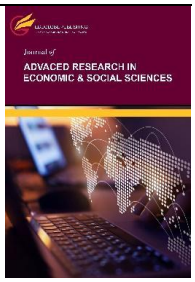
EDUGLOBE PUBLISHING
Expanding Knowledge Globally

Journal of Advanced Research in Economic & Social Sciences (JARESS)

Journal Homepage: www.eduglobepublishing.com



Teacher Workforce Challenges and the Rise of AI-Supported Professional Learning: A Systematic Review

Ibrahim Oleolo[1]*, Shakirah Okeowo[2] Nurudeen Babatunde Bamiro[3], Majd Alhiassah[4]

1.Faculty of Mechanical Engineering Universiti Teknologi Malaysia[1]*

2.Faculty of Medicine, Universiti Sultan Zainal Abidin, Malaysia[2]

3.Department of Eonomics, Universiti Sultan Zainal Abidin, Malaysia[3]

4.Department of Shariah, Universiti Sultan Zainal Abidin, Malaysia[4]

*Corresponding author: olakunle1983@graduate.utm.my

Abstract This systematic literature review synthesizes evidence from 46 peer-reviewed studies to examine teacher workforce challenges and the growing use of AI-supported professional learning as a potential solution. The review investigates four research questions: the nature of contemporary workforce challenges, the AI-supported tools and approaches available, the effectiveness of these systems, and the gaps, risks, and opportunities associated with their integration. A PRISMA-guided search and screening process was conducted across major academic databases. Studies meeting the inclusion criteria were analysed thematically to identify cross-study patterns, implementation mechanisms, and outcome-related insights. The results show that teachers continue to face substantial workload burdens, skill gaps, and limited access to sustained professional development. AI-supported learning tools, including intelligent tutoring systems, analytics dashboards, generative AI assistants, and personalized learning models, are increasingly used to address these challenges. Across studies, AI-supported professional development improves teachers' AI literacy, instructional competence, confidence, and efficiency, while also supporting differentiated pedagogy and reducing administrative tasks. However, effectiveness varies widely and is influenced by infrastructural readiness, teacher attitudes, ethical preparedness, and institutional support. Major gaps and risks include limited empirical testing, ethical vulnerabilities, digital inequality, bias, and concerns about professionalization. Opportunities lie in structured AI literacy programs, ethical design frameworks, and scalable professional learning and development models that integrate pedagogy, technology, and ongoing support. The review concludes that AI-supported professional learning has strong potential to alleviate teacher workforce pressures and strengthen teaching capacity when implemented within an equitable, ethically grounded, and pedagogically aligned ecosystem. Further research is needed to evaluate long-term impacts, address ethical risks, and develop robust human–AI collaboration models for teacher professional growth.
Keywords: Educator Retention, Digital Equity, Ethical Governance, Institutional Readiness, Human–AI Collaboration

1.0 Introduction

Education systems worldwide are undergoing rapid transformation driven by technological, demographic, and pedagogical shifts. Schools increasingly operate within environments shaped by digital infrastructures, data-driven instructional models, and technology-enabled learning processes. The acceleration of artificial intelligence (AI), automation, and learning analytics has introduced new possibilities for teaching, assessment, and instructional support (Holmes et al., 2019). As AI-enhanced technologies become more embedded in school systems, teachers are expected to continuously upgrade their digital competencies, adapt to emerging instructional tools, and navigate evolving expectations surrounding their professional roles (Li et al., 2025). At the same time, structural pressures, including teacher shortages, expanding curriculum demands, and rising accountability requirements, have intensified workload burdens and reshaped the everyday realities of teaching (Henderson, 2025). While advances in educational technology promise efficiency, personalization, and improved instructional quality, they also intersect with a long-standing set of workforce challenges that threaten teachers' well-being and professional sustainability. Recent studies describe teaching as a profession under strain, marked by rising burnout, emotional exhaustion, and a growing sense of role overload (Turner & Garvis, 2023). Teacher shortages across many regions have exacerbated these pressures, leading to larger class sizes, increased administrative duties, and reduced time for planning

and professional learning (García & Weiss, 2020). These systemic demands create a cyclical pattern: heavy workload contributes to burnout, burnout fuels attrition, and attrition increases the burdens placed on the remaining workforce (Darling-Hammond et al., 2023). In this context, teachers must balance instructional responsibilities with rapidly evolving technological expectations, often without adequate training, support, or AI literacy (Tan & Tang, 2025).

Amid these challenges, AI-supported professional learning has emerged as a promising yet under-explored avenue for strengthening teacher capacity and reducing workforce pressures. AI-driven coaching systems, automated feedback tools, personalized learning dashboards, and generative AI assistants are increasingly being proposed as mechanisms for enhancing teachers' access to timely, individualized, and scalable professional development (Luckin & Cukurova, 2019). Emerging evidence suggests that AI can support teachers in lesson planning, assessment design, reflection, and differentiated instruction, potentially reducing administrative load and supporting instructional decision-making (Li et al., 2025). For example, AI-powered feedback systems have been shown to assist teachers in analyzing their instructional strategies, improving reflective practice, and identifying specific areas for growth (Almubarak et al., 2025). These capabilities position AI-enabled professional learning as a possible response to several entrenched workforce challenges. However, while optimism around AI in education is growing, concerns remain regarding its practicality, equity, and long-term impact on the profession. Research highlights significant gaps in teacher AI literacy, infrastructural readiness, and organizational support, which limit meaningful adoption of AI-based tools (Zawacki-Richter et al., 2019). Ethical risks, including issues of algorithmic bias, data privacy, and teacher autonomy, further complicate large-scale integration of AI into professional development systems (Williamson & Eynon, 2020). Moreover, although many AI-related initiatives are emerging, empirical evidence on their effectiveness in reducing workload, improving teacher retention, or enhancing well-being remains limited and fragmented (Fatima, 2025). As a result, the potential of AI-supported professional learning remains more theoretical than fully realized. Given these tensions, there is a pressing need to systematically examine how teacher workforce challenges are currently understood in the literature, the extent to which AI-supported professional learning tools are being developed or implemented, and whether these tools offer substantive solutions to the profession's most persistent problems. A systematic review is also essential for clarifying the opportunities and risks associated with integrating AI into teacher development ecosystems and identifying gaps where further empirical, theoretical, or policy work is needed.

Accordingly, this review is guided by the following research questions:

1. What major teacher workforce challenges are highlighted in recent literature?
2. What AI-supported professional learning tools and approaches have been developed or implemented for teachers?
3. How effective are AI-supported professional learning systems in addressing teacher workforce challenges?
4. What gaps, risks, and opportunities exist for the integration of AI in teacher professional learning?

By addressing these questions, this review contributes to ongoing discussions surrounding the future of the teaching profession and the role of AI in educational improvement. It advances conceptual clarity on teacher workforce challenges, consolidates evidence on AI-supported professional learning interventions, and maps the implications of AI integration for teacher well-being, instructional quality, and workforce sustainability. Ultimately, this review provides a foundation for understanding how AI can support, not replace, teachers, and how technology and human expertise can coexist to strengthen education systems in an era of rapid change.

2.0 Methodology

2.1 Review Design and Rationale

This study employed a Systematic Literature Review (SLR) to synthesise evidence on teacher workforce challenges and the expanding role of AI-supported professional learning across global education systems. The SLR approach was chosen because it provides a rigorous, transparent, and replicable process for consolidating research across diverse fields such as educational technology, teacher development, organisational learning, psychology of teaching, and AI-enhanced pedagogy. A structured method was necessary given the rapid evolution of artificial intelligence in education and the complex, multifaceted nature of teacher workforce pressures. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines (Ahmed et al., 2025; Akinson et al., 2025; Bamiro et al., 2023; Page et al., 2021), which ensured methodical identification, screening, and synthesis of studies while minimising selection bias and enhancing reliability. The decision to use PRISMA was motivated by the need for a standardised process capable of integrating conceptual, empirical, and emerging discourses in a field experiencing accelerated innovation.

2.2 Search Strategy and Data Sources

A comprehensive search strategy was developed to capture relevant academic work published between 2015 and 2025, a period during which teacher shortages intensified, digital transformation reshaped schooling systems, and AI-enhanced learning tools experienced significant development. Scopus served as the primary database because of its extensive coverage of peer-reviewed literature in education, technology, psychology, and the social sciences. Google Scholar supplemented this search to ensure the inclusion of emerging studies, cross-disciplinary research, early-stage AI developments, and contemporary discussions not yet indexed in traditional databases. The search strategy incorporated a combination of key

phrases related to teacher workforce challenges, teacher burnout, professional learning, AI-enabled training tools, digital pedagogy, and technology-supported teacher development. Boolean operators and phrase matching were used to ensure that conceptual variations of these themes were captured. All retrieved records were exported to Microsoft Excel for organisation, preliminary screening, and deduplication. Additional studies were identified through backward and forward reference chasing to ensure that influential works and emerging publications were not missed during initial searches.

2.3 Inclusion and Exclusion Principles

Studies were included based on predetermined criteria to ensure thematic alignment, methodological relevance, and conceptual contribution to the review. Only studies published in English between 2015 and 2025 were considered eligible, reflecting the contemporary nature of AI integration into teacher development practices and the accelerating challenges facing the global teaching workforce. To be included, studies needed to examine teacher workforce issues such as shortages, burnout, workload pressures, digital strain, or skill-development challenges, and they also needed to address AI-supported professional learning, digital upskilling, or the broader role of technology in enhancing teacher capability. Conceptual, qualitative, quantitative, and mixed-method studies were accepted as long as they offered meaningful insights into at least one of the research questions. Studies were excluded if they lacked peer review, focused exclusively on technical AI engineering without educational implications, fell outside the date range, conference paper, books, book chapter, non-English. These conditions ensured that only high-quality and thematically coherent research informed the analysis.

2.4 Screening, Selection, and PRISMA Process

The screening procedure followed the four stages outlined in the PRISMA 2020 framework. The initial search across Scopus and Google Scholar yielded a total of 1,024 records, with Scopus contributing the majority of entries. After exporting and consolidating the search results, 148 duplicates were identified and removed, leaving 876 unique studies for the first stage of screening. Titles and abstracts were then reviewed to determine their relevance to teacher workforce challenges, AI-supported learning, teacher professional development, and the digital transformation of education systems. At this stage, 678 studies were excluded because they did not sufficiently address teachers, workforce issues, AI integration, or professional learning frameworks. The remaining 198 studies underwent full-text screening, during which each document was evaluated for methodological quality, conceptual alignment with the research objectives, and substantive contribution to the themes under investigation. During this stage, 152 studies were excluded due to weak methodological rigour, limited relevance to AI-supported professional learning, or insufficient engagement with teacher workforce issues. Ultimately, 46 studies met all eligibility criteria and were included in the final synthesis. This systematic and transparent selection process ensured that the evidence base was both credible and sufficiently comprehensive to address the research questions guiding the review. A PRISMA flow diagram summarizing the identification, screening, eligibility, and inclusion stages is presented in Figure 1.

