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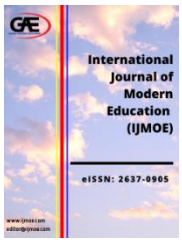

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AI-DRIVEN TECHNOLOGY INTEGRATION AND PEDAGOGICAL INNOVATION IN EDUCATION: A SYSTEMATIC LITERATURE REVIEW

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Abstract:

The rapid advancement of Artificial Intelligence (AI) has profoundly transformed the global educational landscape, necessitating a comprehensive understanding of how technology integration supports pedagogical innovation across diverse educational contexts. Despite the growing body of literature on AI in education, existing studies remain fragmented, often focusing on individual dimensions such as adaptive learning, immersive technologies, teacher readiness, or ethical issues, with limited synthesis of their interconnected roles in sustainable educational transformation. This Systematic Literature Review (SLR) aims to synthesise contemporary research on AI-driven technology integration and pedagogical innovation in education. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure methodological rigour and transparency. A total of 1,485 records were retrieved from the Scopus and Web of Science (WoS) databases, of which 36 peer-reviewed studies published between 2020 and 2025 met the inclusion criteria and were included in the final qualitative synthesis. An integrative thematic analysis revealed four overarching themes: (1) AI-Driven Transformation and Curriculum Innovation, highlighting educator readiness, curriculum redesign, adaptive instruction, and value-driven innovation; (2) Immersive and Extended Reality (XR) Learning Environments, emphasising the use of virtual, augmented, and mixed-reality technologies to enhance experiential learning, pedagogical alignment, and cognitive engagement; (3) Digital Pedagogy, Teacher Competence, and Inclusive Access, underscoring the importance of professional development, institutional support, cultural responsiveness, and equitable digital participation; and (4)

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Ethical, Institutional, and Sustainable AI Governance, emphasising ethical AI implementation, institutional leadership, policy development, digital equity, and long-term sustainability in educational transformation. The findings indicate that successful AI integration extends beyond technological adoption and depends on the interaction between pedagogical competence, institutional readiness, ethical governance, and inclusive educational practices. This review contributes to the literature by providing a comprehensive synthesis that integrates technological, pedagogical, organisational, and ethical perspectives within the Technological Pedagogical Content Knowledge (TPACK) framework, offering evidence-based insights for educators, institutional leaders, and policymakers seeking to implement sustainable AI-supported educational transformation.

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Keywords:

Artificial Intelligence (AI); Technology Integration; Pedagogical Innovation; Adaptive Learning; Extended Reality (XR); Teacher Competence; Machine Learning.

Introduction

Artificial Intelligence (AI) has become one of the most influential technologies transforming education worldwide. Recent advances in AI have accelerated the development of intelligent educational applications, including adaptive learning systems, intelligent tutoring systems, generative AI, learning analytics, and virtual learning environments. These technologies enable more personalised learning experiences, improve instructional efficiency, and support data-informed educational decision-making (Avci et al., 2025; Carvalho et al., 2025; Liu & Li, 2025).

The growing adoption of AI has expanded beyond digital content delivery to encompass curriculum design, classroom assessment, lesson planning, student feedback, and educational administration. AI-supported technologies also facilitate collaborative learning, immersive educational experiences, and differentiated instruction that address diverse learner needs across various educational settings (Phong et al., 2025; Younas et al., 2025; Zhong et al., 2025). Consequently, AI is increasingly recognised as an important driver of pedagogical innovation that encourages more student-centred, flexible, and interactive teaching practices.

Despite these promising developments, successful AI implementation depends largely on teachers' ability to integrate technology meaningfully into their pedagogical practices. The effectiveness of AI is influenced not only by technological availability but also by teachers' digital competence, pedagogical knowledge, institutional support, and readiness to redesign

learning experiences. As educators increasingly assume the role of facilitators of AI-enhanced learning rather than traditional knowledge transmitters, continuous professional development becomes essential for sustainable educational transformation (Asal et al., 2025; Hoang, 2025; van den Berg, 2025).

At the same time, AI integration presents several important challenges. Ethical concerns regarding data privacy, algorithmic bias, transparency, and equitable access remain major considerations for educational institutions (Gouveia et al., 2025; Jackaria et al., 2024; Sholeh, 2025). These issues are particularly significant in educational systems where technological infrastructure, institutional capacity, and digital readiness vary considerably across schools and regions. Therefore, effective AI integration requires not only technological innovation but also appropriate governance, institutional policies, and teacher capacity-building to ensure responsible and inclusive implementation.

Research Gap and Problem Statement

Although AI has become an increasingly important area of educational research, existing systematic reviews have primarily examined individual dimensions such as adaptive learning, generative AI, learning analytics, teacher readiness, or ethical considerations. While these studies provide valuable insights, they often investigate these aspects independently, resulting in a fragmented understanding of how technological innovation, pedagogical practice, institutional readiness, and ethical governance collectively influence sustainable AI implementation in education.

Furthermore, relatively few reviews have interpreted AI integration through a comprehensive theoretical perspective capable of explaining the interaction between technology, pedagogy, and teacher competence. As AI continues to reshape curriculum design, assessment, professional learning, and educational leadership, a more integrated synthesis is required to explain how these multidimensional factors contribute to effective educational transformation. To address this gap, the present systematic literature review synthesises evidence from 36 peer-reviewed studies published between 2020 and 2025 and interprets the findings through the Technological Pedagogical Content Knowledge (TPACK) framework. By integrating evidence on curriculum innovation, immersive learning technologies, digital pedagogy, teacher competence, institutional support, and ethical governance within a single analytical framework, this review provides a more comprehensive understanding of sustainable AI integration in education and offers evidence-based directions for future research, policy, and educational practice.

