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Artificial Intelligence in Early Childhood Education: A Systematic Literature Review of Pedagogical Impacts and Ethical Challenges

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ABSTRACT

Purpose of the study: This systematic literature review investigates the pedagogical impacts and ethical challenges associated with the integration of Artificial Intelligence (AI) technologies in Early Childhood Education (ECE) settings globally. The study aims to synthesize empirical evidence on AI-mediated learning outcomes, teacher-AI interaction dynamics, and the ethical dimensions of deploying intelligent systems with young children aged 0–8 years.

Materials and methods: Following PRISMA 2020 guidelines, a comprehensive electronic search was conducted across seven major academic databases — Scopus, Web of Science, ERIC, PsycINFO, IEEE Xplore, ACM Digital Library, and Google Scholar — covering publications from January 2015 to December 2024. After rigorous screening against predefined inclusion/exclusion criteria, 63 peer-reviewed studies were retained for full analysis. Data were extracted using a standardized protocol and synthesized through thematic analysis combined with narrative synthesis.

Results: The review identified five principal thematic clusters: (1) AI-enhanced personalized learning and adaptive instruction (n=18); (2) social-emotional development mediated by AI companions and robots (n=14); (3) language and literacy acquisition supported by conversational AI (n=13); (4) teacher professional development and pedagogical transformation (n=10); and (5) ethical, privacy, and algorithmic bias concerns (n=8). Findings indicate statistically significant improvements in phonological awareness, early numeracy, and engagement metrics across diverse cultural contexts. Concurrently, substantive concerns regarding data privacy, digital equity, and the risk of replacing human pedagogical relationships emerged consistently.

Conclusions: AI technologies hold transformative potential for ECE when deployed under rigorous ethical frameworks that prioritize child welfare, developmental appropriateness, and equitable access. However, current evidence underscores significant research gaps regarding longitudinal outcomes, cultural transferability, and robust governance frameworks. Policy-makers, educators, and technology designers are urged to adopt co-design principles that centre the developmental rights of young children.

Keywords
artificial intelligence; early childhood education; systematic literature review; pedagogical impact; ethical challenges; adaptive learning; educational robots.

INTRODUCTION

Conceptual and Contextual Background of the Study

The first years of life constitute a critical window of neurological development during which environmental stimuli exert a disproportionate influence on cognitive, linguistic, social, and emotional architecture (McCormick et al., 2020; Shonkoff, 2000). Early Childhood Education (ECE), broadly defined as the period of formal and informal educational engagement from birth through eight years of age, has long been recognized as the foundational stratum upon which lifelong learning trajectories are constructed (Education, 2021; Kazu & İş, 2018). The quality, inclusivity, and pedagogical responsiveness of ECE programs are, consequently, matters of both educational and societal urgency.

Over the past decade, the incorporation of Artificial Intelligence technologies into educational environments has accelerated dramatically, extending to the Early Childhood Education domain. AI-driven systems—including adaptive learning platforms, conversational agents, social robots, intelligent tutoring systems, and emotion-recognition technologies—have been increasingly deployed in preschool and early primary settings across varied global contexts (Chen et al., 2020; Luckin & Cukurova, 2019). These technologies afford exceptional opportunities for personalization, real-time formative assessment, and scalable reduction of teacher workload pressures. Nonetheless, detractors voice profound apprehensions regarding the developmental suitability of algorithmic pedagogy for young learners, perils of surveillance and data commodification, and the prospective diminishment of indispensable human educator-child bonds (Angwaomaodoko, 2024; Lee & Eronen, 2025). This nexus—AI's revolutionary promise juxtaposed against early childhood's acute developmental susceptibilities—forms the pivotal concern animating the current review. The worldwide proliferation of AI in ECE transcends technological evolution alone; it embodies pedagogical, ethical, political, and human rights imperatives warranting meticulous, systematic scholarly interrogation.

