm. TAM suggests that the main factors influencing technology adoption are perceived ease of use and usefulness of the technology. Consistent with TAM's projections, several studies show that these two elements strongly influence behavioral intention to embrace AI in teaching practices (Alrishan, 2023; Ma & Lei, 2024; Sun et al., 2024; Zhang et al., 2023). The broad use and consistent results of TAM-based studies highlight the strong ability of the model to describe aspirations for AI deployment in education. An extended TAM adds personal competency, perceived AI, and social effect among other aspects. This expansion offers a more complete knowledge of adoption intentions by reflecting the special qualities of AI technology and the educational background. In this discipline, another theoretical framework applied is the unified yheory of acceptance and use of technology (UTAUT) (Wang et al., 2024b). UTAUT integrates features from many TAMs—performance expectation, effort expectation, social impact, and facilitating factors.

Furthermore, investigated are AI adoption intentions (Adelana et al., 2024; Mnguni, 2025) applying the theory of planned behavior (TPB). TPB suggests that attitudes, subjective standards, and perceived behavioral control all help to predict behavioral intentions. Research employing TPB found that attitudes and subjective standards significantly affect the desire of using AI-based technology in education. Although the purpose of perceived behavioral control displayed various fluctuations depending on the research, this implies that the unique features of AI technologies could influence the relevance of this construct in the classroom.

Several research used modified or hybrid theoretical models. Sanusi et al. (2024) for example incorporated components of planned behavior theory with other constructions particular to AI, such AI anxiety and basic understanding of AI. This method enables a more customized study of elements particular to the acceptance of AI in education. Ayanwale et al. (2024b) and Sun et al. (2024) chose to focus on a range of elements taken from many frameworks and literature rather than any one theoretical model. This method lets one be flexible in investigating several factors influencing AI adoption aspirations, hence maybe capturing elements that might be missed in more ordered theoretical models.

The influencing factor in the studies varies depending on the theoretical framework chosen. Even if the same theoretical framework is used in studies, the models and results created may differ. Several studies looking at teachers' and PSTs' intentions to use AI technology have shown that a complex interplay of factors influences the adoption of AI in education. Key concepts from TAM such as perceived usefulness and perceived ease of use lead front stage in these aspects. Alrishan (2023), Ma and Lei (2024), Sun et al. (2024), and Zhang et al. (2023) repeatedly show that these impressions directly affect behavioral intention to use AI in educational settings. Teachers are more likely to indicate plans to include AI into their instruction when they see it as advantageous for their profession and simple to apply tool.

Adoption of AI also depends much on the social setting. Adoption intentions are much influenced by subjective norms and social influence, which reflect the supposed expectations and practices of institutional surroundings and coworkers. This implies that a person's choice to adopt AI technology in education can be influenced by the attitudes and behavior of colleagues and managers. Important elements turn out to be educators' self-efficacy and perceived behavioral control of AI use. Although AI self-efficacy indirectly affects behavioral intention (Zhang et al., 2023), the effect of perceived behavioral control varies somewhat depending on Adelana et al. (2024) and Mnguni (2025). This emphasizes the need for helping educators to have faith in their capacity to apply AI technologies with effectiveness.

Fascinatingly, plans for adoption for AI also involve cognitive and emotional elements. AI anxiety has been demonstrated to negatively affect engagement with AI programs (Ayanwale et al., 2024b) as well as behavioral intention to utilize AI (Wang et al., 2024b). On the other hand, better intention to use and interact with the technology (Adelana et al., 2024; Ayanwale et al., 2024b) corresponds with positive sentiments about AI. These results highlight the need for addressing teachers' issues and supporting good opinions about AI in the field of education.

Still another crucial factor is the relevance AI seems to have for different teaching strategies. Job relevance (Zhang et al., 2023) and personal relevance (Sanusi et al., 2024) affect intention to accept AI; so, instructors are more likely to embrace AI if they see it directly applicable to their area of work. AI literacy and knowledge on adoption intents (Ma & Lei, 2024; Sanusi et al., 2024) help to further this even more since more will to utilize the technology results from more awareness of AI principles and applications.