Research Objectives

This systematic literature review aims to:

1. Synthesise contemporary evidence on AI-driven technology integration and pedagogical innovation across educational contexts.
2. Examine how AI technologies support pedagogical transformation, teacher competence, and inclusive learning environments.
3. Analyse the relationships among technological integration, teacher readiness, institutional support, and sustainable AI implementation through the TPACK framework.

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4. Identify the opportunities and challenges associated with AI adoption in education.
5. Provide evidence-based recommendations for educators, policymakers, and educational institutions.

Research Questions

This review is guided by the following research questions:
RQ1: How are AI-driven technologies integrated into teaching and learning to promote pedagogical innovation across educational contexts?
RQ2: How do AI technologies influence student engagement, learning outcomes, and the development of twenty-first-century competencies?
RQ3: How do teacher competence, institutional support, and technological readiness interact to facilitate sustainable AI integration in education?

Literature Review

AI Integration in Education

Artificial Intelligence (AI) has become an important catalyst for educational innovation by transforming teaching, learning, assessment, and curriculum design. Recent studies demonstrate that AI-powered technologies—including intelligent tutoring systems, adaptive learning platforms, learning analytics, generative AI, and immersive technologies—support personalised learning experiences, enhance student engagement, and improve instructional efficiency (Avci et al., 2025; Liu & Li, 2025; Zhong et al., 2025). Beyond content delivery, AI facilitates data-informed instructional decision-making, automated assessment, curriculum planning, and differentiated instruction. These technologies encourage learner-centred pedagogies by enabling real-time feedback, adaptive learning pathways, collaborative learning environments, and higher-order thinking skills (Alqahtani & Wafula, 2025; Hoang, 2025; Phong et al., 2025; Younas et al., 2025). Emerging technologies such as Augmented Reality (AR), Virtual Reality (VR), and Extended Reality (XR) further enrich learning by providing immersive educational experiences that enhance conceptual understanding, collaboration, and problem-solving abilities (Carvalho et al., 2025; Thangavel et al., 2025). Nevertheless, researchers emphasise that AI should complement rather than replace teachers' professional judgement. Human interaction, pedagogical expertise, and socio-emotional support remain essential components of meaningful learning experiences (Carvalho et al., 2025; van den Berg, 2025).

Teacher Readiness and the TPACK Framework

Successful AI integration depends not only on technological advancement but also on teachers' readiness to integrate AI into classroom practice. The Technological Pedagogical Content Knowledge (TPACK) framework provides a comprehensive theoretical foundation by explaining how technological knowledge, pedagogical knowledge, and content knowledge interact to support effective technology integration (Koehler & Mishra, 2009). Recent studies suggest that AI implementation requires competencies extending beyond traditional TPACK domains. Teachers are expected to possess AI literacy, digital competence, ethical awareness, and critical thinking skills to evaluate AI-generated information and design meaningful learning experiences (Gaviria-Rodríguez et al., 2025; Jeevarajathy & Hema, 2025).

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Professional development programmes integrating digital literacy with pedagogical knowledge have therefore become increasingly important in supporting sustainable AI adoption (Asal et al., 2025; Kedraka & Mitits, 2025; Mathebula et al., 2025). Complementary frameworks such as DigCompEdu and AI-specific competency models further strengthen teachers' capacity to implement AI responsibly and effectively across diverse educational settings.

Rural School Context

Despite the growing adoption of AI in education, implementation remains uneven across different educational contexts. Schools located in rural and underserved communities frequently encounter challenges related to technological infrastructure, internet connectivity, access to digital resources, institutional support, and opportunities for professional development (Jackaria et al., 2024; Rocha-Castillo et al., 2025). The literature indicates that effective AI integration requires more than technological availability. Sustainable implementation depends on institutional leadership, supportive school policies, continuous teacher training, and context-sensitive pedagogical practices that respond to local educational needs (Ouahmiche & Bouguebs, 2025; Uriarte, 2025). These findings highlight the importance of examining AI adoption within diverse educational environments rather than assuming uniform implementation across schools.

Ethical and Sustainable AI Integration

The rapid expansion of AI in education has generated increasing attention towards ethical governance and sustainable implementation. Researchers consistently identify issues related to data privacy, algorithmic bias, transparency, accountability, and equitable access as critical challenges that influence responsible AI adoption (Arriazu, 2025; Gouveia et al., 2025; Sholeh, 2025). At the same time, AI presents significant opportunities to improve educational quality through personalised instruction, administrative efficiency, and evidence-based decision-making. Sustainable implementation therefore requires balancing technological innovation with ethical governance, inclusive educational policies, and human-centred pedagogical principles. Current literature increasingly advocates for comprehensive AI governance frameworks that integrate technological innovation, teacher competence, institutional readiness, and ethical responsibility to ensure equitable educational transformation.

Research Methodology

Study Design and PRISMA Protocol

This study employed a Systematic Literature Review (SLR) design to synthesise existing scholarly evidence on AI-driven technology integration and pedagogical innovation in education. The review was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 framework proposed by Page et al. (2021). The PRISMA framework ensured that the review process was conducted systematically, transparently, and reproducibly through four main stages: identification, screening, eligibility assessment, and final inclusion.