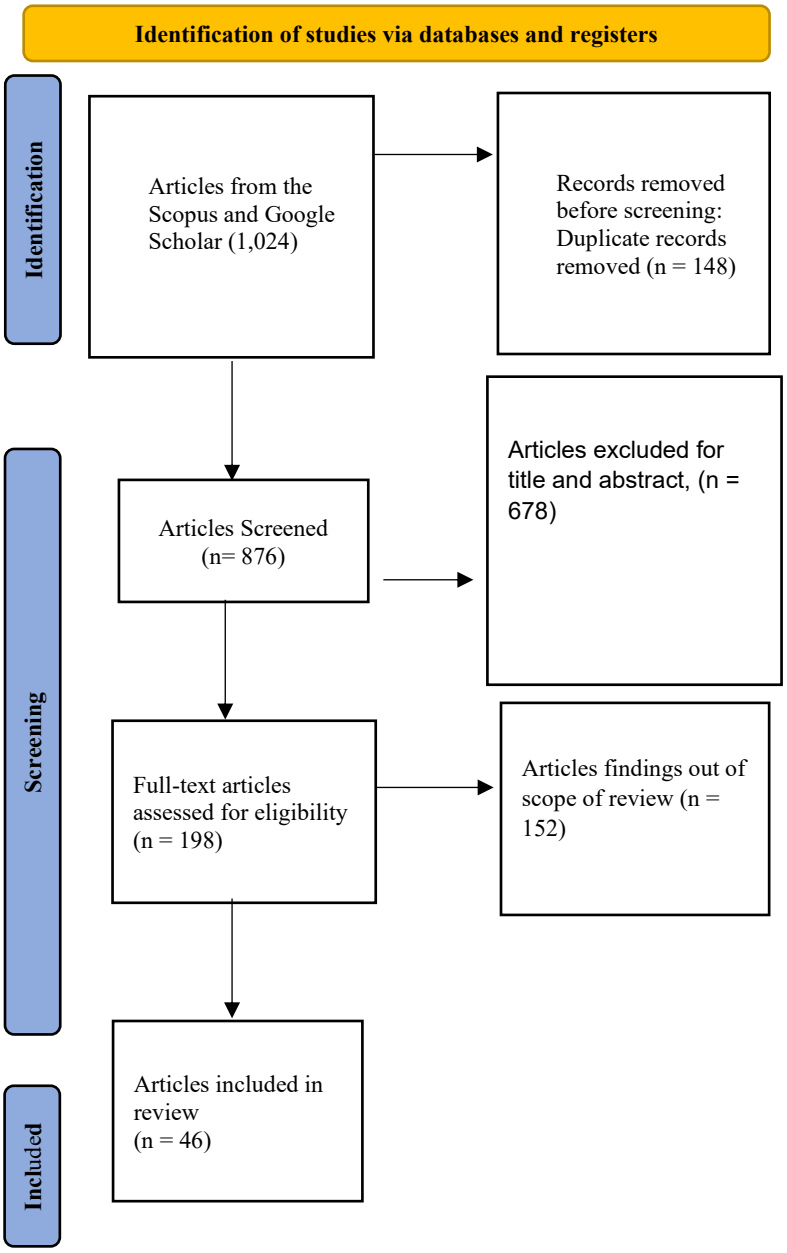


Figure. 1: PRISMA flow diagram

3.0 Data Extraction

As seen in Table 1, data extraction was carried out for all 46 studies that met the inclusion criteria, providing a structured foundation for analysing teacher workforce challenges and the emerging landscape of AI-supported professional learning. A comprehensive data extraction template was developed to ensure consistency, reliability, and comparability across studies, allowing the diverse evidence base to be systematically organised. The template captured core bibliographic and contextual information under the following categories: Author and Year, Country, Teacher Workforce Challenges Identified, AI-supported Professional Learning Tool or Intervention, Methodology, and Journal of Publication. These categories were selected to align directly with the objectives of the review and to enable a coherent mapping of how different educational systems, methodological approaches, and technological interventions intersect with teacher workforce issues. For each study, contextual attributes such as country and research setting were recorded to support an understanding of regional differences in teacher workforce pressures and the adoption of AI-enabled learning tools. Documenting the teacher workforce challenges presented in each article helped reveal patterns across issues such as burnout, shortages, digital strain, workload intensification, and skill gaps. Similarly, capturing the specific AI-supported professional learning tools or interventions described in each study made it possible to compare how machine learning platforms, intelligent tutoring systems, analytics dashboards, recommender systems, and adaptive learning environments were being used to support teachers' professional growth. The methodological details of each study were also carefully extracted to illuminate the diversity of research designs informing the field. Recording the journals of publication further supported an assessment of disciplinary breadth within the

evidence base. This systematic and well-structured data extraction procedure ensured that the substantive contributions of each study were captured accurately and in a format that supported thematic synthesis. By organising the literature according to both conceptual and methodological dimensions, the extraction process created a solid analytical foundation for comparing findings, identifying emerging patterns, and interpreting how AI-supported professional learning responds to teacher workforce challenges across contexts. The robustness of this extraction phase strengthened the validity of subsequent synthesis and ensured that the overall analysis remained aligned with the aims and research questions of the review.

S/N	Author & Year	Country	Teacher Workforce Challenges Identified	AI-Supported Professional Learning Tool/Intervention	Methodology	Journal
1	Al-Zyoud (2020)	UAE	Limited training, low AI literacy, inadequate databases, and insufficient PD pathways.	Intelligent apps, AI-based training pathways, educational software, global educational databases.	Qualitative	Universal Journal of Educational Research
2	Ding et al. (2024)	USA	Low AI literacy; difficulty applying AI knowledge; limited familiarity with AI integration.	Case-based AI PD, direct instruction, structured/ill-structured case analyses	Mixed-Method	Computers and Education Open
3	Nazaretsky et al. (2022)	Israel	Fear of AI replacing teachers; low trust; insufficient AI understanding.	AI-focused PD combining discourse analysis, problem-solving tasks, direct instruction	Qualitative	British journal of educational technology
4	Fatima (2025)	Pakistan	Low AI literacy, ethical concerns, resistance, algorithmic bias.	AI analytics, tutoring systems, adaptive platforms, chatbots, virtual assistants.	Qualitative	AI EDIFY Journal
5	Omidvar and Meihami (2025)	Iran	Low pedagogical/digital literacy, lack of infrastructure, risk of decreased creativity and interaction.	Personalized learning AI tools, assessment support systems, time-management and motivational tools.	Qualitative	Computers and Education: Artificial Intelligence
6	Alwaqdani (2025)	Saudi Arabia	Training burden, fear of job displacement, lack of creativity/critical thinking, trust issues.	AIED tools for personalization, activity design, and time-saving automation.	Quantitative	Education and Information Technologies
7	Vashetina et al. (2022)	Russia, India, Brazil	Low professional development (PD) levels, financial hardship, lack of time, psychological stress, job insecurity	Not stated	Qualitative	Education and Self Development
8	Nyaaba and Zhai (2024)	Ghana	Low GAI literacy, infrastructural gaps, cost barriers, ethical concerns.	Generative AI PD webinar, automatic scoring, academic writing tools, image-generation tools.	Qualitative	Journal of AI
9	Ismail et al. (2024)	Nigeria	Fear of replacement, low AI literacy, insufficient PD, need for continuous training.	AI literacy development, AI-integrated coursework, collaborative	Qualitative	Journal of Artificial Intelligence, Machine Learning and Neural Network

				learning, continuous PD.		
10	Brandão et al. (2024)	Portugal	Low AI literacy, insufficient ethical preparedness, lack of hands-on GenAI experience	AI literacy training, hands-on GenAI activities, collaborative lesson planning.	Qualitative	Digital Education Review
11	Roshan et al. (2024)	Pakistan	Lack of training, low confidence, limited resources	AI-focused professional development	Quantitative	Journal of Asian Development Studies
12	Jamal (2023)	India	Skill gaps, ethical concerns, implementation challenges	AI for personalized learning and teacher support	Qualitative	International Journal of Research and Analytical Reviews
13	Lan (2024)	China	Identity tensions, readiness issues	AI-enhanced teacher training using conceptual models	Mixed-Method	Teaching and Teacher Education
14	Lamrabet et al. (2025)	Morocco	Limited training, poor infrastructure, low familiarity	AI competencies in teacher training programs	Quantitative	International Journal of Information and Education Technology
15	Velander et al. (2024)	Sweden	AI misconceptions, lack of literacy, unclear guidelines	AI literacy-focused professional development	Mixed-Method	Education and Information Technologies
16	Qureshi (2025)	Pakistan	Need for new digital literacy skills, ethical concerns, and shifting pedagogical responsibilities	Intelligent tutoring systems, adaptive learning platforms, automated assessment tools.	Qualitative	AI Edify Journal
17	Sun et al. (2023)	China	Lack of trained CS teachers, limited AI knowledge, and low self-efficacy.	TPACK-based AI professional development program.	Qualitative	Education and information technologies
18	Nurjanah et al. (2025)	Indonesia	Administrative overload, low-tech competence, and limited time for PD.	Use of ChatGPT, Perplexity, Google Sites, and other AI tools for TPD.	Qualitative	JALTCALL Trends
19	Ng et al. (2023)	China	Low AI competence, difficulty adapting to online/blended environments.	Revised AI-integrated DigCompEdu and 21st Century frameworks	Qualitative	Educational technology research and development
20	Uygun (2024)	Turkey	Ethical concerns, privacy fears, trust issues	Provides insights into AI perception for PD planning	Quantitative	Advances in Mobile Learning Educational Research
21	Diana et al. (2025)	Indonesia	Low digital literacy, limited AI experience, heavy workload	AI-assisted training using ChatGPT & Merlin AI	Qualitative	Jurnal Pengabdian Masyarakat Dan Penelitian Thawalib
22	Soelistiono (2023)	Indonesia	Teachers' adaptation to supportive roles and AI integration	Intelligent Adaptive Learning System (AILS)	Qualitative	International Journal of Science Review
23	Rostami and Longo (2024)	Canada	Technical difficulties, lack of training, little admin support	AI-based learning tools for special education	Qualitative	Psychological Research in Individuals with Exceptional Needs
24	Boeve-de Pauw et al. (2022)	Sweden	Difficulty sustaining self-efficacy when applying new practices	None	Quantitative	Environmental Education Research