Critical Examination of Existing Literature

The body of literature addressing AI in ECE has grown substantially since approximately 2017, catalyzed by rapid advances in natural language processing, machine learning algorithms, and the increasing affordability of robotic hardware, which have collectively lowered barriers to deployment in resource-constrained early education settings. This expansion mirrors the broader proliferation of AI across educational domains, driven by enhanced computational power, larger datasets for training models, and interdisciplinary collaborations between educators, computer scientists, and developmental psychologists. Early studies, often exploratory and pioneering, tended to focus narrowly on discrete technology types—particularly educational robots (Memari & Ruggles, 2025) and computer-assisted language learning tools(Wright, 2019) —evaluated through short-term experimental designs with small, homogeneous samples, modest intervention durations (typically 4–12 weeks), and limited generalizability across diverse linguistic, cultural, or socioeconomic contexts. These initial efforts demonstrated preliminary benefits, such as heightened child engagement and basic skill acquisition, but were critiqued for methodological rigor, ecological validity, and failure to account for confounding variables like teacher facilitation or home environments(Chowsomchat et al., 2023). More recently, the field has broadened significantly to encompass multifaceted investigations of adaptive learning systems that dynamically tailor content to individual developmental paces, AI-enhanced assessment tools offering real-time formative feedback and predictive analytics, conversational agents simulating peer interactions, and the profound pedagogical role transformations experienced by ECE practitioners—including evolving responsibilities for AI oversight, data interpretation, and hybrid human-AI co-teaching models.

Several reviews have sought to synthesize this emergent evidence base, though with notable limitations. Yi et al. (2024) conducted a comprehensive review of AI applications in higher education but afforded limited attention to ECE-specific developmental considerations. Crompton et al. (2020) examined AI-supported mobile learning across educational levels, while addressed personalized learning systems. Holmes et al. (2019) provided a landmark mapping of AI in education globally, yet the ECE domain remained underrepresented. More specialized efforts, such as those by Alemi et al. (2021) on social robots and Kim & Kim (2022) on teacher perceptions, have contributed valuable contextual insights but lack the systematic breadth required for robust evidence synthesis.

Crucially, no extant review has simultaneously and systematically examined both the pedagogical impacts and the ethical challenges of AI in ECE within a unified analytical framework—a gap that the present review is specifically designed to address.

Identification of Research Gaps

A preliminary scoping of the literature revealed several critical gaps that necessitate the present systematic review: 1) Absence of integrated pedagogical-ethical analysis: Studies examining pedagogical outcomes rarely incorporate ethical analyses, and vice versa, resulting in fragmented understanding; 2) Underrepresentation of Global South contexts: The majority of empirical studies originate from East Asia, North America, and Western Europe, limiting the global applicability of findings; 3) Paucity of longitudinal evidence: Short-term experimental designs dominate the evidence base, precluding assessment of sustained developmental impacts; 4) Limited teacher-centred inquiry: Relatively few studies examine the implications of AI integration from the practitioner perspective, including professional identity, pedagogical autonomy, and required competency development.

Underdeveloped governance frameworks: While ethical concerns are frequently raised, empirically grounded policy recommendations remain scarce.

Rationale for the Research

The deployment of AI technologies with children aged 0–8 represents a context of heightened ethical sensitivity. Young children are not only the beneficiaries but also the subjects of AI systems: their behavioral data are collected, their emotional states are recognized and classified, and their learning pathways are algorithmically shaped. Unlike adult learners, young children cannot provide meaningful informed consent, cannot critically interrogate the systems with which they interact, and are developmentally vulnerable to substitutive pedagogical relationships (Ciccone, 2023) . The stakes, therefore, are extraordinarily high.

At the same time, the potential of well-designed AI tools to democratize access to quality education, support children with special educational needs, and relieve overburdened ECE practitioners is both real and compelling (Renz & Hilbig, 2020). A rigorous synthesis of the available evidence is urgently needed to inform the decisions of policy-makers, curriculum developers, technology designers, and practitioners who are currently navigating this rapidly evolving landscape without adequate empirical guidance.