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Information Sources and Search Strategy

The literature search was conducted using two major academic databases, namely Scopus and Web of Science (WoS), due to their extensive coverage of peer-reviewed publications in education, educational technology, artificial intelligence, and interdisciplinary research. The search was conducted in November 2025 and was limited to studies published between 2020 and 2025. The search strategy combined Boolean operators and key terms related to technology integration, pedagogical innovation, and artificial intelligence.
For Scopus, the search string was:

TITLE-ABS-KEY (("Technology Integration" OR "Technology Adoption" OR "Digital Integration") AND ("Pedagogical Innovation" OR "Teaching Innovation" OR "Instructional Innovation") AND ("Artificial Intelligence" OR "AI" OR "Machine Learning" OR "Adaptive Learning")) AND DOCTYPE("ar") AND PUBSTAGE("final") AND SRCTYPE("j") AND LANGUAGE("English")

For Web of Science, the search string was:

TS=(("Technology Integration" OR "Digital Integration" OR "Technology Adoption") AND ("Pedagogical Innovation" OR "Teaching Innovation" OR "Instructional Innovation") AND ("Artificial Intelligence" OR "AI" OR "Machine Learning" OR "Adaptive Learning")) AND Document Type=(Article) AND Language=(English)

Inclusion and Exclusion Criteria

Clear inclusion and exclusion criteria were established to ensure that only relevant and high-quality studies were selected. The criteria covered language, publication year, document type, publication status, subject area, and research type. Only English-language peer-reviewed journal articles published between 2020 and 2025, with final publication status and direct relevance to education, educational technology, pedagogy, and empirical or theoretical research, were included. Non-English publications, conference papers, book chapters, editorials, reviews, opinion pieces, papers in press, and studies outside educational contexts were excluded shown in Table 1.

Table 1 Selection Criteria

Criterion	Inclusion	Exclusion
Language	English-language publications	Non-English publications
Publication Year	2020–2025	Published before 2020
Document Type	Peer-reviewed journal articles	Conference papers, book chapters, editorials, reviews, opinion pieces, papers in press
Publication Status	Final published version	In-press/pre-publication
Subject Area	Education, Educational Technology, Pedagogy	Non-educational domains without educational relevance
Research Type	Empirical studies (quantitative, qualitative, mixed methods), theoretical framework studies	Opinion essays, commentaries without empirical evidence

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Study Selection Process

The study selection process followed the PRISMA 2020 procedure. During the identification stage, 1,485 records were retrieved from Scopus and Web of Science, comprising 790 records from Scopus and 695 from Web of Science. After removing 46 duplicate records, 1,439 records were screened based on title and abstract. A total of 979 records were excluded because they did not meet the review focus, leaving 460 articles for full-text assessment.

At the eligibility stage, 424 full-text articles were excluded due to scope misalignment, limited focus on AI-related technology integration and pedagogical innovation, insufficient discussion of implementation or outcomes, or non-educational contexts. Finally, 36 studies met all eligibility criteria and were included in the qualitative synthesis. The PRISMA 2020 flow diagram in Figure 1 illustrates the systematic reduction of records from the initial search to the final included studies.

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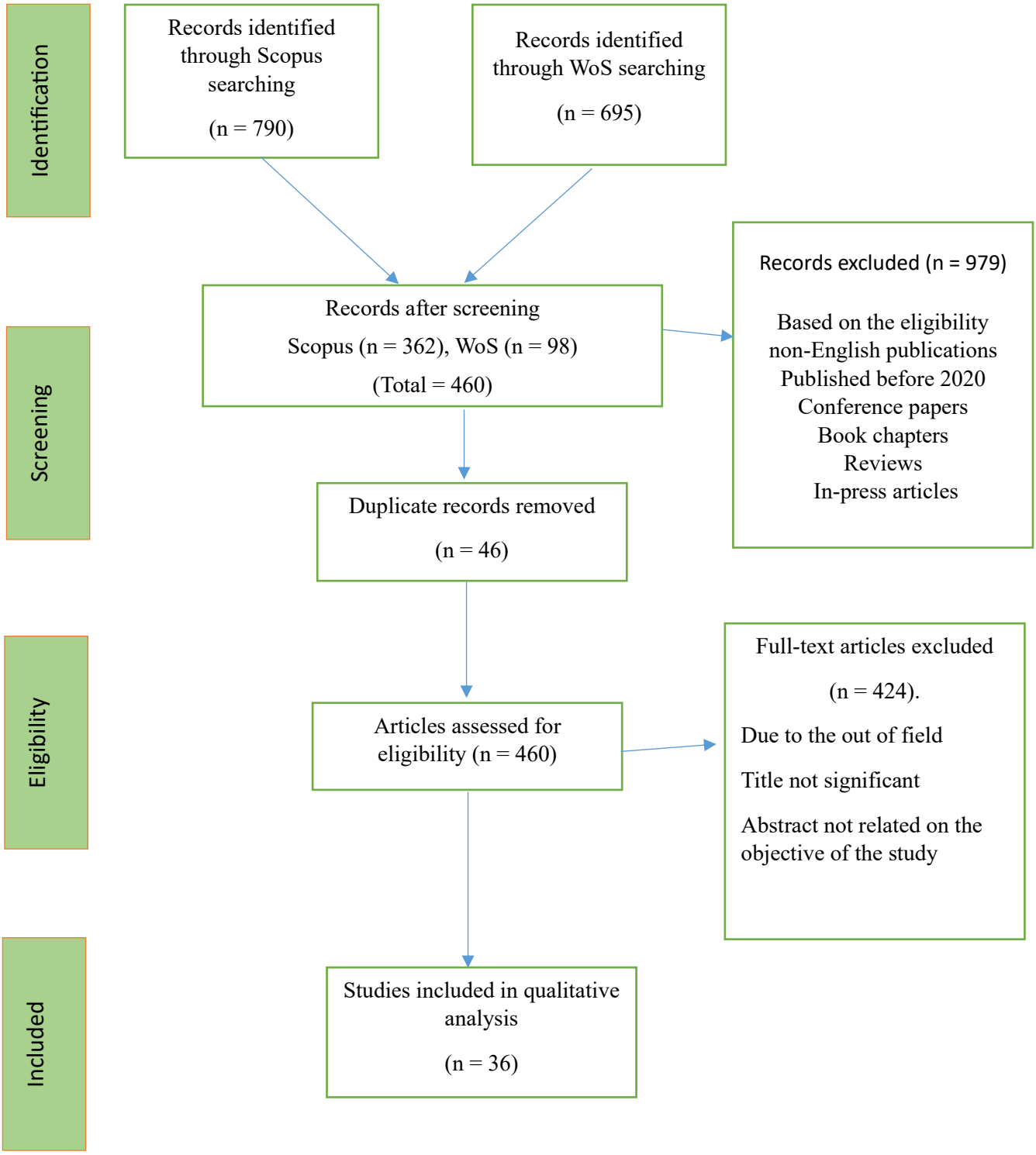