25	Montero-Mesa et al. (2023)	Spain	Lack of adequate PD for digital risk education; teachers reduced to passive software implementers	None	Qualitative	Education Sciences
26	Giannakos et al. (2025)	USA	Ethical, pedagogical, and ecosystem disruptions related to AI adoption	GenAI tools (LLMs)	Qualitative	Behaviour & Information Technology
27	Kostka and Toncelli (2023)	USA	Concerns about academic integrity and teacher reliance on AI	ChatGPT (LLM)	Qualitative	Tesl-Ej
28	Fernandes et al. (2023)	Portugal	Need for effective PD to enhance teaching practices	None	Mixed-Method	Education Sciences
29	Orland-Barak and Wang (2021)	USA	Limited mentor preparation; conceptual challenges in mentoring models	None	Qualitative	Journal of teacher education
30	Arvin et al. (2023)	Iran	Low digital literacy/readiness, technical issues, resource inequity, lack of policies/ethical guidance	Not a tool test; identifies need for PD, equitable access, and ethical guidelines	Qualitative	AI and Tech in Behavioral and Social Sciences
31	Chiu et al. (2024)	China	Need for teacher mediation of AI; differential effects by student expertise	Chatbot integration in classroom as an AI learning technology; teacher support as moderator	Mixed-Method	Interactive Learning Environments
32	Chen (2025)	China	Need to align teacher support with AI features; importance of motivation	AI features like personalized prompts/adaptive feedback combined with teacher support; hybrid systems	Qualitative	Learning and Motivation
33	Ahmed et al. (2022)	Malaysia	Lack of resources/support/recognition; funding and equipment gaps	Institutional resourcing, incentives, and support mechanisms for AI adoption	Qualitative	Eurasian Journal of Educational Research
34	Tariq (2024)	Pakistan	Fear of job displacement, ethical concerns, reliability doubts, pedagogical limitations, lack of PD	Recommends comprehensive PD, ethical frameworks, collaborative AI designs	Qualitative	AI EDIFY Journal
35	Zhang and Zhang (2024)	China	Digital skill gaps; obstacles to integrating AI in teacher education	Multiple AI applications: classroom management support, inclusive learning tools, adaptive methods, digital literacy supports	Quantitative	Journal of Computer Assisted Learning
36	Roshan et al. (2024)	Pakistan	Low familiarity and confidence; lack of PD and resources	Targeted professional development linked to increased confidence	Qualitative	Journal of Asian Development Studies
37	Pratiwi et al. (2025)	Indonesia	Limited infrastructure, low motivation, low AI literacy, regulatory barriers	Not stated	Qualitative	Journal of Pedagogical Research

38	Chou et al. (2023)	China	Low perceived resource support despite demand; background-related differences	Resource support, innovative teaching	Qualitative	Research and practice in technology enhanced learning
39	Filiz et al. (2025)	Turkey	Technical issues, curriculum misalignment, ethical concerns, cultural/localization barriers	Professional development program using online forums and AI-supported design tasks as PD model	Qualitative	Education and Information Technologies
40	Rui et al. (2025)	Finland	Unpreparedness and ambivalence; gaps in AI competencies and ethics	Specifies training needs across technological, pedagogical, content, and ethical domains	Mixed-Method	Computers and Education Open
41	Nikitina and Ishchenko (2024)	Malaysia	Teacher fears of job loss and lack of training	Conceptual discussion of AI as automation of routine tasks to free teachers for mentoring; implies PD and role redesign	Qualitative	Scientific Journal of Polonia University
42	Daher (2025)	Canada	Risk of deepening digital divide; insufficient teacher AI literacy	Progressive Adaptation	Qualitative	Discover Artificial Intelligence
43	Almethen (2024)	Saudi Arabia	Resource limitations, technical support gaps	Infrastructure investment, and policy support	Qualitative	Journal of Faculty of Education-Assiut University
44	Chou et al. (2024)	China	Need for organizational innovation, recognition and teacher innovative intention	Organizational interventions to boost innovation identification and intention to adopt AI	Mixed-Method	Journal of Computers in Education
45	Shi et al. (2024)	China	Varied teacher perceptions and pedagogical orientations affecting use	Inq-ITS features (virtual tutor, real-time alerts, teacher reports) function as professional supports	Mixed-Method	Education Sciences
46	De la Vall and Araya (2023)	Chile	Need for more human interaction, contextual language complexity, data requirements	VR/AR, adaptive algorithms	Qualitative	International Journal of Social Sciences and Humanities Invention

Table 1: Data extraction table

3.1 Year of Publication Analysis

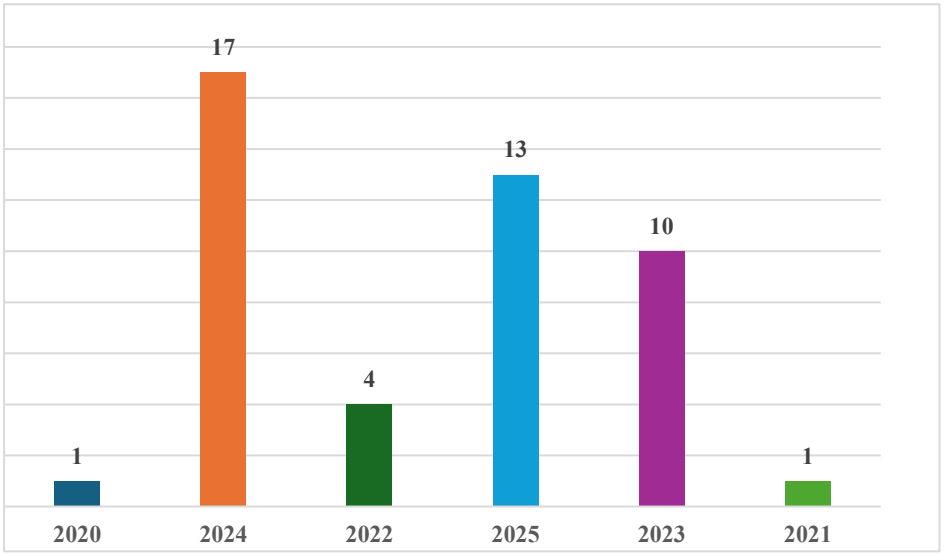


Figure 2: Publication Year Analysis

The temporal distribution of the 46 studies included in this systematic review illustrates a sharp and accelerating growth in scholarly interest surrounding teacher workforce challenges and AI-supported professional learning. As shown in Figure 2, the majority of publications fall between 2022 and 2025, reflecting the increasing urgency to address teacher shortages, burnout, digital skill gaps, and evolving professional development needs within technology-driven educational systems.

The year 2024 recorded the highest number of studies (n = 17), marking a peak in academic attention toward the transformative role of artificial intelligence in teacher learning and support. This surge corresponds with a period in which global education systems intensified their adoption of AI tools, analytics platforms, and automated instructional support systems, prompting researchers to examine their effectiveness, limitations, and broader implications for the teaching profession.

The second-highest contribution came from 2025, with 13 studies, reflecting continued momentum and the emergence of more mature analyses of AI-enabled professional learning. These studies often build on earlier conceptual and empirical work, offering deeper insights into the integration of AI into teacher development ecosystems and the practical challenges experienced in real-world settings. The year 2023 contributed 10 studies, representing a substantial body of literature produced during a time when educational institutions were consolidating digitally enhanced teaching practices initially adopted during the pandemic era. Research in this period frequently examined teacher workload, digital stressors, and the increasing reliance on AI-based tools to enhance instructional quality and support career-long professional learning. Earlier contributions were more modest, with four studies published in 2022, and only one study each in 2021 and 2020. These foundational studies captured early reflections on the emerging role of AI in teacher support and highlighted initial concerns about digital competency, workload intensification, and the need for innovative professional development models. Despite their limited number, these early studies laid important groundwork that informed the broader surge in research from 2023 onward. Overall, the pattern shows that scholarly interest in AI-supported teacher professional learning has grown rapidly, with more than 85% of the reviewed studies published between 2023 and 2025. This trend underscores the contemporary relevance of the topic, the urgency of addressing global teacher workforce challenges, and the accelerating pace at which AI technologies are being integrated into professional learning environments. The publication trajectory also reinforces the timeliness of the present review, positioning it within a rapidly expanding and increasingly critical research domain.