AI adoption goals also mirror organizational and environmental factors. Instructor assistance (Alrishan, 2023) and facilitating environments (Wang et al., 2024b) help to define teacher preparedness to apply AI. This highlights the importance of institutional support and infrastructure for the acceptability of AI in educational settings. Personal qualities of teachers, including innovativeness (Alrishan, 2023) and self-transcendent aspirations (Ayanwale et al., 2024b) have been found to affect adoption intentions for AI. This suggests that based on their own tastes and goals, some professors might be more open to integrating AI into their courses.

Finally, attitudes on AI itself—including its perceived intelligence and dependability—have bearing on planned application (Dahri et al., 2024). This implies that when AI technologies keep expanding and proving their worth in educational settings, teachers could start to welcome them. The aim to employ AI in education is ultimately shaped by a complicated mix of elements including personal ideals, social influences, institutional support, and opinions of the technology itself. This all-encompassing viewpoint provides legislators aiming to promote the effective integration of AI into learning settings with incisive analysis as well as for educational institutions.

AI-Based Teaching Experiences

AI-powered lesson planning

Two different studies yielded the results relevant to the topic of "AI-powered lesson planning." PSTs, especially ChatGPT, find rather useful AI apps for lesson planning. Every one of these devices performs several purposes. One research indicates that ChatGPT may "design activities for different levels" (Kartal, 2024), so allowing teachers to produce a variety of instructional resources. As one teacher observed, "it allowed me to save a lot of time when preparing for lessons" (Kartal, 2024), so saving time as well. One teacher said, "a brainstorming activity with ChatGPT is very useful," suggesting ChatGPT's value for producing ideas (Kartal, 2024). AI can even draft comprehensive courses of action. "A 15-week course plan, enhanced by ChatGPT assistance and inclusive of supplementary materials such handouts and teacher notes" (Okulu & Muslu, 2024). As it "not simply introduced terms in science education (or education) jargon such as science process skills, think-pair-share, and formative assessment, but also effectively incorporated them into the course plan in a meaningful way," the AI tool showed it could use terms correctly (Okulu & Muslu, 2024). These results reveal that pre-service instructors' preparing their courses and classes is benefiting from AI tools as effective aids.

Collaborative learning with AI

Four studies on "collaborative learning with AI" produced results. In teacher education, collaborative learning with AI tools and systems seems promising. Several research have examined how PSTs might use AI in collaborative learning. PSTs improved their critical thinking and creativity using ChatGPT group activities. In Kartal (2024), "group brainstorming sessions that included evaluating the AI-generated content critically were seen as a successful technique to improve critical thinking abilities and foster creativity." Sharing AI-generated insights improved peer learning, as "exchanging insights produced by ChatGPT enabled them to acquire fresh viewpoints and concepts on a variety of subjects."

Another study implemented a system called CLAIS, which incorporated AI speakers into collaborative learning groups. Lee et al. (2024a) reported that "the developed CLAIS system prototype was successfully implemented in a session of the science education course, where 15 students participated for 60 min. A total

of five groups were formed, each consisting of an AI speaker and 3-4 pre-service elementary science teachers." According to the study, "AI had become the mediator of knowledge delivery, while at the same time bringing about changes in the roles of teacher and student, and thus the aspects of teacher-student and student-student interactions in the classroom."

Research has also created AI chatbots for pre-service instructors to practice individually. A chatbot in publication (Lee & Yeo, 2022) imitated a student with fraction misconceptions, allowing PSTs to practice responsive teaching. It said that "this study contributes to the knowledge base by investigating if AI-based chatbots can provide personalized interactions on a meaningful task on a more authentic and open-ended platform than in previous approaches." These AI technologies show potential, but researchers stress the need for human guidance and contextualization of AI-generated educational content. "While it can foster innovation and efficiency, human expertise remains essential in shaping educational experiences" (Okulu & Muslu, 2024).