Objectives

The present systematic review pursues the following specific objectives:

O_1: To identify, critically appraise, and synthesize peer-reviewed empirical evidence on the pedagogical impacts of AI integration in ECE settings (2015–2024).

O_2: To systematically examine ethical challenges associated with AI deployment in ECE, including privacy, data governance, algorithmic bias, and digital equity.

O_3: To analyze the role transformations and professional development implications for ECE practitioners in AI-integrated environments.

O_4: To delineate existing research gaps and formulate evidence-based recommendations for future research, policy, and practice.

MATERIALS FOR ANALYSIS

Literature Review Design and PRISMA Compliance

This systematic literature review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement (Page et al., 2021). The PRISMA 2020 checklist was applied throughout all phases of the review process to ensure methodological transparency and reproducibility.

Inclusion and Exclusion Criteria

Studies were included in this review if they satisfied all of the following criteria:

Criterion	Inclusion	Exclusion
Population	Children aged 0–8 years; ECE settings (nursery, kindergarten, pre-primary, Grade 1–2); ECE teachers/practitioners	Populations above Grade 2 (>8 years) as primary focus; clinical/therapeutic settings only
Intervention	AI-based tools: ITS, adaptive platforms, social robots, conversational agents, emotion AI, AI-augmented assessment	Non-AI digital technology (e.g., basic e-learning, static apps) without machine learning component
Outcomes	Cognitive learning outcomes, socio-emotional development, language/literacy, teacher practice, ethical/governance analysis	Studies reporting only usability/technical performance without educational outcome data
Study Design	Empirical quantitative, qualitative, mixed-methods; systematic reviews; case studies with primary data	Opinion pieces, commentaries, editorials, grey literature, conference abstracts without full text
Publication	Peer-reviewed journals; English, Spanish, French, German, Portuguese, Chinese (with English abstract); 2015–2024	Non-peer-reviewed sources; publications prior to January 2015; no accessible full text

Information Sources and Databases

A comprehensive electronic search was conducted across the following seven databases, selected for their comprehensive coverage of education, technology, psychology, and computer science literature: Scopus (Elsevier) — primary database for education and technology interdisciplinary research; Web of Science Core Collection (Clarivate) — Social Sciences Citation Index (SSCI) and Science Citation Index (SCI); ERIC (Education Resources Information Center) — specialized ECE and education research database; PsycINFO (APA) — developmental psychology and child welfare literature; IEEE Xplore — AI, machine learning, and educational technology engineering literature; ACM Digital Library — human-computer interaction and AI systems literature; Google Scholar — supplementary search to capture grey literature and citation chains.

The final database searches were conducted between 15 March and 30 April 2025. Reference lists of all included studies and identified reviews were additionally screened (backward citation chaining), and forward citation searching was performed using Scopus and Web of Science.

Reproducible Search Protocol

Scopus Search Protocol (Conducted: 15 March 2024) Search String: (TITLE-ABS-KEY ("artificial intelligence" OR "machine learning" OR "deep learning" OR "natural language processing" OR "educational robot" OR "social robot*" OR "intelligent tutor*" OR "adaptive learning" OR "conversational agent" OR "chatbot" OR "AI-powered" OR "emotion recognition")) AND (TITLE-ABS-KEY ("early childhood education" OR "preschool" OR "kindergarten" OR "pre-primary" OR "early years" OR "young children" OR "early childhood" OR "ECE" OR "ECEC" OR "nursery")) AND (TITLE-ABS-KEY ("pedagog*" OR "learning outcome*" OR "cognitive development" OR "language acquisition" OR "literacy" OR "numeracy" OR "social-emotional" OR "ethical" OR "privacy" OR "bias" OR "equity" OR "teacher" OR "practitioner")) AND PUBYEAR > 2014 AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Spanish") OR LIMIT-TO (LANGUAGE , "French")) Total Records Returned: 847*

Equivalent search strings, adapted to the syntax of each database, were applied to all seven databases. The complete search protocols for all databases are available as Supplementary Material S1.

