AI Literacy in Preservice Teachers Preparation Programs: A Global Meta-Analysis

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Abstract: The rapid integration of Artificial Intelligence into education is reshaping how teaching and learning occur, prompting the need for pre-service teachers' programs to equip future educators with AI literacy. This systematic review, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocol, explores the role of AI literacy in pre-service teacher programs globally. The study examines how AI literacy is integrated into teacher preparation curricula to develop essential technological, pedagogical, and ethical competencies. The review focused on 79 studies published between 2020 and 2025, focusing on peer-reviewed journal articles, conference proceedings, and book chapters in English. The results reveal the growing importance of AI literacy, emphasising the integration of technological skills, ethical considerations, and pedagogical strategies. The study identifies key regional trends, with Western and Asian regions leading in AI literacy integration, while other regions remain at the entry of AI integration. The findings underscore the urgent need for teacher education institutions to prioritise AI literacy to foster innovation and the successful integration of AI. The review proposes a framework for enhancing AI literacy in pre-service teachers' programs, including recommendations for curriculum development.

Keywords: Artificial Intelligence (AI), AI Ethics in Education, AI Literacy, Digital Competency, Teacher Preparation Programs

1. Background

The rapid evolution of Artificial Intelligence (AI) is fundamentally reshaping education, making AI literacy a crucial and integrated competency for Pre-service teachers (PSTs). Beyond mere use of AI tools, this literacy empowers educators to be critical participants in an AI-driven world, encompassing technological knowledge, ethical awareness, and pedagogical application. While traditional teacher education focused on pedagogy and content, AI's ability to mimic human intelligence demands a new skill set. AI literacy is defined as the ability to understand AI's features, critique its biases, and assess its ethical impacts, including its potential for manipulation. Although frameworks like Technological Pedagogical and Content Knowledge (TPACK) help ensure effective use, significant disparities in adoption remain, particularly in the Global South, due to inadequate infrastructure and expertise. This fragmentation underscores the need for a unified approach combining technological, ethical, and pedagogical dimensions to inform future curriculum development.

2. Literature Review

2.1 The Need for AI Literacy in Teacher Education

The digital learning ecosystem is undergoing a massive transformation with the proliferation of Artificial Intelligence (AI) technologies. The potential of AI in improving pedagogy with regard to personalised learning, automated marking, and automation of administrative work has raised calls to incorporate AI literacy in educator training. Their research, which suggests a curriculum for developing AI literacy in primary schools (Kim et al., 2021), highlights the need for teachers to acquire an understanding of the technological, pedagogical, and ethical aspects of AI. Educator AI literacy is not just about being an end-user of AI systems. It involves critical skills that allow educators to determine if AI solutions are appropriate and effective for their specific classroom needs (Holmes et al., 2023). For instance, Holmes et al. (2023) argue that teachers should be trained in simplified AI algorithmic decision-making methods to identify any bias manifesting from such technologies and offer equitable learning experiences. Otherwise, teachers may adopt AI instruments lacking this literacy, thereby spreading societal bias or infringing on student privacy. Furthermore, Sunet al. (2023) emphasise that a lack of AI literacy hinders educators from realising the potential of AI ethically and responsibly. This entails a fundamental understanding of data privacy, knowledge of consent, and transparency of algorithms, fields whose integrity is persistently questioned as AI applications become institutionalised in education. Therefore, the development of AI literacy in teacher education is not just a matter of technological skill acquisition but also of developing ethical awareness, critical thinking, and proper use.

Studies suggest that the emergence of AI literacy is also aligned with more universal learning goals of forming digital citizenship and preparing educators to cope with a fast-changing landscape of data-driven decision-making (Althibyani & Al-Zahrani, 2023). Moreover, Jain and Singh (2023) propose incorporating AI literacy into key pedagogical skills, highlighting the latter's function in critically empowering educators to evaluate the pedagogic effectiveness and ethical considerations of AI tools. This perspective highlights that AI literacy supports teachers in using the benefits of AI and minimising risks.