AI-based feedback and evaluation

Results of four "AI-based feedback and evaluation" studies AI-based feedback and evaluation systems help PSTs. Personalized feedback, higher learning results, and better instruction are other benefits of these systems. Several studies have examined how AI can give pre-service educators feedback. For example, publication (Sailer et al., 2023) revealed that PSTs' diagnostic reasoning ability improved with adaptive feedback derived from AI. The study found, "results regarding the quality of justification in the learning process show a large main effect of automatic adaptive feedback." As the post-test data show, this adaptive feedback was especially helpful for group projects and had long-lasting impacts. Additionally created to offer quick, customized feedback are AI chatbots. Lee and Yeo (2022) detailed a method whereby PSTs could only interact one-on-one with the virtual student, who responded automatically to their inquiries. PSTs might thus immediately get tailored answers on their inquiries. Under this strategy, PSTs might hone their teaching abilities in a low-risk setting.

In the context of writing and argumentation, AI feedback has shown to be helpful for PSTs. Martono et al. (2023) reported that "AI feedback facilitated their focus on their arguments and quotations, leading to decreased worry about writing errors on accuracy." The same study found that AI-generated scores motivated PSTs to revise and improve their writing, stating, "PSTs could reflect on the scores and target higher scores from AI." AI systems have also been integrated into collaborative learning environments. Lee et al. (2024a) described the CLAIS system, where "students in a group could interact with human and AI speaker peers, asking questions about the learning content and listening to the peer responsible for specific content respond." This system not only provided feedback but also increased PSTs' knowledge in various domains.

These results imply that by giving individualized, instantaneous feedback and generating chances for practice and skill growth, AI-based feedback and evaluation systems could improve PST education. These systems are supposed to enhance rather than replace, therefore, human knowledge in teacher development.

AI Training and Professional Development

In 11 studies, findings related to the theme of "AI training and professional development" were obtained. Research indicates that AI training and PDPs are effective in improving PSTs' AI literacy, teaching skills, and understanding of AI integration in education. These programs cover various aspects of AI and its applications in teaching.

Several studies have shown the positive impact of AI training on PSTs' knowledge and skills. For example, publication (Kim, 2024) found that "PSTs who received AI education also experienced improvements in their AI-integrated teaching expertise." The study reported significant improvements in various areas, including technological knowledge, context knowledge, and TPACK. AI literacy programs have been particularly effective. Younis (2024) reported a significant increase in AI literacy scores after participating in a PDP. The study noted, "the mean AI literacy score increased from 2.294 (standard deviation [SD] = 0.4181) before participating in the PDP to 4.325 (SD = 0.3781) after participating in the PDP." Hands-on experience with AI tools has proven to be an important aspect of training. Uzumcu and Acilmis (2024) observed that "using an AI-powered tool gave a little idea about what AI is and how it works." This suggests that practical experience can serve as a form of informal training.

Several training courses have concentrated on AI applications for education. For PSTs, for example, publishing of Lee and Yeo (2022) created an AI chatbot to hone responsive teaching techniques. According to Lozano and Blanco Fontao (2023), "PSTs could only communicate one-on-one with the virtual student, who responded to their queries automatically." PSTs might thus immediately get tailored answers on their inquiries. Pre-service instructors understand the need for AI education. "96% of the future teachers consider it necessary to know the new AI tools in order to better prepare and evaluate the tasks so that the students reach the desired competencies ..." These results draw attention to the rising significance of AI instruction for programs on teacher preparation. They propose that PSTs can be adequately ready for including AI into their future classes by combining academic knowledge, practical experience, and specialized AI applications.

DISCUSSION

The results of this comprehensive analysis provide important perspectives on the current state of AI in PST education. The studies covered by this review range from 2021 to 2024, with a noticeable increase in publications in 2024, indicating a growing interest in this area of research. The research covers a variety of fields, including STEM education, language education, and primary education, and highlights the wide applicability of AI in a variety of educational settings.