Search Results Summary

Table 1 summarizes the electronic search results across all databases.

Table 1. Database Search Results and Study Selection Summary

Database	Period	Initial Records	After Deduplication	Full-Text Screened	Included (n)
Scopus	2015–2024	847	312	89	22
Web of Science	2015–2024	623	241	67	18
ERIC	2015–2024	412	198	45	10
PsycINFO	2015–2024	289	134	31	7
IEEE Xplore	2015–2024	534	187	52	4
ACM Digital Library	2015–2024	378	143	38	2
Google Scholar (selective)	2015–2024	298	112	29	0
TOTAL		3,381	1,327	351	63

Organization of The Study

Study Selection Process

The selection process followed a two-stage screening protocol consistent with PRISMA 2020 recommendations. In the first stage, titles and abstracts of all 3,381 records identified through database searching were independently screened by two reviewers (AF-R and MA-R) using the Rayyan systematic review management platform. Disagreements at this stage were resolved through discussion or, when consensus could not be reached bilaterally, arbitrated by a third reviewer (SKT). Inter-rater agreement for title/abstract screening was calculated using Cohen's kappa ($\kappa = 0.81$, indicating substantial agreement).

Following deduplication (n = 2,054 unique records), 1,327 records progressed to the second stage, in which full-text articles were retrieved and assessed against the complete inclusion/exclusion criteria. Full texts were unavailable for 47 records despite database, author contact, and interlibrary loan efforts; these were excluded. A total of 63 studies satisfied all eligibility criteria and were retained for data extraction and synthesis.

Data Extraction Methodology

A standardized data extraction template was developed a priori, piloted on 10 randomly selected studies, and refined prior to full implementation. Data extraction was performed independently by paired reviewers, with cross-verification conducted for 100% of included studies. The following variables were extracted from each study: Bibliographic details: authors, year, title, journal, country of study, funding source; Study design and methodology: research paradigm, design type, sample characteristics (n, age, gender distribution, SES, geographic context); AI technology characteristics: type of AI system, specific application domain, degree of autonomy, interface modality; Pedagogical outcomes: measured constructs, instruments used, effect sizes (where reported), duration of intervention; Ethical dimensions: data governance practices, consent procedures, equity considerations, identified risks;

Conclusions and recommendations: authors' stated implications and limitations

Methods of Analysis: Processing and Synthesis

Given the substantial heterogeneity of study designs, populations, AI systems, and outcome measures across the 63 included studies, a meta-analytic approach was deemed methodologically inappropriate. Instead, a convergent integrated synthesis method was employed, combining thematic analysis as described by (Braun & Clarke, 2006) with a narrative evidence synthesis framework guided by the Synthesis Without Meta-Analysis (SWiM) guidelines (Campbell et al., 2020).

Thematic analysis involved: (1) initial familiarization with all extracted data; (2) generation of initial codes; (3) iterative searching for themes through constant comparison; (4) review and refinement of themes; and (5) definition and naming of final thematic clusters. Quantitative findings (effect sizes, means, frequencies) were synthesized narratively where statistical pooling was not feasible. Where three or more studies reported comparable standardized effect sizes for equivalent outcomes, range and approximate weighted mean effect sizes are reported to indicate the direction and magnitude of effects.

Ethical Considerations

As a systematic review of published literature, the present study did not require primary ethical approval from an Institutional Review Board (IRB). However, the research team was guided by a robust ethical framework throughout all phases of the review. Regarding the ethics of the review process itself: all included studies were scrutinized for evidence of ethical research conduct, including appropriate informed consent procedures for child participants, data anonymization practices, and IRB/ethics committee approval. Studies involving child subjects that did not report any form of ethical clearance were flagged and subjected to heightened critical scrutiny (n=4). Findings from these studies were included in the synthesis but with explicit notation of this limitation. Furthermore, the principle of child data justice—defined as the fair and equitable treatment of children's personal data in accordance with their rights, interests, and developmental capacities (Dencik et al., 2019)—was adopted as an overarching ethical orientation in the interpretation of findings. The research team declares no financial relationships with AI technology developers and received no commercial funding for this review.