3.2 Country of Publication Analysis

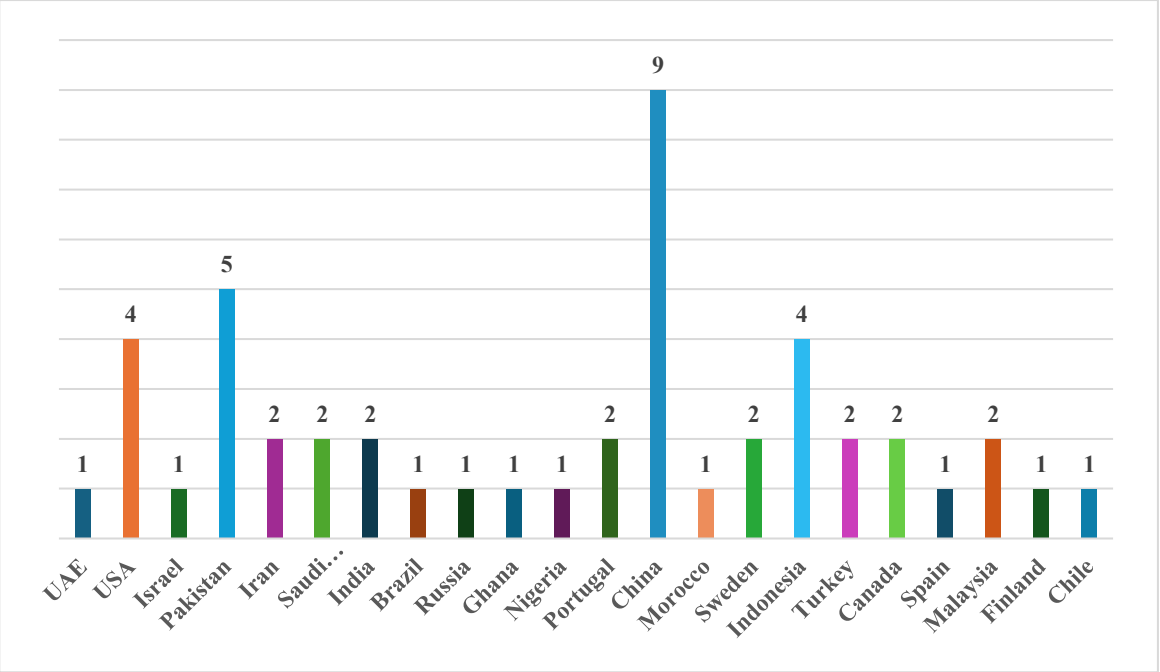


Figure 3: Research Country Analysis

The geographical distribution of the 46 studies included in this review demonstrates a wide global interest in understanding teacher workforce challenges and the expanding role of AI-supported professional learning. As illustrated in Figure 3, research contributions span multiple continents, reflecting the universal nature of teacher shortages, digital skill requirements, and the rising relevance of AI-driven educational tools across diverse educational systems. China emerged as the most dominant contributor with nine studies, indicating significant national investment in AI-driven educational technologies and a strong research focus on how these tools can support teacher capacity-building and alleviate systemic workforce pressures. China's leadership in AI research likely contributes to this high output, as its educational sector has rapidly integrated intelligent tutoring systems, analytics dashboards, and automation tools into professional development initiatives. South Asia and Southeast Asia also showed considerable engagement. Pakistan contributed five studies, while Indonesia provided four, highlighting growing regional interest in AI-enabled teacher learning, particularly in countries with large, diverse, and resource-constrained education systems. India and Malaysia each contributed two studies, suggesting an increasing scholarly focus on digital transformation and teacher workforce needs within emerging economies. North America and Europe also featured prominently. The United States contributed four studies, reflecting its strong research culture and active exploration of AI applications in teacher support, instructional enhancement, and professional development. European contributions came from Sweden (two studies), Portugal (two studies), Spain (one), and Finland (one), showing consistent interest in leveraging AI to support teachers in high-technology, innovation-driven education systems. Canada added two studies, aligning with its growing adoption of AI and analytics in school systems. In the Middle East, countries such as Saudi Arabia (two studies), Iran (two), the UAE (one), and Israel (one) produced research that underscores regional investments in digital infrastructure and AI-driven educational reforms. These contributions reflect a broader effort to strengthen teacher training and support mechanisms as part of national digital transformation strategies. Contributions from Africa and Latin America, though smaller in volume, highlight important emerging perspectives. Ghana and Nigeria each contributed one study, offering insights from contexts where teacher shortages, workload pressures, and limited training opportunities remain acute challenges. Similarly, Brazil (one study) and Chile (one) represent Latin American engagements with AI-supported teacher learning. Overall, the country distribution reveals a diverse and globally representative evidence base. The widespread geographical spread underscores that teacher workforce challenges, and the search for AI-enhanced solutions, are shared concerns across both developed and developing nations. This broad representation strengthens the generalizability of the review and highlights AI-supported professional learning as a global educational priority.

3.3 Methodology Analysis

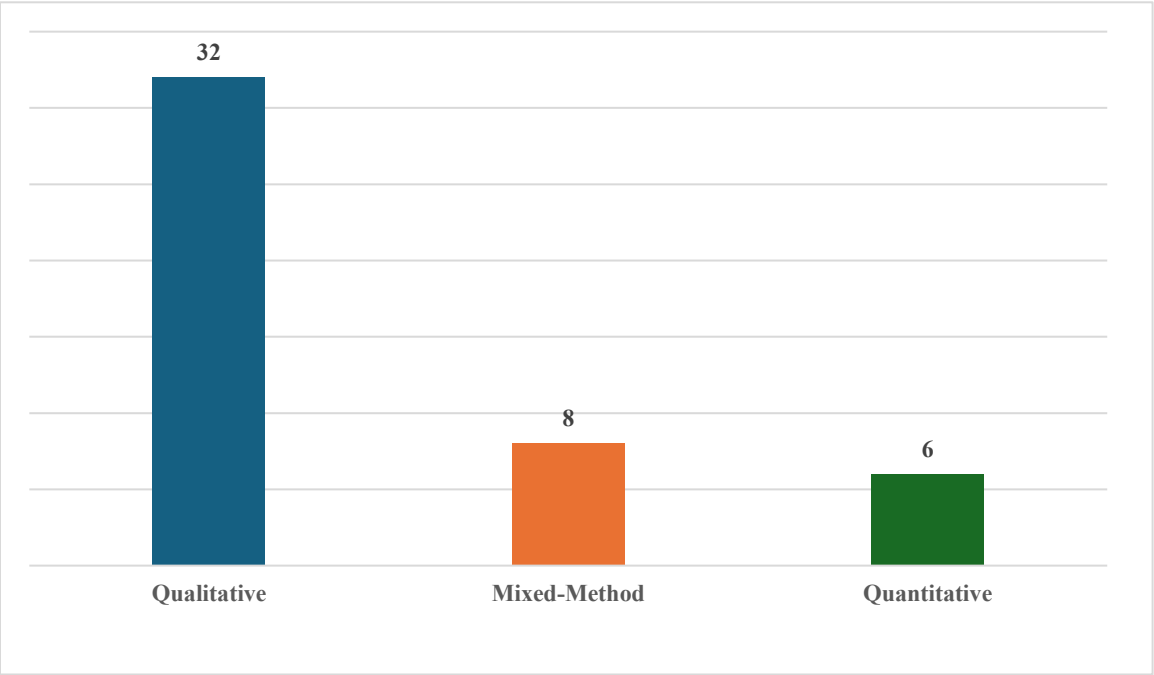


Figure 4: Methodology Analysis

As seen in Figure 4, the methodological distribution of the reviewed studies provides a clear picture of how researchers have approached the investigation of teacher workforce challenges within the context of emerging AI-supported professional learning. Across the included publications, qualitative research designs were overwhelmingly dominant (n = 32), indicating a strong scholarly emphasis on capturing teachers' lived experiences, perceptions, and contextual realities as they navigate rapidly evolving AI-integrated educational environments. These studies frequently employed interviews, focus groups, classroom observations, and thematic analyses to illuminate how teachers interpret AI tools, manage associated anxieties, and respond to shifting professional expectations. Quantitative studies represented a smaller but meaningful segment of literature (n = 6). These studies typically relied on surveys, experimental designs, or statistical modeling to measure variables such as AI literacy levels, attitudes toward AI tools, adoption rates, and the relationship between AI integration and teacher outcomes such as workload, self-efficacy, and professional learning engagement. Their contribution demonstrates an increasing interest in producing measurable and generalizable evidence to inform policy and system-level decision-making around AI in education. Mixed-methods research accounted for eight studies (n = 8), reflecting researchers' intent to integrate the depth of qualitative inquiry with the precision of quantitative approaches. These studies were particularly valuable in triangulating teachers' subjective experiences with empirical patterns, offering holistic insights into emerging challenges such as AI-related professional development needs, technological inequities, and the changing nature of pedagogical labor. Overall, the methodological landscape reveals a field that is both developing and highly exploratory, with researchers relying predominantly on qualitative methods to unpack the nuanced and context-dependent challenges teachers face in AI-supported ecosystems. The presence of quantitative and mixed-method studies further strengthens the evidence base, ensuring that conclusions drawn from this review are grounded in both rich experiential narratives and empirically validated patterns.

3.4 Teacher Workforce Challenges Identified Across the Reviewed Studies

Across the body of reviewed literature, a consistent and multifaceted picture emerges of teachers struggling to adapt to the rapid rise of AI-supported professional learning environments. The challenges identified span technological, pedagogical, psychological, infrastructural, and ethical domains, revealing deep structural tensions within the teacher workforce as educational systems integrate increasingly sophisticated AI tools.

1. Pervasive Low AI Literacy and Limited Training Opportunities

The most dominant challenge across studies is the widespread lack of AI literacy among teachers. Numerous publications reported that teachers possess limited understanding of AI concepts, weak familiarity with AI-integrated pedagogies, and insufficient hands-on experience with generative AI tools. Compounding this issue is inadequate access to structured professional development (PD) pathways, limited time for training, and a persistent shortfall of qualified trainers or mentors. Teachers frequently expressed low confidence, difficulty translating abstract AI knowledge into practice, and concerns about

sustaining self-efficacy when applying new AI-supported instructional strategies. Studies also highlighted gaps in specialized training, for example, the shortage of AI-competent computer science teachers and mentors prepared to guide colleagues in AI-rich environments.

2. Infrastructural, Resource, and System-Level Limitations

Beyond skill deficits, structural constraints significantly hinder teachers' capacity to adopt AI. Several studies pointed to inadequate infrastructure, including unreliable hardware, poor connectivity, and insufficient databases, to support effective AI integration. Resource inequity across schools and regions further exacerbates disparities, leaving many teachers without essential devices, software, or technical support. Financial barriers, limited funding for technological upgrades, and lack of administrative support were repeatedly identified. Additionally, curriculum misalignment and unclear policy guidelines restrict teachers' ability to integrate AI meaningfully within existing educational systems. These conditions often force teachers into passive roles as mere implementers of software rather than empowered pedagogical designers.

3. Ethical, Privacy, and Trust Concerns

Ethical uncertainties surrounding AI use form another major cluster of challenges. Teachers expressed concern about algorithmic bias, unreliable AI outputs, data privacy risks, and the opacity of AI decision-making processes. The lack of ethical preparedness, especially regarding responsible AI use, academic integrity, and student data protection, was widely reported. Low trust in AI systems often stems from limited understanding of how algorithms work, cultural or contextual biases embedded in AI tools, and fears of misalignment with pedagogical values. These concerns collectively contribute to ambivalence toward AI adoption, even among teachers who recognize its potential benefits.

4. Psychological Stressors, Fear of Job Displacement, and Identity Tensions

A substantial portion of the literature highlights the psychological burden associated with AI's growing presence in education. Teachers reported stress, anxiety, and job insecurity, driven by fears that AI could diminish their professional identity or even replace aspects of their instructional role. Concerns about reduced creativity, diminished teacher–student interaction, and the shifting of teachers into more supportive, or even administrative, roles further fuel these anxieties. Identity tensions arise as educators attempt to reconcile traditional pedagogical expertise with the expectation to adapt to AI-mediated forms of teaching and assessment. These emotional and cognitive pressures often compound existing workload demands, administrative overload, and time constraints.

5. Pedagogical and Instructional Integration Challenges

Many studies documented teacher difficulty integrating AI into meaningful pedagogical practice. Low digital and pedagogical literacy, mismatches between AI capabilities and curricular objectives, and uncertainty about how to support diverse student needs in AI-rich classrooms all hinder effective implementation. Teachers reported challenges with maintaining pedagogical agency, aligning AI-supported activities with learning goals, and mediating AI-driven learning experiences for students with varying levels of digital expertise. Additional concerns include risks of over-reliance on AI, reduced opportunities for creative or critical thinking, and potential erosion of human-centered teaching practices.