The literature has highlighted the potential of AI to transform educational administration (Xing, 2023), improve students' comprehension and expertise in AI (Srinivasan & Murthy, 2021; Yang & Xu, 2024), and enhance the efficacy and efficiency of educational management in schools (Çayır, 2023). The review identified PSTs' perspectives and attitudes regarding AI in education as a prominent subject. Several studies have found that people generally have positive attitudes towards AI and recognize its potential benefits (Younis, 2024; Zhang et al., 2023). However, there are also widespread fears and anxieties about how AI may affect teaching and learning (Lee et al., 2024a; Hur, 2025; Pokrivcakova, 2023). Researchers have emphasized the need to examine ethical concerns and formulate policies to effectively manage the complexities and advantages associated with AI technology in higher education (Eden et al., 2024; Kuleto et al., 2021; Qadhi et al., 2024). These findings are consistent with the broader discussions in the literature regarding the potential advantages and obstacles related to AI in education (Ocaña-Fernández et al., 2019; Wang et al., 2023).

The review also provided insight into the levels of AI knowledge and skills among pre-service instructors. The literature has emphasized the importance of AI literacy among educators to effectively integrate AI into their teaching approaches and ensure ethical and responsible use in educational settings (Boscardin et al., 2024; Dai et al., 2023; Rüttil-Joy et al., 2023). However, several studies have indicated that PSTs initially possess inadequate understanding of AI (AlKanaan, 2022; Younis, 2024). Despite the initial lack of AI knowledge, it has been demonstrated that training programs and practical exposure to AI tools can enhance their AI literacy and teaching abilities (Hur, 2025; Pu et al., 2021). It is crucial to include AI education in teacher preparation programs in order to provide future instructors with the essential skills and knowledge (Rüttil-Joy et al., 2023; Shen & Cui, 2024). The literature has also emphasized the need for educators to offer customized assistance in AI education, while institutions should provide specific courses to improve AI literacy (Shen & Cui, 2024). Moreover, the post-pandemic environment has heightened the importance of developing AI digital capabilities among educators to learn the indispensable skills required for the future (Ng et al., 2023).

It has been discovered that there are several factors that influence the willingness of pre-service instructors to adopt AI technologies. Alrishan (2023), Ma and Lei (2024), and Zhang et al. (2023) have shown that these factors include perceived usefulness, ease of use, social influence, and self-efficacy. Furthermore, these aspects are influenced by social influence. The findings of this review, which highlight the influence of perceived usefulness, ease of use, social influence, and self-efficacy on PSTs' intention to use AI technologies, align with the key constructs of the TAM and UTAUT. These results suggest that teacher education programs should focus on demonstrating the value and benefits of AI technologies for teaching and learning, providing user-friendly AI tools and platforms, fostering a supportive social environment that encourages AI adoption, and offering training and support to enhance PSTs' self-efficacy in using AI technologies. It should be noted, however, that the conventional TAM/UTAUT constructs may not fully capture the complexity of AI technology adoption. Kuzu (2025) argues that AI-specific factors such as trust, transparency, and ethical concerns need to be integrated into the traditional dimensions of perceived usefulness and ease of use. The trust deficit

identified by Pum (2025), where students reported significant concerns about the factual accuracy and contextual sensitivity of AI outputs, further complicates the adoption picture. These findings suggest that intention to use AI technologies is mediated not only by perceived utility but also by the degree to which users trust the reliability and appropriateness of AI-generated content.

Positive experiences with AI-based teaching were reported by pre-service instructors, particularly in the areas of lesson design, collaborative learning, and feedback and evaluation on student performance. According to Kartal (2024) and Okulu and Muslu (2024), AI tools such as ChatGPT have been acknowledged as significant resources that may assist with the planning of lessons and the development of educational materials. These tools allowed PSTs to create a variety of instructional resources, save time in lesson preparation, and generate ideas for teaching (Kartal, 2024). Lee and Yeo (2022) and Lee et al. (2024a) have demonstrated that the utilization of AI systems, such as chatbots and AI speakers, in collaborative learning has demonstrated potential for improving critical thinking, creativity, and peer learning. These findings highlight the potential of AI technologies to create engaging and interactive learning experiences that promote higher-order thinking skills and collaborative learning among PSTs.