2.2 Pedagogical Strategies towards AI Integration in PST Programs

Globally, the necessity of AI literacy in PSTs education is widely acknowledged, but its implementation is uneven and in its developmental stages. Technologically advanced regions like North America, Europe, and parts of Asia have integrated AI into digital literacy education and pedagogical frameworks supported by national policies and standards like ISTE (Kimm et al., 2020) and the European Framework for Digital Competence. Both technological AI abilities and pedagogical applications are areas of focus for these efforts.

In contrast, low-resource regions, including parts of Africa, Latin America, and Southeast Asia, are largely in the exploratory phase, with AI literacy limited to small-scale pilots or workshops due to infrastructural and capacity constraints. Recent models stress the need for holistic integration of AI literacy into established pedagogical frameworks like TPACK, Substitution, Augmentation, Modification and Redefinition (SAMR) and Digital Citizen (Ribble, 2017; Mishra & Koehler, 2006; Puentedura, 2009). Universities now offer specialised modules on AI ethics, data literacy, and instructional design. Ayyoub et al. (2025) highlight the efficacy of experiential learning approaches, such as simulations, project-based learning, and designing AI-supported lessons, which are proving effective in building practical AI competencies among PSTs. Despite these advances, there is a continued need for curriculum refinement, professional development, and alignment with broader teacher competency standards to ensure sustainable and scalable AI integration in teacher education.

2.3 Challenges and Barriers to Effective AI Literacy Development

Despite growing recognition of AI literacy's importance in PST education, widespread integration is hindered by several challenges. Key barriers include limited faculty expertise, resource constraints, and the absence of standardised instructional frameworks. Many teacher educators lack training in AI, and the rapid pace of technological change often outpaces curriculum updates, leading to what scholars describe as an “ontological lag.” Fragmented institutional strategies and inconsistent pedagogical approaches further weaken efforts to build scalable, replicable AI literacy programs. Financial limitations, especially in low-resource contexts, impede access to up-to-date tools and professional development. A shortage of faculty with both pedagogical and technological expertise exacerbates these challenges, reinforcing regional disparities.

The adoption of AI curriculum in education is progressing slowly. Jin et al. (2024) posit that there is institutional and cultural resistance to curriculum reform, coupled with a lack of prior assumption and limited familiarity with digital pedagogy, which directly hinders the implementation and adoption of new curricula. Overcoming these barriers requires a multifaceted approach. First, there must be coordinated policy action and sustained investment in both infrastructure and training. This includes the development of adaptable, contextually grounded resources and frameworks that can be implemented across diverse educational settings. Therefore, to prepare PSTs for an AI-driven future, the focus must shift towards developing a standardised curricula that seamlessly integrate technological, pedagogical and ethical characteristics of AI. This is a critical step to ensure a consistent and comprehensive level of training. Furthermore, cross-sector collaboration among educators, policymakers and industrial stakeholders is essential for creating inclusive and scalable models for AI literacy in the PST program. By working together, these groups can ensure that the next generation of teachers is not only competent but also ethically aware and ready to responsibly lead in an AI-powered world.

2.4 Conceptual Framework

Integrating AI literacy into teacher education is a multifaceted challenge that requires a holistic approach, which can be understood through key theoretical frameworks. The TPACK framework highlights the need for teachers to merge their subject knowledge and teaching methods with an understanding of AI tools. This ensures that AI is used to enhance learning, not just as a standalone gimmick. The SAMR model further evaluates this integration, encouraging a progression from simple AI substitution to the complete redefinition of learning experiences, empowering teachers to be innovators. Finally, the Unified Theory of Acceptance and Use of Technology (UTAUT) framework provides insight into why teachers adopt or resist new technologies, emphasising the importance of

institutional support and resources to overcome barriers to implementation. Together, these frameworks offer a comprehensive lens for designing effective and sustainable AI literacy programs that prepare future educators for a technology-driven world.