Figure 1. PRISMA 2020 Flow Diagram

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Data Extraction Procedure

A standardised data extraction template was developed to ensure consistency in retrieving relevant information from the selected studies. The extracted data included bibliographic details, study characteristics, educational context, technology or intervention type, pedagogical approach, key findings, outcomes, barriers, enablers, and methodological quality indicators. The extraction process focused on evidence related to student learning, engagement, teacher practices, instructional transformation, implementation challenges, and institutional support. Methodological information such as research design, sample size, data analysis procedures, ethical considerations, and study limitations was also recorded.

Quality Appraisal

The quality of the selected studies was assessed using a structured quality assessment framework adapted from Kitchenham (2007) and Abouzahra et al. (2020). Six criteria were applied: clarity of research objective, relevance of the study, appropriateness of methodology, clarity of key concepts or theoretical approaches, comparison with prior research, and acknowledgement of limitations. Each criterion was scored using a three-point scale: 1.0 for fully met, 0.5 for partially met, and 0.0 for not met. Studies with a total score above 3.0 out of 6.0 were accepted for synthesis. To enhance reliability, three independent content experts assessed the quality of each study, and any discrepancies were resolved through consensus.

Thematic Analysis Approach

An integrative thematic analysis approach was used to synthesise findings from the 36 selected studies. The analysis was guided by Braun and Clarke's (2006) thematic analysis procedure, which involved data familiarisation, inductive coding, theme development, theme refinement, and final interpretation. Relevant findings related to AI-driven technology integration and pedagogical innovation were extracted and coded. Recurring patterns were grouped into preliminary themes, which were then reviewed and refined to ensure conceptual clarity, internal consistency, and alignment with the research objectives. The final analysis generated four major themes: AI-driven transformation and curriculum innovation; immersive and extended reality learning environments; digital pedagogy, teacher competence, and inclusive access; and ethical, institutional, and sustainable AI governance.

Results

Study Selection Outcomes

The study selection process followed the PRISMA 2020 guidelines to ensure a transparent and systematic review. The database search initially identified 1,485 records from Scopus and Web of Science. Following duplicate removal and a multi-stage screening process, 36 peer-reviewed studies satisfied all eligibility criteria and were included in the final qualitative synthesis. The detailed study selection process is summarised in Table 2 and illustrated in Figure 1, demonstrating the rigorous application of the predefined inclusion and exclusion criteria.

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Table 2 PRISMA Screening and Eligibility Summary

Stage	**Number of Records**	**Records Excluded**	**Records Retained**
Identification (Database Search)	1,485	—	1,485
Deduplication	1,485	46	1,439
Screening (Title/Abstract)	1,439	979	460
Eligibility (Full-Text Review)	460	424	36
Final Inclusion (Qualitative Synthesis)	36	0	36

Characteristics of Included Studies

The 36 selected studies demonstrate considerable methodological and contextual diversity (Table 3). Qualitative research was slightly more prevalent than quantitative and mixed methods approach, reflecting the increasing emphasis on understanding educators' experiences alongside empirical evaluation of AI implementation. Geographically, the reviewed studies were dominated by the Asia-Pacific region, followed by Europe and the Americas, indicating growing international interest in AI-supported educational transformation. Higher education emerged as the most frequently investigated educational setting, although substantial research was also conducted within primary and secondary education. Across the reviewed literature, Extended Reality (VR/AR/MR), AI-generated tools, and adaptive learning platforms represented the dominant technological innovations, while personalised and adaptive learning constituted the most frequently adopted pedagogical approach. Collectively, these findings demonstrate that AI integration is increasingly being explored across diverse educational contexts, technologies, and instructional approaches.

Table 3 Study Characteristics Summary (n = 36)

Characteristic	**Frequency**	**Percentage (%)**
Study Design		
Quantitative	12	33.3%
Qualitative	14	38.9%
Mixed-Methods	10	27.8%
Geographic Context		
Asia-Pacific	18	50.0%
Europe	10	27.8%
Americas	6	16.7%
Africa/Middle East	2	5.6%
Educational Level		
K-12 (Primary/Secondary)	14	38.9%
Higher Education	16	44.4%
Mixed/Other	6	16.7%
Technology Type		
Adaptive Learning Platforms	8	22.2%
Extended Reality (VR/AR/MR)	10	27.8%

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AI-Generated Content/Tools	10	27.8%
Learning Management Systems	5	13.9%
Other Digital Tools	3	8.3%
Pedagogical Approach		
Problem-Based Learning	8	22.2%
Inquiry-Based Learning	7	19.4%
Personalized/Adaptive Learning	11	30.6%
Design Thinking	4	11.1%
Other	6	16.7%

Quality Assessment Results

The methodological quality assessment indicates that the selected studies provide a robust evidence base for this systematic review (Table 4). Overall, the studies achieved a high average quality score of 5.1 out of 6.0 (84.7%), demonstrating strong methodological rigour across the reviewed literature. Most studies clearly articulated their research objectives, methodological procedures, and theoretical foundations. Comparatively lower scores were observed in benchmarking findings against previous research and explicitly acknowledging study limitations. Nevertheless, all selected studies satisfied the predetermined quality threshold and were therefore considered suitable for thematic synthesis. These findings provide confidence that the conclusions presented in this review are supported by methodologically sound and reliable evidence.