6. Contextual, Cultural, and Ecosystemic Barriers

Teachers' engagement with AI is also shaped by broader ecosystem conditions. Cultural and linguistic barriers, especially the challenges of contextualizing AI tools for local realities—were widely noted. Teachers highlighted the need for AI systems that reflect diverse student backgrounds and avoid reinforcing cultural or linguistic biases. Furthermore, differences in teacher motivation, pedagogical orientation, and readiness influence adoption patterns. Studies also emphasized that without organizational recognition of teacher innovation, support structures, and aligned AI features, teachers are less likely to integrate AI sustainably into their practice. These findings reveal that the challenges teachers face in AI-supported educational environments are deeply interconnected. Low AI literacy and insufficient PD opportunities sit at the center of a broader ecosystem of infrastructural constraints, ethical uncertainties, psychological pressures, pedagogical complexities, and cultural misalignments. Addressing these challenges requires systemic and coordinated efforts that go beyond technical training, encompassing policy reform, ethical frameworks, leadership support, and the redesign of professional learning models that empower teachers rather than marginalize them in the age of AI.

3.5 AI-Supported Professional Learning Tools and Interventions Identified Across the Reviewed Studies

The reviewed studies reveal a diverse landscape of AI-supported professional learning tools and interventions designed to enhance teachers' skills, support instructional decision-making, and improve professional development models. Although the approaches vary considerably in structure and technological sophistication, several coherent patterns emerge across the literature.

1. Intelligent Applications and Adaptive Learning Systems

Many studies identified the use of intelligent educational applications that operate through automation, real-time analytics, and adaptive feedback. These include AI-based tutoring systems, intelligent adaptive learning systems, global educational databases, and platforms that provide diagnostic information to guide teacher decision-making. Applications such as virtual assistants, chatbots, and real-time alert systems were introduced to support both instructional monitoring and professional learning. The Inq-ITS platform, adaptive learning environments, and VR or AR applications exemplify how AI can function as a partner in professional development by offering immediate insights and content personalization.

2. AI-Focused Professional Development Programs

A large proportion of studies implemented or evaluated structured professional development programs centered on building teachers' AI literacy. These programs typically combined direct instruction with hands-on exploration, collaborative lesson design, discourse analysis activities, and problem-based learning tasks. Some interventions utilized conceptual frameworks such as TPACK, DigCompEdu, 21st century competencies, or revised models specifically designed to integrate AI competencies into teacher education. Several studies described AI-focused PD models delivered through webinars, online forums, and course-based AI literacy curricula that enabled teachers to gain practical experience with AI tools in authentic contexts.

3. Generative AI and Emerging AI Tools in Teacher Training

Generative AI tools played a major role in many of the identified interventions. Platforms such as ChatGPT, Perplexity, Merlin AI, and various academic writing and automatic scoring tools were used to support teacher learning. Image generation tools and other large language model applications were integrated into workshops, collaborative planning exercises, and content development tasks. These interventions helped teachers understand both the capabilities and limitations of generative AI, enhanced their confidence in leveraging these tools, and supported the development of new pedagogical strategies that incorporate AI output responsibly.

4. Personalized and Teacher-Supportive AI Systems

Several studies examined AI tools designed to personalize learning pathways for teachers. These included systems offering personalized prompts, motivational feedback, time-management recommendations, and activity design suggestions. AI features were often combined with human support to form hybrid teacher development ecosystems where automated feedback was moderated by teacher mentors or facilitators. These personalized systems supported individual growth by enabling teachers to work at their own pace while receiving context-sensitive guidance.

5. AI-Integrated Coursework and Collaborative Learning Models

AI literacy training embedded in formal coursework was identified across multiple studies. These approaches involved structured engagement with AI tools through collaborative learning models, group tasks, and shared problem-solving. Teachers participated in AI-supported design tasks, used AI to develop teaching materials, and engaged in online professional learning communities. This approach positioned AI not only as a tool for automation but also as a catalyst for collective knowledge-building among educators.

6. Conceptual and System-Level Professional Learning Interventions

A few studies focused on conceptual discussions, policy strategies, and ecosystem-level interventions rather than specific tools. These papers emphasized the need for ethical frameworks, infrastructural investment, organizational incentives, and the redesign of teacher roles in AI-mediated educational environments. Others highlighted the importance of aligning teacher support structures with AI functionalities to ensure meaningful adoption. In several instances, studies did not implement a specific AI tool but instead identified training needs, recommended equitable access strategies, or provided frameworks for guiding future professional development.

7. Broad AI Applications Supporting Inclusive and Innovative Practice

Some studies expanded their focus to include multiple AI applications that support diverse pedagogical needs. Examples include AI for inclusive education, classroom management, digital literacy support, and adaptive instructional methods. These tools allowed teachers to streamline administrative tasks, reduce workload, and gain insights that guided innovative teaching practices. Professional development linked to these tools often resulted in increased teacher confidence and readiness to integrate AI meaningfully into daily teaching.The reviewed literature demonstrates that AI-supported professional learning interventions range from highly structured PD programs and generative AI workshops to intelligent adaptive systems and conceptual policy frameworks. Although the tools differ in purpose, they collectively reflect a shift toward more data-informed, personalized, and technology-enhanced professional development for teachers. The integration of generative AI, adaptive platforms, and AI literacy training programs shows that professional learning in the age of AI is increasingly multi-modal, interactive, and shaped by both human expertise and machine intelligence.

4.0 Discussion of Findings

RQ1: Major Teacher Workforce Challenges

Across the reviewed literature, a consistent picture emerges of a teacher workforce grappling with profound structural, technological, and pedagogical challenges as education systems transition toward AI-supported environments. The most pervasive issue highlighted by scholars is the widespread lack of AI literacy among teachers, reported by Al-Zyoud (2020), Ding et al. (2024), Fatima (2025), Nyaaba and Zhai (2024), Brandão et al. (2024), and numerous others. Teachers across contexts are entering classrooms without adequate understanding of how AI functions or how it can be pedagogically integrated, resulting in persistent uncertainty, low confidence, and resistance. This shortage of knowledge is further compounded by insufficient exposure to hands-on AI tools, limited digital competencies, and a lack of structured training pathways, as emphasized by Sun et al. (2023), Diana et al. (2025), Velander et al. (2024), and Roshan et al. (2024). Collectively, these gaps signal a global skills deficit that constrains teachers' ability to adapt to AI-enhanced professional learning models. Another recurring challenge concerns teachers' fears, ethical concerns, and emotional tensions surrounding AI adoption. Several studies, including those by Nazaretsky et al. (2022), Alwaqdani (2025), Tariq (2024), Qureshi (2025), and Uygun (2024), show that many teachers distrust AI systems, worry about privacy and data misuse, and fear that AI may replace or diminish the human elements of teaching. These concerns generate psychological barriers to adoption, reflected in anxiety, skepticism, and moral unease. Lan (2024) further deepens this perspective by identifying identity-related tensions, where teachers grapple with redefining their professional roles in relation to technology. Such emotional and ethical apprehensions accentuate the complexity of integrating AI into teacher development, suggesting that technological readiness alone is insufficient without addressing deeper cultural and relational dimensions. The literature also highlights widespread infrastructural and systemic barriers that undermine teacher readiness for AI-supported learning. Studies conducted across multiple contexts, including those by Vashetina et al. (2022), Lamrabet et al. (2025), Pratiwi et al. (2025), and Almethen (2024), reveal challenges such as insufficient technological infrastructure, unequal access to devices and internet, financial constraints, and limited availability of premium AI tools. These constraints are further exacerbated by weak institutional support, as reported by Ahmed et al. (2022), Rostami and Longo (2024), and Omidvar and Meihami (2025), who found that many teachers lack access to technical assistance, administrative backing, and coherent policy frameworks that guide AI implementation. Curriculum misalignment, regulatory gaps, ambiguous guidelines, and fragmented educational databases add a layer of uncertainty that complicates teachers' efforts to integrate AI meaningfully. Compounding these issues are persistent professional development shortcomings. Numerous studies, including those by Al-Zyoud (2020), Roshan et al. (2024), Montero-Mesa et al. (2023), and Orland-Barak and Wang (2021), show that teachers often lack access to sustained, high-quality professional learning opportunities that build digital and pedagogical capacity. Even where PD exists, it is frequently inadequate, poorly structured, or disconnected from classroom needs. Teachers struggle with time constraints, heavy workloads, and administrative overload, as noted by Nurjanah et al. (2025) and Chou et al. (2023). These pressures limit their ability to engage in ongoing training, leading to a widening gap between technological innovation and teachers' practical capacity to use AI effectively. Finally, broader contextual and socio-cultural factors further shape the landscape of workforce challenges. Studies such as those by Filiz et al. (2025) highlight cultural barriers and localization issues that hinder the applicability of AI content, while De la Vall and Araya (2023) emphasize the enduring importance of human interaction and contextual language complexity in teacher learning. Together, these perspectives underscore that teacher workforce challenges are not purely technical, but are intertwined with cultural expectations, pedagogical traditions, and the human dimensions of teaching. Overall, the literature collectively portrays a teacher workforce struggling to adapt to rapid technological shifts due to limited AI literacy, pervasive ethical concerns, systemic infrastructural constraints, and insufficient professional development support. These interconnected challenges reveal that effective AI integration in teacher learning requires not only technological tools and training but also structural reform, emotional support, and context-sensitive implementation strategies.

RQ2: AI-Supported Professional Learning Tools and Approaches

The literature describes a diverse ecosystem of AI-supported tools and pedagogical approaches designed to build teacher competence, ranging from intelligent tutoring systems and adaptive learning platforms to generative AI, chatbots, and AI-driven analytics. Several studies highlight concrete tool classes: intelligent educational applications and interconnected AIED systems that support real-time analytics and structured development pathways (Al-Zyoud, 2020; Soelistiono, 2023; Fatima, 2025), automated scoring and writing aids alongside image generation and other generative applications showcased in PD webinars (Nyaaba & Zhai, 2024; Kostka & Toncelli, 2023), and conversational agents used both for teacher experimentation and for classroom scaffolding (Chiu et al., 2024; Chiu et al., 2024; Nurjanah et al., 2025). Beyond tools themselves, research documents structured professional learning models that foreground active, practice-based learning: case-based PD with video-recorded discussions and problem-solving tasks (Ding et al., 2024), TPACK-informed interventions combining programming, lesson design, and pedagogical training (Sun et al., 2023), experiential in-class application with peer collaboration and reflection (Rostami & Longo, 2024), and forums with design tasks that encourage iterative development (Filiz et al., 2025). Several frameworks and programmatic proposals further articulate how AI should be taught and integrated:

the Intelligent-TPACK mapping of technological, pedagogical, content, and ethical training needs (Rui et al., 2025), EQUIP's emphasis on ethical governance and partnerships (Daher, 2025), and competency reconceptualizations that adapt DigCompEdu for AI affordances (Ng et al., 2023). Studies also emphasize the emotional and organizational levers that make these tools effective; for example, AI framed as a collaborator rather than a replacement can build trust (Nazaretsky et al., 2022), while organizational innovation and teachers' intentions drive uptake (Chou et al., 2024). Altogether, the field presents both technological variety and pedagogical sophistication: AI tools are being deployed not only to automate tasks but to support personalized teacher learning, formative feedback, curriculum design, and reflective practice, supplied through a mix of short webinars, intensive structured interventions, and long-term integrated programs (Diana et al., 2025; Nurjanah et al., 2025; Lan, 2024). Nevertheless, across studies there is an implicit caution that tool availability alone is insufficient; effectiveness depends on contextualized mentoring, scaffolded experimentation, and alignment with curricular and ethical guidance (Brandão et al., 2024; Shi et al., 2024; Filiz et al., 2025).