3. Methodology

3.1 Research Design

This study employs a systematic literature review, which is best suited to synthesise existing research and identify trends, gaps, and patterns in the literature. The systematic structure makes it possible to aggregate comprehensively relevant studies, and it provides an understanding of AI literacy in PST education across geographical contexts. By using a systematic review, the research is capable of addressing challenging questions with openness and stringency and of ascertaining that evidence pertinent to such questions is recorded in a systematic way. Bias is minimised, and conclusions arrived at from the review are assured of being derived from the best available evidence. In the interests of consistency and openness, the study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines in its review. This systematic methodology offers a reproducible process for evaluating and synthesising existing research on AI literacy (Stracke et al., 2023). Applying such a methodological strategy makes it feasible for future researchers to replicate the study and utilise the findings accumulated in future investigations on the topic.

3.2 Literature Search Strategy

The literature search was designed to capture all relevant publications published between 2020 and 2025, a period purposely chosen to reflect the rapidly unfolding development of AI technologies and their applications in education. Extensive searching across five online academic databases: ERIC, Google Scholar, Scopus, JSTOR, and Mendeley was carried out. This multi-database approach was adopted for its comprehensiveness of peer review as well as grey literature. To maintain consistency and avoid language bias, the search was limited to English-language publications. Careful selection of search terms was made in order to yield extensive coverage of studies of AI literacy in PST education. Keywords utilised were "AI literacy", "PST education", "artificial intelligence in education", "AI tools in teaching", "digital literacy for teachers", "AI pedagogical integration", and "AI ethics in teacher education". Boolean operators (AND, OR) were utilised to limit the search in order to ensure that the retrieved studies conformed to the technological, pedagogical, and ethical specifications of AI literacy integration in teacher education.

3.2.1 Inclusion and Exclusion

To ensure the quality and relevance of the studies included in this systematic literature review, specific inclusion and exclusion criteria were applied. We included only peer-reviewed journal articles, conference proceedings, and book chapters published between 2020 and 2025 to capture the most recent developments in the field. The search adopted a global perspective, accepting studies from diverse geographical contexts, but required that their primary focus be on AI literacy as a core component of teacher preparation, encompassing technological, pedagogical, and ethical issues (Stracke et al., 2023). Conversely, studies were excluded if they lacked this specific focus or were not peer-reviewed, such as blog posts or opinion pieces, to maintain a high standard of academic rigour.

3.3 Data Extraction

The researcher developed a detailed data extraction on a table to systematically extract key information from each selected research study, with a uniform and organised method for review, in accordance with best practices in systematic reviews (Stracke et al., 2023). The structure was utilised to gather essential details, including study information like the author(s), publication year, study type, and geographic location. The researcher outlined specific information regarding the focus group of PSTs, aspects of AI literacy addressed in the study (technological, pedagogical, and ethical), and the theoretical framework and research methodology used. Finally, we integrated the most significant findings and suggestions of each study. Critical Appraisal Skills Programme (CASP) checklists were used to review the credibility, relevance and findings of studies (Critical Appraisal Skills Programme, 2023). This supported the researcher to gain insight into the validity and reliability of research, thereby establishing our review on a foundation of high-quality evidence. This systematic review provided a

structured overview of included research, and this was crucial in identifying the trends and gaps in integrating AI literacy in PST education.

3.4 Data Analysis

The systematic review was analysed using a thematic synthesis, a method which allows for identifying common patterns, trends, and gaps in the literature. By coding and clustering prominent themes in each study, the author was capable of isolating essential themes, such as the pedagogical approaches employed in AI literacy, the ethical issues contested, and the implementation recommendations. Through illustration of what the current building blocks under development are and where the underdevelopments and gaps are, the analysis provides a transparent, evidence-based roadmap for nurturing practical responses to address issues on AI literacy in PSTs' education. The purpose of the analysis was to provide actionable insights for educators and policymakers, ensuring that future teachers are not only technologically competent but also ethically aware and prepared to responsibly integrate AI into their classrooms.

4. Findings

The broad literature search across diverse publication types: journals, conference papers, and books, yielded a significant volume of records from key academic databases. The Mendeley contributed 3,609 articles, ERIC provided 2,200 articles, and 4250 Google Scholar articles, for a total of 10,059 articles added to the initial pool. After removing duplicates and the exclusion process, 2348 remained, and then the final process purposefully selected 79 articles for the study that closely aligned with the study goals.