Table 4 Quality Assessment Summary of Included Studies

Paper ID	**QA1**	**QA2**	**QA3**	**QA4**	**QA5**	**QA6**	**Total**	**%**
PS1 (Avci et al., 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS2 (Carvalho et al., 2025)	Y	Y	P	P	P	Y	4.5	75.0%
PS3 (Zagami, 2025)	Y	Y	Y	Y	P	N	4.5	75.0%
PS4 (Pino Tarragó et al., 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS5 (van den Berg, 2025)	Y	Y	Y	Y	Y	Y	6.0	100.0%
PS6 (Phong et al., 2025)	Y	Y	Y	Y	P	N	4.5	75.0%
PS7 (Espitia Barrero et al., 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS8 (Jeevarajathy & Hema, 2025)	Y	Y	P	P	Y	Y	5.0	83.3%
PS9 (Liu & Li, 2025)	Y	Y	Y	Y	Y	Y	6.0	100.0%
PS10 (Hoang, 2025)	Y	Y	Y	Y	Y	Y	6.0	100.0%
PS11 (Stambekova et al., 2025)	Y	Y	Y	Y	P	N	4.5	75.0%
PS12 (Ouahmiche & Bouguebs, 2025)	Y	Y	P	P	P	N	3.5	58.3%
PS13 (Asal et al., 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS14 (Alqahtani & Wafula, 2025)	Y	Y	Y	Y	Y	Y	6.0	100.0%
PS15 (Rocha-Castillo et al., 2025)	Y	Y	Y	Y	P	N	4.5	75.0%
PS16 (Thangavel et al., 2025)	Y	Y	P	P	P	Y	4.0	66.7%
PS17 (Méndez Gijón et al., 2025)	Y	Y	P	P	P	N	3.5	58.3%

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PS18 (Rutten & Brouwer-Truijn, 2025)	Y	Y	Y	Y	Y	Y	6.0	100.0%
PS19 (Mathebula et al., 2025)	Y	Y	Y	Y	Y	Y	6.0	100.0%
PS20 (Dehbi et al., 2025)	Y	Y	Y	P	P	Y	4.5	75.0%
PS21 (Kedraka & Mitits, 2025)	Y	Y	P	P	P	N	3.5	58.3%
PS22 (Younas et al., 2025)	Y	Y	Y	Y	Y	Y	6.0	100.0%
PS23 (Flores & Aguilar-Esteva, 2025)	Y	Y	Y	Y	P	N	4.5	75.0%
PS24 (Seitaliyeva et al., 2025)	Y	Y	Y	Y	P	N	4.5	75.0%
PS25 (Gaviria-Rodríguez et al., 2025)	Y	Y	Y	Y	Y	Y	6.0	100.0%
PS26 (Yue & Sukumaran, 2025)	Y	Y	Y	Y	P	N	4.5	75.0%
PS27 (Al-Obaydi et al., 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS28 (Zhong et al., 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS29 (Li, 2025)	Y	Y	P	P	P	Y	4.0	66.7%
PS30 (Islam et al., 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS31 (Fitria et al., 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS32 (Al-Khresheh et al., 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS33 (Sarzhanova et al., 2025)	Y	Y	Y	Y	P	N	4.5	75.0%
PS34 (Espartinez, 2025)	Y	Y	Y	Y	P	Y	5.5	91.7%
PS35 (Uriarte, 2025)	Y	Y	Y	Y	P	N	4.5	75.0%
PS36 (Morgado et al., 2025)	Y	Y	Y	P	P	Y	4.5	75.0%
AVERAGE	—	—	—	—	—	—	**5.1**	**84.7%**

Thematic Analysis Results

The thematic analysis generated four overarching themes that collectively explain how artificial intelligence supports technology integration and pedagogical innovation in education. Rather than representing isolated technological developments, these themes illustrate the interdependent relationships among curriculum innovation, immersive learning environments, teacher competence, institutional readiness, and ethical governance. Together, they demonstrate that sustainable AI implementation requires the integration of technological capability with pedagogical expertise, organisational support, and responsible governance. Table 5 summarises the identified themes, associated subthemes, representative studies, and their frequency across the reviewed literature.

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Table 5 Overview of Identified Themes and Subthemes

Primary Theme	Subthemes	Supporting Studies	Frequency
THEME 1: AI-Driven Transformation & Curriculum Innovation			
	Educator readiness and digital competence	Avci et al. (2025); Asal et al. (2025); Hoang (2025)	12
	Curriculum redesign and alignment	Pino Tarragó et al. (2025); Zhong et al. (2025)	10
	Ethical governance and policy frameworks	Jackaria et al. (2024); Sholeh (2025)	8
	Value-driven and human-centered innovation	van den Berg (2025); Carvalho et al. (2025)	8
THEME 2: Immersive & Extended Reality Learning Environments			
	Pedagogical design and framework alignment	Liu & Li (2025); Carvalho et al. (2025)	12
	Teacher competencies for XR integration	Rutten & Brouwer-Truijn (2025); Zagami (2025)	10
	Infrastructure, cost, and equitable access	Thangavel et al. (2025); Méndez Gijón et al. (2025)	9
	Cognitive and creative skill development	Zagami (2025); Liu & Li (2025)	8
THEME 3: Digital Pedagogy, Teacher Competence & Inclusive Access			
	Professional development and training	Mathebula et al. (2025); Seitaliyeva et al. (2025)	14
	Institutional support and policy alignment	Alqahtani & Wafula (2025); Kedraka & Mitits (2025)	11
	Cultural responsiveness and contextualization	Rocha-Castillo et al. (2025); Ouahmiche & Bouguebs (2025)	10
	Digital equity and accessibility	Jackaria et al. (2024); Al-Khresheh et al. (2025)	9

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Theme 1 AI-Driven Transformation and Curriculum Innovation

AI-driven curriculum transformation emerged as one of the dominant themes across the reviewed studies. The evidence consistently indicates that AI extends beyond supporting instructional delivery to facilitating curriculum redesign, adaptive assessment, and personalised learning experiences. These developments reflect a shift from teacher-centred instruction towards more flexible, learner-centred pedagogical approaches that respond to individual learning needs.