The utilization of AI-based feedback and evaluation systems has been shown to enhance the diagnostic reasoning and writing skills of PSTs, as demonstrated by studies conducted by Sailer et al. (2023) and Martono et al. (2023). An example of this is when artificial neural networks produce adaptive feedback, which has been proven to greatly enhance the diagnostic reasoning capacity of PSTs. This impact is especially notable in the context of simulation-based learning, as demonstrated by Sailer et al. (2023). AI-generated feedback and scores in the field of writing and argumentation prompted PSTs to edit and enhance their writing. This resulted in less concern about writing faults and more emphasis on the quality of their arguments and citations (Martono et al., 2023). The results indicate that AI-driven feedback and evaluation systems have the potential to offer individualized, prompt, and practical feedback to aspiring instructors, thereby assisting them in enhancing their abilities and introspection.

This review also highlighted the significance of AI training and PDPs. Research findings consistently showed that participating in these programs led to notable enhancements in PSTs' AI literacy, teaching skills, and comprehension of AI integration in education (Kim, 2024; Younis, 2024). As an illustration, individuals training to become teachers who were exposed to AI education saw enhancements in their ability to incorporate AI into their teaching. Additionally, these programs were essential in providing them with the skills they would need to integrate AI into their future teaching. According to Lozano and Blanco Fontao (2023) and Uzumcu and Acilmis (2024), these findings highlight the significance of teacher education institutions providing comprehensive AI education and real-world experiences to prepare future instructors for AI-integrated classrooms. The integration of AI technologies into curricula and the importance of AI literacy cannot be overstated in teacher education programs. This will guarantee that educators in the future are prepared to use AI effectively in their lesson plans.

However, the review also revealed several challenges and ethical concerns related to AI integration in education. PSTs expressed concerns about data privacy, academic honesty, fairness, and the potential negative impact of AI on student learning (Hur, 2025; Markos et al., 2024; Mnguni, 2025). For instance, PSTs raised concerns about the misuse of AI tools like ChatGPT for generating fake academic content, plagiarism, and the potential weakening of critical thinking skills among students (Markos et al., 2024). Additionally, PSTs worried about the accuracy of AI-generated data, the presence of AI bias, and the potential for widening educational gaps due to unequal access to AI technologies (Hur, 2025; Mnguni, 2025). These findings emphasize the need for teacher education programs to address the ethical dimensions of AI and provide guidance on responsible AI use in educational settings (Boscardin et al., 2024; Dai et al., 2023). Teacher education institutions should incorporate ethical considerations into their AI curricula, fostering PSTs' understanding of data privacy, algorithmic bias, and the responsible use of AI technologies in teaching and learning. By equipping PSTs with the necessary knowledge and skills to navigate the ethical challenges associated with AI integration, teacher education programs can contribute to the development of a responsible and equitable AI-enhanced education system. The ethical dimensions of AI integration extend beyond the classroom to the broader ecosystem of scholarly communication. Adhikari et al. (2025) emphasized that ChatGPT has become a systemic force reshaping how knowledge is produced and disseminated in higher education, raising fundamental questions about authorship attribution, AI

hallucination in reference generation, and the erosion of independent scholarly argumentation. Their finding that overreliance on AI may erode essential skills such as critical thinking and argument development aligns closely with the concerns expressed by PSTs in the present review. This convergence underscores the urgency of equipping future teachers not only with the technical skills to use AI but also with the critical literacy to evaluate AI outputs and the ethical awareness to model responsible AI use for their students.