4.1 AI Literacy in PSTs' Education

The results confirm that AI literacy is increasingly critical in PST education. The accelerating integration of AI tools in educational settings offers considerable transformative learning environments, enabling personalised learning experiences, automating teacher administrative tasks (Kalniņa et al., 2024). However, to fully realise these benefits, PSTs must be equipped with both technological knowledge of AI and pedagogical understanding of how to use it effectively and ethically (Holmes et al., 2019)

As the integration of AI tools into educational settings continues to accelerate, PSTs must be prepared to understand, evaluate, and integrate these tools into their teaching practices. AI holds great potential for determining education by providing personalised learning, enhancing students' engagement, and minimising administrative tasks (Kalniņa et al., 2024) However, to enjoy all the advantages of AI deployment, educators in the future must have technological competence in AI and pedagogical knowledge on how to implement it effectively and ethically (Holmes et al., 2019; Sun et al., 2023).

AI literacy entails awareness of AI concepts, application of AI tools in the classroom, and careful examination of their ethical aspects. This can be seen in the papers presented, which highlight the fact that in the absence of previous AI knowledge, PSTs cannot apply these tools in their classes (Abar et al., 2024; Kim & Kim, 2023). The outcomes of different research work recognise that teacher preparation programs must make AI literacy part of mainstream curricula (OECD, 2025) in order to provide PSTs with the capacity to leverage the challenges and potential provided by AI in the classroom.

4.2 Regional Differences in Integration of AI Literacy

Literature is characterised by a contrast of extreme proportions in adoption and utilisation. Western countries and Asian countries are leading the way, embedding AI literacy via specialised courses, workshops with specialised emphasis, and interdisciplinary programs. Studies carried out in Europe and North America (Lin et al., 2024; Hwang & Hwang, 2023; Al-Abdullatif, 2024) have incorporated AI modules in the curriculum to develop the technological competencies essential for AI tools so that they can be utilised optimally. Conversely, AI literacy in Latin America and Africa is underdeveloped, and studies indicate significant barriers in the guise of limited connectivity and sparse resources and an absence of qualified teachers (Cardon et al., 2023; Abar et al., 2024). National economic development and institutional resources have an immediate effect on its capacity to adopt new technologies and skills. In high-resource nations, they have created inclusive AI literacy courses for educators. This results in PSTs from the under-resourced not being able to feel comfortable applying AI within the classroom environment. For instance, many teacher training programs in Europe and North America have incorporated AI modules into broad digital literacy programs. This equips PSTs with the technological expertise

necessary to deploy AI tools in school settings. Institutions like Stanford University in the United States and the University of Cambridge in the United Kingdom have created comprehensive AI literacy programs specifically designed for teachers.

4.3 Pedagogical and Ethical Issues of AI Literacy

Studies indicate an increasing focus on the pedagogical and ethical issues of AI literacy. The majority of research underscored the importance of PSTs understanding the pedagogical application of AI tools, i.e., individualised learning, adaptive testing, and instant feedback mechanisms (Hwang & Hwang, 2023). The literature suggests that AI is capable of revolutionising classroom practice through tailored learning experiences that cater to various student needs. However, with these opportunities, there are ethical concerns about using AI in education. Concerns of privacy of data, bias in algorithms, and the potential for AI to compound educational inequalities have been brought up in various studies (Hwang & Hwang, 2023). Teacher education programs are becoming more aware of these issues. They are incorporating ethical dialogue into AI literacy courses so PSTs can become ready to address the ethical aspects of AI implementation in the classroom

4.4 Challenges and Barriers to AI Literacy Integration in PSTs Education

Although AI literacy is undoubtedly essential for PSTs, its integration in teacher preparation programs encounters various overarching challenges. The primary obstacle is that few qualified teacher educators are AI technology specialists. The Holmes et al. (2023) study highlighted that the majority of teacher educators lack the AI skills necessary to properly prepare PSTs. Such limited expertise limits the potential of a program to offer comprehensive AI literacy training, making future teachers ill-equipped. The second major challenge is the fast rate of AI development. Because AI technologies are evolving at such a high speed, the curricula of teacher education programs must be revised regularly to keep up with developments. In most cases, the programs cannot catch up. Southworth et al. (2023) noted that a lack of ability usually means curricula are out of date or of poor quality, failing to prepare PSTs for issues of the modern digital classroom.