Teacher readiness emerged as a key factor influencing successful AI integration. Studies consistently demonstrated that educators with strong technological, pedagogical, and content knowledge were better able to implement AI-supported instructional strategies effectively. These findings reinforce the TPACK framework, highlighting that meaningful AI integration depends on the interaction between technological capability and sound pedagogical practice rather than technological expertise alone.

The reviewed studies further emphasised that curriculum innovation should be supported by ethical governance, institutional commitment, and human-centred educational values. Collectively, these findings suggest that sustainable curriculum transformation depends on the combined influence of teacher competence, curriculum flexibility, institutional readiness, and responsible AI implementation.

Theme 2 Immersive and Extended Reality Learning Environments

The second theme highlights the growing role of immersive technologies—including Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and Extended Reality (XR)—in enhancing educational experiences. The reviewed studies consistently reported that these technologies promote experiential learning, conceptual understanding, collaboration, and student engagement by enabling authentic and interactive learning environments.

However, the findings indicate that the effectiveness of immersive technologies depends primarily on pedagogical integration rather than technological sophistication. Successful implementation requires teachers to possess specialised pedagogical competencies and institutions to provide adequate infrastructure, technical support, and equitable access. These findings suggest that immersive technologies contribute most effectively to educational innovation when supported by appropriate instructional design and organisational readiness.

Theme 3 Digital Pedagogy, Teacher Competence, and Inclusive Access

Professional development emerged as the most frequently reported factor supporting sustainable AI integration. The reviewed studies consistently demonstrated that teachers with strong digital literacy, AI competence, and pedagogical knowledge were more likely to implement technology-enhanced learning that improved student engagement and learning outcomes. Institutional leadership and supportive educational policies further strengthened successful implementation by providing continuous professional development, technological infrastructure, and strategic guidance. At the same time, the literature highlighted that inclusive AI adoption requires equitable access to digital resources while recognising differences in socioeconomic conditions, geographical location, and cultural contexts. These findings

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illustrate that successful digital transformation depends on the interaction between teacher capability, institutional support, and educational equity.

Theme 4 Ethical, Institutional, and Sustainable AI Governance

The final theme emphasises that sustainable AI integration requires comprehensive ethical governance alongside institutional leadership and long-term strategic planning. Across the reviewed studies, data privacy, algorithmic bias, transparency, accountability, and responsible AI use consistently emerged as fundamental considerations for educational institutions. The findings further indicate that strong institutional leadership plays an essential role in establishing coherent policies, supporting cross-disciplinary collaboration, and ensuring continuous evaluation of AI initiatives. At the same time, persistent disparities in technological infrastructure and digital access continue to limit equitable implementation, particularly in under-resourced educational settings. Collectively, these findings demonstrate that sustainable AI integration depends not only on technological innovation but also on ethical governance, institutional commitment, and inclusive educational policies.

Discussion

Curriculum Innovation

This review demonstrates that AI is reshaping curriculum design, instructional delivery, and assessment by enabling adaptive learning, personalised instruction, and data-informed teaching. Rather than functioning as an autonomous instructional system, AI emerged as a pedagogical partner that supports teachers in designing more flexible and learner-centred educational experiences. This finding is consistent with previous studies suggesting that meaningful curriculum innovation occurs when technological tools are aligned with sound pedagogical principles rather than adopted solely for technological advancement. The findings further indicate that curriculum transformation requires continuous interaction between technology, pedagogy, and teacher expertise. The integration of AI therefore extends beyond classroom digitalisation towards redesigning learning experiences that promote collaboration, creativity, critical thinking, and personalised learning. These findings reinforce the TPACK framework by demonstrating that curriculum innovation depends on the effective integration of technological, pedagogical, and content knowledge.

Teacher Competency

Teacher competence emerged as the strongest enabling factor influencing successful AI implementation across the reviewed studies. Effective AI integration requires more than technical proficiency; it depends on educators' ability to combine digital literacy, pedagogical knowledge, instructional design, and ethical decision-making within authentic classroom practice. Consequently, professional development should prioritise AI literacy alongside pedagogical innovation rather than focusing exclusively on technology skills.

The findings also extend the TPACK framework by highlighting that AI-supported teaching increasingly requires competencies related to ethical awareness, reflective practice, and continuous professional learning. These broader competencies enable teachers to evaluate AI-generated information critically while maintaining human-centred educational practices.

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Institutional Readiness

The review consistently demonstrates that successful AI implementation depends on institutional readiness as much as individual teacher competence. Educational institutions that provide strategic leadership, technological infrastructure, professional development opportunities, and supportive organisational cultures are more likely to achieve sustainable technology integration. Institutional readiness is particularly important in ensuring equitable implementation across diverse educational contexts. Schools and universities require coordinated policies, adequate digital infrastructure, and long-term investment to support AI adoption. These findings suggest that sustainable educational transformation depends upon collaboration among teachers, institutional leaders, and policymakers rather than isolated classroom initiatives.