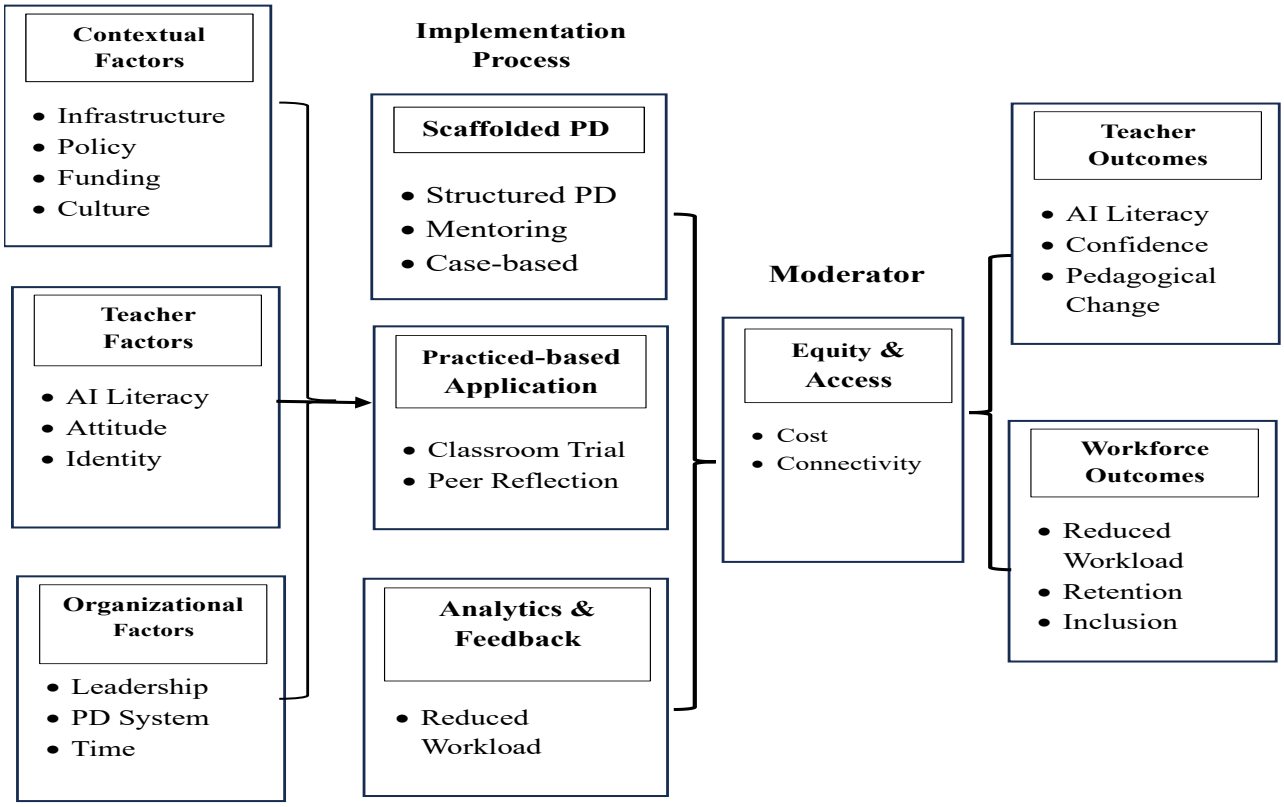
RQ3: Effectiveness of AI-Supported Professional Learning Systems

Evaluations of AI-supported professional learning reveal promising but conditional effectiveness: many studies report gains in AI knowledge, confidence, and short-term readiness, while also noting limited or uneven translation into sustained classroom change. Empirical interventions show that AI-infused PD can significantly improve conceptual understanding, lesson planning, and self-efficacy when designed around coherent frameworks such as TPACK or Intelligent-TPACK (Sun et al., 2023; Rui et al., 2025). Programs using case-based instruction, video reflection, and hands-on practice increase conceptual literacy and deeper reasoning in complex cases (Ding et al., 2024), and GenAI-focused PD that combines literacy, experimentation, and peer collaboration enhances teachers' ability to implement tools ethically and pedagogically (Brandão et al., 2024). Multiple studies report reductions in workload and improvements in instructional capacity when AI tools are paired with adequate training—teachers gained time savings, improved materials design, and greater motivation to integrate AI (Fatima, 2025; Alwaqdani, 2025; Diana et al., 2025; Nurjanah et al., 2025). At the same time, evidence points to limits: conceptual gains do not always translate automatically into classroom enactment without ongoing support, iterative practice, and institutional alignment (Ding et al., 2024; Boeve-de Pauw et al., 2022). Conditional effects are also evident in studies of AI as in-class collaborators, where tool impact depended on student competence and teacher scaffolding (Chiu et al., 2024), and where perceived effectiveness was mediated by teacher support and student motivation (Chen, 2025). Several authors further emphasize infrastructure and acceptance as moderators of effectiveness: when equipment, connectivity, or trust are lacking, AI's benefits are muted or unevenly distributed (Omidvar & Meihami, 2025; Lamrabet et al., 2025; Qureshi, 2025). Longitudinal studies suggest that short-term PD can produce initial dips in efficacy followed by recovery and stronger practice only when PD is sustained, iterative, and supported through communities of practice (Boeve-de Pauw et al., 2022; Fernandes et al., 2023). In sum, AI-supported systems are effective in enhancing knowledge, reducing routine burdens, and enabling new pedagogical designs when programs are robustly scaffolded, contextually sensitive, and accompanied by policy, infrastructure, and emotional supports; absent these conditions, effectiveness is partial, fragile, and highly context dependent.

RQ4: Gaps, Risks, and Opportunities Exist for the Integration of AI in Teacher Professional Learning

Across the reviewed literature, the integration of AI in teacher professional learning reveals a complex landscape of gaps, risks, and opportunities that collectively shape the future of AI-mediated teacher development. A dominant theme across the studies is that despite AI's transformative potential, systemic issues persist that limit its meaningful implementation. Many authors point to fundamental gaps related to teacher readiness, training, and infrastructure. For example, Al-Zyoud (2020), Roshan et al. (2024), Lamrabet et al. (2025), and Rostami and Longo (2024) all emphasize persistent shortages in training resources, inadequate infrastructure, and insufficient institutional support. Correspondingly, Ng et al. (2023) and Sun et al. (2023) identify the absence of structured competency frameworks and large-scale AI-focused professional development programs, suggesting that teachers remain underprepared to integrate AI effectively. These gaps are further deepened by limited digital literacy, as highlighted by Soelistiono (2023), and affordability barriers, as discussed by Nyaaba and Zhai (2024), making equitable adoption difficult, particularly in resource-constrained contexts. Beyond structural limitations, several authors foreground psychological, ethical, and identity-related gaps that complicate teachers' engagement with AI. Studies by Nazaretsky et al. (2022), Alwaqdani (2025), Ismail et al. (2024), and Velander et al. (2024) reveal deep-seated issues of low trust, emotional resistance, fears of unintended consequences, and apprehension about potential job displacement. Relatedly, Lan (2024) observes that AI adoption often triggers identity tensions, including fears of dehumanization and loss of professional autonomy, while Nikitina and Ishchenko (2024) and Qureshi (2025) similarly note teachers' anxiety about role shifts and concerns over whether AI may replace elements of human judgment. These findings converge with broader ethical concerns raised by Jamal (2023), Fatima (2025), Uygun (2024), and Kostka and Toncelli (2023), who point to algorithmic bias, privacy threats, fairness issues, and risks of misinformation, problems exacerbated when teachers lack the literacy required to detect inaccuracies or critically evaluate AI-generated content. The risks associated with premature or unguided adoption also feature prominently. Giannakos et al. (2025) warn about disruptions to learning ecosystems, ethical misuse, and the dangers of adopting generative AI without evidence-based models, while Arvin et al. (2023) and Daher (2025) highlight the possibility that uneven access to AI tools and training could widen existing educational inequities. Excessive reliance on AI poses its own challenges, with Omidvar and Meihami (2025) cautioning that overdependence may reduce human interaction and creativity, while Ahmed et al. (2022) observe that inconsistent or

insufficient institutional investment creates scalability risks. These concerns are amplified by Filiz et al. (2025), who argue that without longitudinal research, long-term implications of AI-based TPD remain poorly understood. Similarly, Nurjanah et al. (2025) identify the lack of detailed examination of specific AI tools as a persistent research gap, noting that insufficient evaluation hinders confident adoption. Despite these challenges, the reviewed literature presents a wide spectrum of opportunities for advancing teacher professional learning through AI. A recurring observation is that AI has the capacity to enhance personalization, streamline instructional design, and reduce teacher workload. Authors such as Fatima (2025), Omidvar and Meihami (2025), Alwaqdani (2025), Nyaaba and Zhai (2024), and Nikitina and Ishchenko (2024) highlight opportunities for differentiated learning pathways, improved assessment, and enhanced content creation. Similarly, Brandão et al. (2024) and Giannakos et al. (2025) emphasize that generative AI can strengthen lesson design, produce automated feedback, and support richer student guidance. Opportunities for improving teacher confidence, creativity, and well-being are also noted by Ismail et al. (2024) and Arvin et al. (2023), suggesting that AI can support professional growth when used as a partner rather than a replacement. At the system level, several studies identify opportunities for rethinking teacher education and institutional strategies. Tariq (2024), Ahmed et al. (2022), Rui et al. (2025), and Chou et al. (2024) argue that the institutional environment, through supportive policies, incentives, and innovative cultures, can play a decisive role in enabling responsible and effective AI integration. Al-Zyoud (2020) and Daher (2025) extend this by highlighting opportunities for global data networks, scalable equity-focused frameworks, and context-responsive professional learning models. These systemic perspectives align with Lamrabet et al. (2025) and Sun et al. (2023), who frame the integration of AI competencies into teacher education curricula as a long-term opportunity capable of building sustained professional readiness. Collectively, the findings show that while AI presents far-reaching opportunities for improving professional learning, these benefits are conditional upon addressing extensive gaps in training, infrastructure, ethics, and policy. The literature



consistently suggests that responsible, teacher-centered, and ethically grounded implementation strategies are necessary to mitigate risks related to bias, inequity, identity tensions, and pedagogical misalignment. The convergence of studies indicates that the potential of AI-supported professional learning will only be realized when technological advancements are paired with robust frameworks, comprehensive and continuous PD, and institutional structures that prioritize teacher agency, trust, and well-being.