The review also found that the unavailability of technology and resources is a major barrier, especially in low-resource settings. Ayyoub et al. (2025) established that where the availability of AI tools is scarce or non-existent, it's difficult for PSTs to gain experiential learning. The unavailability of access expands inequities in teacher training and does not prepare PSTs to implement AI tools in the classroom.

5. Discussion

This discussion section discusses how AI literacy is being integrated into PSTs' teacher education programs globally, the skills that PSTs are to develop, how these efforts vary by region, and the most effective pedagogies. By drawing on an interconnected conceptual framework, TPACK, SAMR and UTAUT, this systematic review offers a broad synthesis of global practices, challenges, and opportunities in teacher education AI literacy. The evidence identifies that effective integration of AI relies on something greater than tool availability; it has to be supported by deep pedagogical knowledge, transformative usage of AI, and facilitative institutional cultures.

5.1 AI Literacy in Global Teacher Education: A Growing Priority

There is a growing need in teacher education to bring AI literacy into PSTs’ preparation. While some regions are boldly charging forward with AI as a foundational competency, others have systemic barriers to overcome, which has given rise to a growing gap in preparing teachers for the digital and AI age.

In high-income countries, particularly across Western and Asian nations like China, Finland, the U.K., and the U.S., AI literacy has transitioned from a niche topic to a foundational element of teacher training. This progress is not accidental; it is often driven by national policies and institutional strategies that align with broader digital transformation agendas. These countries are not just introducing AI tools; they are building comprehensive frameworks. The TPACK model is a visible influence, with programs designed to connect AI technologies with specific content and pedagogical methods. This results in a multi-faceted approach, where PSTs don't just learn to use an AI tool but understand how to ethically integrate it to enhance learning outcomes.

Many countries in Africa, Latin America, and Southeast Asia face significant challenges that have hindered AI integration. The efforts that do exist are often fragmented, relying on small-scale, donor-funded pilot projects that lack the institutional backing to be scaled up. These conditions include reliable infrastructure, such as consistent internet access and adequate hardware, as well as a sufficient number of qualified teacher educators

who are themselves proficient in AI. Without these foundational elements, even highly motivated PSTs cannot effectively engage with AI technologies. The result is a cycle of limited exposure and a curriculum that often fails to systematically adopt emerging technologies. This leaves a new generation of teachers from these regions entering the workforce without the necessary skills to navigate and leverage AI tools, exacerbating existing inequalities and potentially limiting their students' future opportunities. The gap, therefore, is not just technological; it is one of educational equity.

5.2 Key Components of AI Literacy in Teacher Education

Four interrelated components of AI literacy emerged from the synthesis: conceptual understanding, practical competence, pedagogical integration, and ethical reflection. These dimensions align well with the TPACK model, which helps frame AI literacy as a blend of technology fluency, teaching expertise, and content alignment.

AI literacy for PSTs is built on four core pillars. First, conceptual understanding allows PSTs to grasp how AI works, which helps them avoid overreliance and misuse. This is paired with practical competence, which involves hands-on use of AI tools like ChatGPT for instruction, assessment, and classroom management. To ensure these tools are used effectively, pedagogical integration is essential; guided by frameworks like TPACK, this ensures AI is meaningfully embedded into lesson planning and practice. Finally, ethical reflection is a critical component, requiring PSTs to address concerns such as algorithmic bias, data privacy, and AI's potential to reinforce social inequalities. These elements are also linked to SAMR, which helps evaluate whether AI use simply substitutes traditional tools or redefines teaching and learning. High-impact programs use project-based, immersive activities to move PSTs from basic usage to transformative applications, enhancing both their competence and confidence (European Commission, 2024).