Ethical Governance

Ethical governance emerged as a fundamental condition for sustainable AI integration. Across the reviewed studies, data privacy, algorithmic bias, transparency, accountability, and equitable access were consistently identified as major considerations influencing responsible AI adoption. These findings indicate that technological innovation should be accompanied by governance frameworks that protect learners' rights while ensuring fairness and transparency in educational decision-making. The review therefore supports a human-centred approach to AI implementation in which technology complements rather than replaces educators' professional judgement. Sustainable AI integration requires balancing technological advancement with ethical responsibility, educational equity, and learner well-being through comprehensive institutional and national policy frameworks.

Strengths and Limitations

This review offers several methodological strengths, including the application of the PRISMA 2020 framework, comprehensive searches of Scopus and Web of Science, explicit inclusion criteria, structured quality appraisal, and rigorous thematic synthesis. Together, these procedures strengthen the transparency, reliability, and credibility of the review findings.

Nevertheless, several limitations should be acknowledged. The review included only English-language journal articles published between 2020 and 2025 and indexed in Scopus or Web of Science. Consequently, studies published in other languages, regional databases, conference proceedings, and grey literature were excluded. Furthermore, the methodological diversity of the included studies limited opportunities for quantitative meta-analysis.

Directions for Future Research

Future studies should investigate the long-term effects of AI integration on student learning, teacher professional development, and institutional transformation through longitudinal research designs. Greater use of mixed-methods approaches would also provide richer understanding of how quantitative learning outcomes relate to educators' and students' experiences during AI implementation.

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Further research is particularly needed in rural, under-resourced, and culturally diverse educational settings where evidence remains relatively limited. Future investigations should also examine emerging issues such as explainable AI, algorithmic fairness, ethical governance, and culturally responsive AI implementation to support more inclusive and sustainable educational transformation.

Conclusion

This systematic literature review synthesised evidence from 36 peer-reviewed studies published between 2020 and 2025 to examine how artificial intelligence (AI) supports technology integration and pedagogical innovation across diverse educational contexts. Guided by the PRISMA 2020 framework and interpreted through the Technological Pedagogical Content Knowledge (TPACK) framework, the review identified four interrelated dimensions underpinning sustainable AI implementation: curriculum innovation, teacher competence, institutional readiness, and ethical governance. The findings indicate that AI has evolved beyond a technological support tool to become a strategic enabler of educational transformation. However, effective AI integration depends not only on technological capability but also on teachers' pedagogical competence, institutional support, responsible governance, and equitable access to digital resources. These interconnected factors collectively determine whether AI contributes to meaningful and sustainable educational innovation.

A key contribution of this review is its integrated synthesis of technological, pedagogical, organisational, and ethical perspectives within a single analytical framework. Unlike previous reviews that examined AI implementation from isolated perspectives, this study demonstrates how these dimensions interact to shape sustainable AI adoption across diverse educational settings. The findings also extend the application of the TPACK framework by highlighting the complementary roles of institutional readiness and ethical governance in supporting effective AI integration. Although this review followed rigorous systematic review procedures, it was limited to English-language journal articles indexed in Scopus and Web of Science between 2020 and 2025. Future research should expand the evidence base through longitudinal and mixed-methods studies while giving greater attention to rural, under-resourced, and culturally diverse educational contexts. Overall, AI should be viewed not as a replacement for educators but as a pedagogical partner that enhances teaching, learning, and institutional innovation. Sustainable educational transformation will depend on collaborative efforts among educators, institutional leaders, researchers, policymakers, and technology developers to ensure that AI is implemented responsibly, inclusively, and in ways that improve learning for all students.

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Author Contribution Statement: Siti Hasmah Binti Amat Baking conceptualised the study, designed the methodology, conducted the literature search, performed the data extraction and thematic analysis, interpreted the findings, and prepared the original manuscript. Sabariah Sharif supervised the study, critically reviewed the manuscript, and provided academic guidance throughout the research process. Both authors reviewed and approved the final manuscript.

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Appendices

Appendix A:

Table C1 Quality Assessment Criteria with Detailed Descriptions

Criterion	Description	Scoring Guide
QA1: Clear Research Purpose	Study objectives, research questions, and/or hypotheses are explicitly stated	Y = 1.0 if fully articulated; P = 0.5 if partially articulated; N = 0.0 if absent/unclear
QA2: Relevance & Usefulness	Significance of the research and contribution to the field are clearly articulated	Y = 1.0 if explicitly justified; P = 0.5 if mentioned but underdeveloped; N = 0.0 if absent
QA3: Methodology Clarity	Research design, sample/participants, data collection methods, and data analysis procedures are clearly described	Y = 1.0 if comprehensive; P = 0.5 if partially described with gaps; N = 0.0 if vague/missing
QA4: Concept Definition	Key theoretical constructs, frameworks, and variables are clearly defined and operationalized	Y = 1.0 if comprehensive definitions; P = 0.5 if some definitions lacking; N = 0.0 if absent
QA5: Comparison with Prior Work	Study is positioned within existing literature; findings are compared/contrasted with prior research	Y = 1.0 if thorough literature positioning; P = 0.5 if limited comparison; N = 0.0 if absent
QA6: Limitations Reporting	Study acknowledges limitations of design, methods, sample, generalizability, and findings	Y = 1.0 if explicit and detailed; P = 0.5 if mentioned briefly; N = 0.0 if not addressed