Figure 5: Conceptual Framework by author

The conceptual framework (Figure 5) illustrates how AI-supported professional learning operates within a system shaped by contextual, teacher-level, and organizational factors, which jointly influence the implementation processes and ultimately lead to teacher and workforce outcomes. It also integrates key moderators, particularly issues of equity and access, that determine the overall effectiveness and inclusiveness of AI-supported professional development (PD). At the foundation of the framework, contextual factors such as infrastructure, policy environments, funding structures, and institutional culture shape teachers' readiness and capacity to engage with AI-enhanced learning systems. Multiple studies emphasized the critical role of infrastructure and organizational support in determining whether AI tools can be integrated effectively. For instance, Omidvar and Meihami (2025) and Alwaqdani (2025) found that inadequate infrastructure and limited technological support

constrain the uptake of AI-based PD. Similarly, Fatima (2025) and Ahmed et al. (2022) highlight how insufficient institutional backing, poor data systems, and resource limitations slow adoption and increase disparities in teacher preparedness. Teacher factors, including AI literacy, attitudes, and professional identity, serve as another core input in the framework. Findings from Nazaretsky et al. (2022) show that trust, fear of replacement, and unfamiliarity with AI significantly shape teachers' acceptance and engagement. Lan (2024) and Lamrabet et al. (2025) similarly show that teacher identity tensions, low literacy, and inconsistent technological proficiency can either support or hinder the successful uptake of AI tools. These insights position teacher-level dispositions not as peripheral elements but as central determinants of how AI-supported learning unfolds. Organizational factors, including leadership, structured PD systems, and workload conditions, further shape the implementation landscape. Studies such as Ismail et al. (2024) and Filiz et al. (2025) argued that systematic training programs, supportive leadership, and clear institutional guidelines are prerequisites for meaningful integration. Rui et al. (2025) and Nikitina and Ishchenko (2024) reinforce the need for strategic direction and training frameworks to prevent misuse, ensure ethical grounding, and scaffold teacher development. These three categories of input factors feed directly into the implementation processes, represented in the framework by scaffolded PD, practice-based application, and analytics-driven feedback. Evidence overwhelmingly supports the view that AI-supported PD is most effective when structured, iterative, and aligned with pedagogical frameworks. For example, Sun et al. (2023) demonstrate that TPACK-aligned, scaffolded PD significantly strengthens teachers' AI knowledge, technical skills, and instructional confidence. Ding et al. (2024) and Brandão et al. (2024) similarly show that mentoring, case-based learning, and hands-on experimentation enhance conceptual understanding and literacy, although Ding et al. note that these gains do not always translate directly into classroom implementation. The second process, practice-based application, captures how teachers engage in classroom trials, reflection, and peer collaboration. Empirical evidence from Boeve-de Pauw et al. (2022) and Fernandes et al. (2023) indicates that sustained, practice-oriented PD leads to longer-term changes in pedagogy, even when initial attempts are challenging. Nurjanah et al. (2025) also confirm that actual classroom engagement with AI tools boosts pedagogical, social, and technological competence. The third implementation pathway, analytics and feedback, reflects the role of AI in automating routine tasks, providing data-driven insights, and reducing workload pressures. Qureshi (2025), Diana et al. (2025), and Rostami and Longo (2024) highlight how AI-supported feedback systems improve efficiency, reduce administrative burdens, and enhance teacher motivation. This pathway aligns with findings from Al-Zyoud (2020) and Arvin et al. (2023), who identify learning analytics and automation as major opportunities for enhancing professional growth and supporting teachers' evolving roles. The framework incorporates equity and access as a critical moderating variable. Studies by Nyaaba and Zhai (2024), Daher (2025), and Giannakos et al. (2025) emphasize that cost, connectivity, digital inequality, and ethical vulnerabilities shape who benefits from AI-supported PD. These moderators determine whether professional learning systems promote inclusion or deepen disparities. Velander et al. (2024) and Tariq (2024) further warn that without ethical safeguards and equitable implementation, teachers may misinterpret AI capabilities or experience heightened job insecurity. These processes and moderators culminate in two categories of outcomes: teacher outcomes and workforce outcomes. The literature strongly supports improvements in AI literacy, confidence, instructional competence, and pedagogical innovation. For example, Roshan et al. (2024), Lamrabet et al. (2025), and Ismail et al. (2024) find that AI PD enhances knowledge, motivation, and readiness for integration, while Jamal (2023) and Chou et al. (2024) highlight improvements in instructional quality and professional identity alignment. Workforce-level outcomes include reduced workload, increased retention, and strengthened inclusion, consistent with findings from Fatima (2025), Diana et al. (2025), Nurjanah et al. (2025), and Alwaqdani (2025). Overall, the framework synthesizes cross-study evidence to show that AI-supported professional learning is not a linear technology adoption process but an interconnected ecosystem. Its effectiveness depends on systemic supports, teacher readiness, structured implementation mechanisms, and equitable access conditions. When these elements align, AI has the potential to significantly enhance teacher professional competence, reduce administrative pressures, and support long-term workforce sustainability, as evidenced across the reviewed studies.

5.0 Conclusion

This systematic review of 46 peer-reviewed studies provides a comprehensive understanding of teacher workforce challenges and the emerging role of AI-supported professional learning in addressing them. The evidence shows that the global teacher workforce continues to face persistent structural pressures—including shortages, rising workload, rapidly evolving skill demands, and insufficient access to high-quality professional development. Across contexts, AI-supported learning has been introduced as a potential response to these challenges by providing scalable, adaptive, and data-driven professional learning pathways. Findings reveal that AI-supported professional development enhances teachers' conceptual understanding of AI, improves digital and pedagogical competence, strengthens confidence, and contributes to more effective instructional design. AI tools also offer meaningful support in reducing teacher workload, delivering personalized feedback, and facilitating continuous, practice-based growth. However, the review also highlights that effectiveness is not uniform; it depends strongly on contextual factors such as infrastructure, institutional support, teachers' readiness, ethical literacy, and sustained opportunities for application. Despite the promise of AI, significant gaps and risks persist, including ethical challenges, bias, transparency issues, digital inequality, and fears of teacher displacement. Opportunities exist in structured AI literacy programs, ethical frameworks, human–AI collaboration models, and scalable professional development systems focused on both technical and pedagogical competence. Taken together, the findings indicate that AI-supported professional learning

can contribute meaningfully to strengthening teacher capacity and mitigating workforce pressures when implemented within an equitable, pedagogically grounded, and well-supported ecosystem.

6.0 Study Implications

This review offers several key implications for policy, practice, and research. For policy makers, the findings highlight the urgent need to develop national and institutional AI-readiness frameworks that integrate infrastructure investment, ethical safeguards, and long-term funding for teacher professional development. Without such systemic support, the adoption of AI risks widening existing inequalities across schools and teacher populations. For practitioners and school leaders, the evidence underscores that AI-supported professional learning is most effective when scaffolded, iterative, and closely tied to classroom practice. Educators benefit when PD programs combine AI literacy, hands-on experimentation, pedagogical alignment, and opportunities for peer collaboration. Institutions should therefore prioritize structured, continuous PD models that help teachers build both confidence and competence while addressing concerns related to trust, autonomy, and professional identity. For researchers, the review identifies clear gaps in empirical evaluation, long-term impact studies, and comparative analyses across different AI tools and pedagogical contexts. Future research should examine how AI-supported professional learning contributes to sustained instructional change, workforce retention, teacher well-being, and student outcomes. Additionally, there is a need for evidence on ethical design principles, human–AI collaboration models, culturally responsive AI systems, and the integration of generative AI into teacher education.

Reference

Ahmed, K. O., Adekunle, S. M., Olalekan, E. I., Yusuff, O., Ajao, T. O., Adeoba, M., & Rafiu, A. O. (2025). A Systematic Review of Inclusive Economic Growth Through A Sustainable Model for Climate Action Among Member States of the United Nations: 62-87. *Elicit Journal of Economics and Management Studies*, *1*(1).

Ahmed, S., Khalil, M. I., Chowdhury, B., Haque, R., Rahman, A., Senathirajah, S., & Din, O. (2022). Motivators and barriers of artificial intelligent (AI) based teaching. *Eurasian Journal of Educational Research*, *100*(100), 74-89.

Akinson, A. O., Obasanya, A., Raimi, B. O., & Oshoba, A. O. (2025). Does Economic Literacy Matter for Firm Performance and Competitive Advantage: A Systematic Review. *Elicit Journal of Economics and Management Studies*, *1*(1).

Almethen, A. (2024). Challenges in implementing‒ artificial intelligence applications in secondary-level education: A teacher-centric perspective. *Journal of Faculty of Education-Assiut University*, *40*(5.2), 1-32.

Almubarak, A., Alhalabi, W., Albidewi, I., & Alharbi, E. (2025). An AI-powered framework for assessing teacher performance in classroom interactions: a deep learning approach. *Frontiers in Artificial Intelligence*, *8*, 1553051.

Alwaqdani, M. (2025). Investigating teachers' perceptions of artificial intelligence tools in education: potential and difficulties. *Education and Information Technologies*, *30*(3), 2737-2755.

Al-Zyoud, H. M. M. (2020). The role of artificial intelligence in teacher professional development. *Universal Journal of Educational Research*, *8*(11B), 6263-6272.

Arvin, N., Hoseinabady, M., Bayat, B., & Zahmatkesh, E. (2023). Teacher experiences with ai-based educational tools. *AI and Tech in Behavioral and Social Sciences*, *1*(2), 26-32.