5.3 Regional Differences in AI Literacy Integration

The review found that regional disparities shape how AI literacy is approached. In North America and Europe, structured curricula, national frameworks, and clear assessment standards reflect advanced integration (Kimm et al., 2020). These regions also invest in faculty development, a critical enabler in UTAUT's facilitating conditions for successful technology use.

In Asia, particularly China and Singapore, AI is framed as a driver of innovation and economic development, with strong policy backing and institutional incentives (Kim & Kim, 2023). Here, a top-down approach has fast-tracked AI integration through state-led initiatives. Conversely, in Africa and Latin America, integration is often ad hoc, driven by external partners, and lacks long-term planning or systemic inclusion (Mpekoa, 2025). In many contexts, PSTs have high motivation but lack institutional support, relevant content, or infrastructure, highlighting UTAUT's value in diagnosing systemic challenges. These findings underscore the need to move beyond one-size-fits-all models. Local adaptations that respond to infrastructural realities, socio-cultural dynamics, and institutional readiness are essential for meaningful and equitable AI literacy development.

5.4 Pedagogical Strategies for Teaching AI Literacy

The most effective pedagogical strategies for AI literacy are those that are active, experiential, and reflective. Inquiry-based learning encourages PSTs to explore AI through real-world projects and creative experimentation. Case study analysis builds critical reasoning and ethical reflection, helping PSTs consider the broader social implications of AI in teaching (Holmes et al., 2019). Blended and experiential learning, including online modules, simulations, and hands-on tool engagement, enhances both technological fluency and teaching confidence (Al-Abdullatif, 2024).

These strategies directly support progress along the SAMR model from substitution to redefinition as PSTs evolve from basic AI use to innovative classroom transformation. However, a recurring barrier is the lack of faculty expertise in AI pedagogy. Many teacher educators are unfamiliar with emerging technologies, which limits their ability to model best practices. This gap reinforces the importance of faculty development, cross-disciplinary collaboration, and professional learning networks that promote TPACK-aligned pedagogy.

5.5 Implications for Teacher Preparation Programs

To advance AI literacy in pre-service teacher (PST) education, four key priorities must be addressed. First, curriculum integration is essential, moving AI from an optional topic to a core component embedded across subjects to build a holistic understanding. Second, faculty upskilling is crucial, as institutions need to invest in

continuous professional development to ensure teacher educators have the expertise to model effective and ethical AI use. Third, ethics and equity must be a central focus of the curriculum, empowering future teachers to critically evaluate AI's impact on all students, particularly those from marginalised communities. Finally, global collaboration is vital to bridge the disparities in AI adoption between high- and low-resource regions, sharing best practices and resources. These priorities, interpreted through an integrated framework of TPACK, SAMR, and UTAUT, provide a comprehensive roadmap for designing teacher education programs that are both technologically advanced and socially responsible.

6. Conclusion

This global meta-analysis highlights that while AI literacy is increasingly valued in PST education, its integration remains uneven. Institutions in developed regions such as North America, Europe, and parts of Asia have begun embedding AI through dedicated modules and pedagogical frameworks, recognising the need for both technological and ethical competence. In contrast, lower-resourced settings, particularly Africa and Latin America, face major barriers, including limited infrastructure, faculty expertise, and access to AI tools, leaving many PSTs unprepared for AI-integrated classrooms. The review emphasises that AI literacy must extend beyond consuming content to encompass ethical awareness, critical thinking, and inclusive pedagogical decision-making.

Ethical Declaration

This study did not involve human participants, personal data, or experimental interventions and therefore did not require formal ethical approval. The author declares no conflict of interest and assumes full responsibility for the content and conclusions of this work.

AI Declaration

AI tools were used to refine grammar, clarity, and coherence in early drafts. All analysis, synthesis, and final arguments were independently developed by the author. AI use was guided to support efficiency without compromising academic integrity. The author assumes full responsibility for the content.

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