Appendix B: List of Primary Studies Included in the Systematic Review

No	Authors	Title	Year	Source Title
1	Avci, H., Lunn, S. J., & Hazari, Z.	Exploring STEM educators' perspectives on the integration of AI-enabled technologies in teaching and learning	2025	Computers and Education Open
2	Carvalho, R., Santos, C., & Ramos, F.	Analyzing the transformative power of Immersive Web Environments in classroom through the lens of Bloom's taxonomy	2025	Computers and Education: X Reality
3	Zagami, J.	Virtual maker spaces: Enhancing student engagement through extended reality in the co-creation of learning spaces	2025	Computers and Education: X Reality
4	Pino Tarragó, J. C., et al.	Artificial intelligence and soft skills in civil engineering education: A Latin American curriculum gap with global implications	2025	Research in Globalization

5	van den Berg, G.	Teachers' experiences of using artificial intelligence from an open distance learning context: Successes, challenges, and strategies for success	2025	Discover Education
6	Phong, P., Nguyen, Q., & Huynh, V.	Evaluating impact of digitalization on higher education quality	2025	Journal of Education and Learning
7	Espitia Barrero, J., et al.	Multivariable study of innovative competence profile in university faculty: Analysis of determining factors and their relationship to improvement of educational quality	2025	Education Sciences
8	Jeevarajathy, E. S., & Hema, N.	Integrating digital tools in English language assessments: Insights from tertiary education	2025	Theory and Practice in Language Studies
9	Liu, Q., & Li, Y.	Digital-technology-enhanced immersive learning in Chinese secondary school geography education: A comprehensive comparative analysis of sustainable pedagogical transformation	2025	Sustainability
10	Hoang, N. H.	E-leadership in the AI era: Exploring Vietnamese EFL teachers' digital leadership development in AI integration	2025	Education and Information Technologies
11	Stambekova, S., et al.	Evaluating the impact of digital tools on innovative teaching practices among future educators	2025	Ikenga
12	Ouahmiche, O., & Bouguebs, R.	Crossing the nexus: Language, culture, and technology in a globalized world	2025	Traduction et Langues
13	Asal, M. G. R., et al.	The impact of digital competence on pedagogical innovation among nurse educators: The moderating role of artificial intelligence readiness	2025	Nurse Education in Practice
14	Alqahtani, N., & Wafula, Z.	Artificial intelligence integration: Pedagogical strategies and policies at leading universities	2025	Innovative Higher Education
15	Rocha-Castillo, S., et al.	Technology integration in indigenous schools without internet access	2025	Contemporary Educational Technology
16	Thangavel, S., Sharmila, K., & Sufina, K.	Revolutionizing education through augmented reality (AR) and virtual reality (VR): Innovations, challenges and future prospects	2025	Asian Journal of Interdisciplinary Research
17	Méndez Gijón, F., et al.	The role of open-source software as a technological alternative for blended learning in LMS systems	2025	International Journal of Engineering Pedagogy

18	Rutten, N., & Brouwer-Truijn, K.	Defining XR-specific teacher competencies: Extending the DigCompEdu framework for immersive education	2025	Trends in Higher Education
19	Mathebula, Z., et al.	Inadequate teacher training as a barrier to ICT integration in early childhood education: A case of selected primary schools in Tshwane West District Circuit 4	2025	International Journal of Learning, Teaching and Educational Research
20	Dehbi, A., et al.	Education and smart technologies: Towards a new pedagogical paradigm	2025	International Journal of Evaluation and Research in Education
21	Kedraka, K., & Mitits, L.	The BALKANETUP: Fostering innovation and collaboration in higher education pedagogy in the Western Balkans	2025	Academia (Greece)
22	Younas, M., et al.	Evaluating the effectiveness of digital scenario-based English teaching at the university level using the artificial intelligence generated content	2025	Frontiers in Education
23	Flores, M. M., & Aguilar-Esteva, V.	Planning and socioformative projects: A systematic review in the Mexican educational context	2025	Issues in Educational Research
24	Seitaliyeva, A., et al.	Integration of digital technologies into the methodology of teacher training in the system of dual education	2025	Periodicals of Engineering and Natural Sciences
25	Gaviria-Rodríguez, D. Y., et al.	Intention to use AI in accounting education: An analysis from the TAM and TPB perspectives	2025	Frontiers in Education
26	Yue, W., & Sukumaran, S.	Generative AI and TCM teaching materials	2025	Journal of Management Practices, Humanities and Social Sciences
27	Al-Obaydi, L. H., et al.	Digital literacy of EFL student-teachers using empowerment outreach program: The role of engagement, cognitive learning, and performance	2025	International Journal of Educational Research
28	Zhong, M., Wei, L., & Mo, H.	Enhancing graduate AI education through practical and values-driven curriculum integration	2025	Frontiers in Education
29*	Li, H.	AI foundations in China's medical physiology education: Pedagogical practices and systemic challenges	2025	Advances in Medical Education and Practice
30	Islam, M., et al.	Innovative technologies in tourism and hospitality education: A	2025	Asia-Pacific Journal of Innovation in

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		bibliometric review with future research directions		Hospitality and Tourism
31	Fitria, D., et al.	Integrating blended problem-based learning with ethnoscience to develop twenty-first-century skills in middle school science education	2025	International Journal of Pedagogy and Curriculum
32	Al-Khresheh, M. H., et al.	Digital integration in the Saudi ELT context: A supervisory lens on teachers' technological efficacy	2025	Cogent Social Sciences
33	Sarzhanova, G. B., et al.	Innovative educational approaches of teachers as a condition for psycho-emotional well-being of schoolchildren	2025	Eurasian Journal of Applied Linguistics
34	Espartinez, A. S.	Exploring student perspectives on studying philosophy through design thinking: A narrative case study	2025	Journal of Information Technology Education: Innovations in Practice
35	Uriarte, A. S.	Educational policies on musical identity in Latin America: A systematic review	2025	International Journal of Interdisciplinary Educational Studies
36	Morgado, E., et al.	Technology-mediated education: Impact of AI on the main distance learning modalities	2025	Educational Process: International Journal