Bamiro, N. B., Zakariya, Z. B., & Nasiru, B. A. (2023). Development of halal entrepreneurship framework through business incubator service for sustainability using PRISMA. *Contemporary discourse of halal and Islamic entrepreneurship*, 79-97

Boeve-de Pauw, J., Olsson, D., Berglund, T., & Gericke, N. (2022). Teachers' ESD self-efficacy and practices: A longitudinal study on the impact of teacher professional development. *Environmental Education Research*, *28*(6), 867-885.

Brandão, A., Pedro, L., & Zagalo, N. (2024). Teacher Professional Development for a Future with Generative Artificial Intelligence--An Integrative Literature Review. *Digital Education Review*, *45*, 151-157.

Chen, S. (2025). Perceived teacher support on international students' engagement and psychological well-being in AI-based learning: The mediating role of motivation through the lens of self-determination theory. *Learning and Motivation*, *91*, 102165.

Chiu, T. K., Moorhouse, B. L., Chai, C. S., & Ismailov, M. (2024). Teacher support and student motivation to learn with Artificial Intelligence (AI) based chatbot. *Interactive Learning Environments*, *32*(7), 3240-3256.

Chou, C. M., Shen, T. C., Shen, T. C., & Shen, C. H. (2023). The level of perceived efficacy from teachers to access AI-based teaching applications. *Research and practice in technology enhanced learning*, *18*, 021-021.

Chou, C. M., Shen, T. C., Shen, T. C., & Shen, C. H. (2024). Teachers' adoption of AI-supported teaching behavior and its influencing factors: Using structural equation modeling. *Journal of Computers in Education*, 1-44.

Daher, R. (2025). Integrating AI literacy into teacher education: a critical perspective paper. *Discover Artificial Intelligence*, *5*(1), 217.

Darling-Hammond, L., DiNapoli Jr, M., & Kini, T. (2023). The Federal Role in Ending Teacher Shortages. *Learning Policy Institute*.

De la Vall, R. R. F., & Araya, F. G. (2023). Exploring the benefits and challenges of AI-language learning tools. *International Journal of Social Sciences and Humanities Invention*, *10*(01), 7569-7576.

Diana, R. F., Kusuma, P. S. B., Athoilah, H., & Nisa, C. (2025). Guidance on the Utilization of Artificial Intelligence (AI) in the Development of Instructional Materials. *Jurnal Pengabdian Masyarakat Dan Penelitian Thawalib*, *4*(2), 109-120.

Ding, A. C. E., Shi, L., Yang, H., & Choi, I. (2024). Enhancing teacher AI literacy and integration through different types of cases in teacher professional development. *Computers and Education Open*, *6*, 100178.

Fatima, K. (2025). The role of AI in teacher professional development: implications for AI literacy and training. *AI EDIFY Journal*, *2*(1), 29-37.

Fernandes, S., Araújo, A. M., Miguel, I., & Abelha, M. (2023). Teacher professional development in higher education: The impact of pedagogical training perceived by teachers. *Education Sciences*, *13*(3), 309.

Filiz, O., Kaya, M. H., & Adiguzel, T. (2025). Teachers and AI: Understanding the factors influencing AI integration in K-12 education. *Education and Information Technologies*, 1-37.

García, E., & Weiss, E. (2020). A Policy Agenda to Address the Teacher Shortage in US Public Schools: The Sixth and Final Report in the'Perfect Storm in the Teacher Labor Market'Series. *Economic Policy Institute*.

Giannakos, M., Azevedo, R., Brusilovsky, P., Cukurova, M., Dimitriadis, Y., Hernandez-Leo, D., ... & Rienties, B. (2025). The promise and challenges of generative AI in education. *Behaviour & Information Technology*, *44*(11), 2518-2544.

Henderson, C. (2025). Teacher wellbeing and the shaping of teacher shortages in crisis-affected contexts.

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education promises and implications for teaching and learning*. Center for Curriculum Redesign.

Ismail, A., Aliu, A., Ibrahim, M., & Sulaiman, A. (2024). Preparing teachers of the future in the era of artificial intelligence. *Journal of Artificial Intelligence, Machine Learning and Neural Network*, *44*, 31-41.

Jamal, A. (2023). The role of artificial intelligence (AI) in teacher education: Opportunities & challenges. *International Journal of Research and Analytical Reviews*, *10*(1), 139-146.

Kostka, I., & Toncelli, R. (2023). Exploring applications of ChatGPT to English language teaching: Opportunities, challenges, and recommendations. *Tesl-Ej*, *27*(3), n3.

Lamrabet, M., Fakhar, H., Echantoufi, N., Khattabi, K. E., & Ajana, L. (2025). Revolutionizing Teachers' Professional Development: The Critical Role of AI-Based Tools from Initial Training to Lifelong Learning—A Case Study. *International Journal of Information and Education Technology*, *15*(4).

Lan, Y. (2024). Through tensions to identity-based motivations: Exploring teacher professional identity in Artificial Intelligence-enhanced teacher training. *Teaching and Teacher Education*, *151*, 104736.

Li, K., Wang, P., & Chen, G. (2025). How can AI be integrated into teacher professional development programs? A systematic review based on an adapted technology-based learning model. *Teaching and Teacher Education*, *168*, 105219.

Lindner, A., Romeike, R., Jasute, E., & Pozdniakov, S. (2019, November). Teachers' perspectives on artificial intelligence. In *12th International conference on informatics in schools,"Situation, evaluation and perspectives", ISSEP* (pp. 7893-7925).

Luckin, R., & Cukurova, M. (2019). Designing educational technologies in the age of AI: A learning sciences-driven approach. *British Journal of Educational Technology*, *50*(6), 2824-2838.

Montero-Mesa, L., Fraga-Varela, F., Vila-Couñago, E., & Rodríguez-Groba, A. (2023). Digital technology and teacher professional development: Challenges and contradictions in compulsory education. *Education Sciences*, *13*(10), 1029.

Nazaretsky, T., Ariely, M., Cukurova, M., & Alexandron, G. (2022). Teachers' trust in AI-powered educational technology and a professional development program to improve it. *British journal of educational technology*, *53*(4), 914-931.

Ng, D. T. K., Leung, J. K. L., Su, J., Ng, R. C. W., & Chu, S. K. W. (2023). Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world. *Educational technology research and development*, *71*(1), 137-161.

Nikitina, I., & Ishchenko, T. (2024). The Impact Of Ai On Teachers: Support or Replacement?. *Scientific Journal of Polonia University*, *65*(4).

Nurjanah, L., Cahyono, B. Y., & Suryati, N. (2025). The successful use of AI for English teachers' professional development. *JALTCALL Trends*, *1*(1), 2169-2169.

Nyaaba, M., & Zhaı, X. (2024). Generative AI professional development needs for teacher educators. *Journal of AI*, *8*(1), 1-13.

Omidvar, S., & Meihami, H. (2025). Exploring the "What" and "How" of Opportunities and Challenges of AI in EFL Teacher Education. *Computers and Education: Artificial Intelligence*, 100443.

Orland-Barak, L., & Wang, J. (2021). Teacher mentoring in service of preservice teachers' learning to teach: Conceptual bases, characteristics, and challenges for teacher education reform. *Journal of teacher education*, *72*(1), 86-99.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj*, *372*.

Pratiwi, H., Riwanda, A., Hasruddin, H., Sujarwo, S., & Syamsudin, A. (2025). Transforming Learning or Creating Dependency? Teachers' Perspectives and Barriers to AI Integration in Education. *Journal of Pedagogical Research*, *9*(2), 127-142.

Qureshi, I. (2025). The impact of AI on teacher roles: Towards a collaborative human-AI pedagogy. *AI Edify Journal*, *2*(1), 1-11.

Roshan, S., Iqbal, S. Z., & Qing, Z. (2024). Teacher training and professional development for implementing AI-based educational tools. *Journal of Asian Development Studies*, *13*(2), 1972-1987.

Roshan, S., Iqbal, S. Z., & Qing, Z. (2024). Teacher training and professional development for implementing AI-based educational tools. *Journal of Asian Development Studies*, *13*(2), 1972-1987.

Rostami, M., & Longo, V. (2024). Teachers' Narratives on Implementing AI-Based Learning Tools for Students with Severe Disabilities. *Psychological Research in Individuals with Exceptional Needs, 2*(2), 20-27. https://doi.org/10.61838/kman.prien.2.2.4

Rui, X., Celik, I., & Edwards, J. (2025). Understanding Pre-service Teachers' Needs for Integrating AI-based Tools in Instruction through Intelligent TPACK Framework. *Computers and Education Open*, 100317.

Shi, L., Ding, A. C., & Choi, I. (2024). Investigating teachers' use of an AI-enabled system and their perceptions of AI integration in science classrooms: A case study. *Education Sciences*, *14*(11), 1187.

Soelistiono, S. (2023). Educational technology innovation: Ai-integrated learning system design in ails-based education. *Influence: International Journal of Science Review*, *5*(2), 470-480.

Sun, J., Ma, H., Zeng, Y., Han, D., & Jin, Y. (2023). Promoting the AI teaching competency of K-12 computer science teachers: A TPACK-based professional development approach. *Education and information technologies*, *28*(2), 1509-1533.

Tan, Q., & Tang, X. (2025). Unveiling AI literacy in K-12 education: A systematic literature review of empirical research. *Interactive Learning Environments*, 1-17.

Tariq, U. (2024). Challenges in AI-Powered Educational Technologies: Teacher Perspectives and Resistance. *AI EDIFY Journal*, *1*(3), 1-10.

Turner, K., & Garvis, S. (2023). Teacher educator wellbeing, stress and burnout: A scoping review. *Education Sciences*, *13*(4), 351.

Uygun, D. (2024). Teachers' perspectives on artificial intelligence in education. *Advances in Mobile Learning Educational Research*, *4*(1), 931-939.

Vashetina, O. V., Asafova, E. V., Kaur, B., Singh, B., Sharma, P., Prata-Linhares, M. M., ... & Sibgatullina10, T. V. (2022). Professional development of teachers and future teachers: Factors and challenges. *Education and Self Development*, *3*, 100-117.

Velander, J., Taiye, M. A., Otero, N., & Milrad, M. (2024). Artificial Intelligence in K-12 Education: eliciting and reflecting on Swedish teachers' understanding of AI and its implications for teaching & learning. *Education and Information Technologies*, *29*(4), 4085-4105.

Williamson, B., & Eynon, R. (2020). Historical threads, missing links, and future directions in AI in education. *Learning, Media and Technology*, *45*(3), 223-235.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators?. *International journal of educational technology in higher education*, *16*(1), 1-27.

Zhang, J., & Zhang, Z. (2024). AI in teacher education: Unlocking new dimensions in teaching support, inclusive learning, and digital literacy. *Journal of Computer Assisted Learning*, *40*(4), 1871-1885.