Overall, this systematic review offers a thorough grasp of how AI is being incorporated into the training of future teachers. Emphasizing the value of including AI education in teacher preparation courses, addressing PSTs' points of view and issues, and giving hands-on experience with AI technologies can help to change the outcome. Teacher education institutions and legislators must aggressively address the opportunities and problems presented by AI in education if we are to properly equip future teachers to include it in classrooms.

CONCLUSION

The present situation of including AI into PST education has been carefully examined in this systematic review. The findings highlight the growing importance of AI literacy and the need for teacher education initiatives to fit the fast-evolving field of AI technology in education.

PSTs have good opinions as well as concerns about using AI in the classroom. They express questions about the ethical implications and the impact on their professional obligations, even while they recognize the possible benefits of AI in enhancing education. These findings emphasize the significance of addressing the perceptions of PSTs and equipping them with the essential information and abilities to properly handle the problems and opportunities related to AI in education. PSTs have low starting knowledge and skills in AI, but targeted training programs and hands-on interaction with AI tools can considerably improve them. This highlights the critical need for teacher education institutions to include AI education in their courses and providing PSTs the possibility to interact with AI technologies in actual learning surroundings.

Moreover, the study has exposed several elements influencing PSTs' intention to apply AI technology: perceived value, simplicity of use, social influence, and self-efficacy. These results line up with well-known theories of technology acceptance and suggest that teacher education initiatives should give top priority to highlighting the advantages of AI technologies, providing user-friendly tools, creating a positive social environment, and increasing PST confidence in using AI. The review has also emphasized the favorable encounters of PSTs with AI-driven instruction, encompassing activities such as lesson preparation, cooperative learning, and assessment/assessment. The findings indicate that AI technologies can be excellent tools for pre-service instructors, assisting them in developing interesting and successful learning experiences. Nevertheless, the review has also pinpointed other obstacles and moral considerations associated with the incorporation of AI, including issues of data privacy, academic integrity, impartiality, and the potential adverse effects on student learning. These problems emphasize the necessity for teacher education programs to tackle the ethical aspects of AI and offer guidance on the responsible utilization of AI in educational environments.

SUGGESTIONS

Teacher education institutions should place high priority on cultivating AI literacy among PSTs by integrating AI education into their curricula and offering practical opportunities to engage with AI tools in authentic learning environments. Equally important is the need for these programs to address the attitudes and concerns of PSTs regarding AI integration by promoting open communication, providing accurate information about AI capabilities and limitations, and demonstrating the tangible benefits of AI technologies for teaching and learning. In parallel, teacher education programs should establish a supportive social atmosphere that fosters the acceptance of AI technologies through the promotion of collaboration among peers, the exchange of effective practices, and the provision of mentorship opportunities that connect PSTs with experienced educators who have successfully integrated AI into their instruction. Finally, teacher education institutions should incorporate ethical considerations into their AI curricula, fostering PSTs' understanding of data privacy, algorithmic bias, and the responsible utilization of AI technologies in educational settings.

LIMITATIONS

The studies analyzed in this review were mainly carried out in particular geographical contexts, which could restrict the applicability of the findings to different educational systems and cultures. In addition, the swift progress in AI technologies has the potential to affect the relevance of some findings over time, as the emergence of new tools and applications continues to reshape the educational landscape. It should also be acknowledged that this review was based on the existing published literature, and there may be further unpublished studies or ongoing research that could offer additional insights into the subject. Despite these limitations, this systematic review provides valuable insights into the current state of AI integration in PST education and establishes a foundation for future research and practice.

Although there are certain limitations, this systematic review gives significant insights into the status of AI integration in PST education and establishes a basis for future research and implementation. Given the ongoing progress and influence of AI technologies in education, it is imperative for teacher education institutions, policymakers, and academics to work together and tackle the obstacles and possibilities that come with integrating AI into education. By providing PSTs with the necessary skills to effectively use AI technologies and understand the ethical considerations, we can guarantee that the future generation of educators can utilize AI's promise to improve teaching and learning in the 21st century.

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