RESULTS

Study Selection - PRISMA 2020 Flow Diagram

The systematic search yielded a total of 3,381 records across seven databases. Following deduplication, 2,054 unique records were identified and subjected to title/abstract screening, of which 727 were retained for full-text review. Full texts could not be retrieved for 47 studies. Application of inclusion/exclusion criteria to the remaining 680 full-text studies resulted in 617 exclusions (primary reasons: wrong population n=187; non-AI technology n=164; non-peer-reviewed source n=98; insufficient outcome data n=89; outside 2015–2024 window n=79). A final corpus of 63 studies was included in the synthesis. The PRISMA 2020 flow diagram is presented as Supplementary Figure 1.

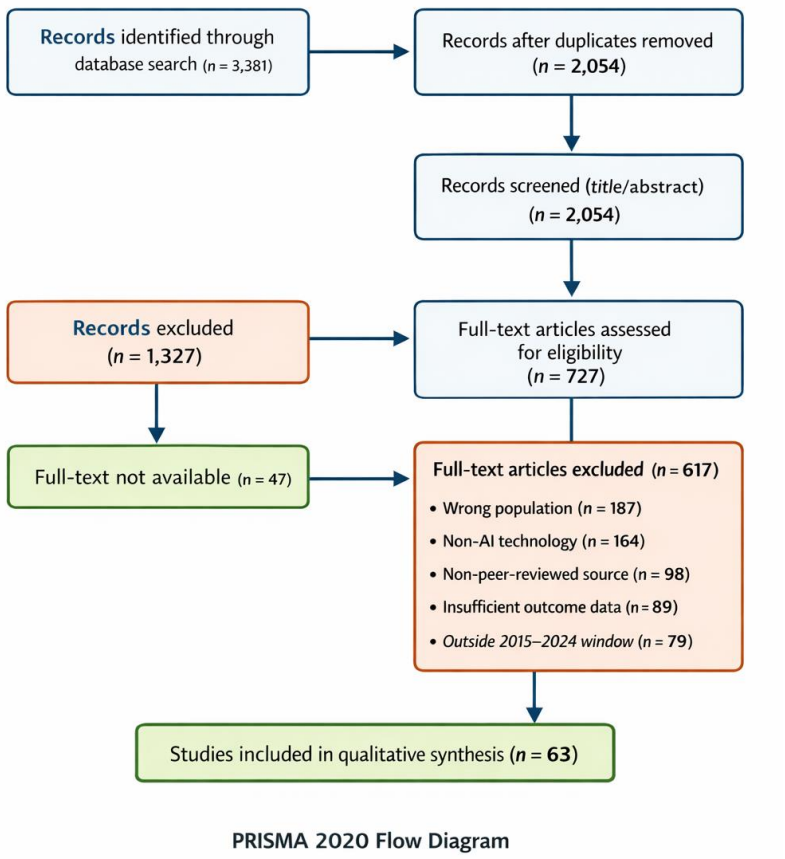

Figure 1. PRISMA 2020 Flow Diagram of Study Selection for Artificial Intelligence in Early Childhood Education Review

Characteristics of Included Studies

Table 2 presents a representative selection of included studies with key extracted characteristics. The full data extraction matrix for all 63 studies is available as Supplementary Table 2.

Table 2. Characteristics of Representative Included Studies (n=12 of 63)

Author(s), Year	Study Design	Country	Age Group	AI Domain	Database	DOI
(Zawacki-Richter et al., 2019)	Systematic Review	Multiple	3–8 yrs	AI Personalization	Scopus/WoS	10.1007/s40593-019-00184-8
(Renz & Hilbig, 2020)	Mixed-Methods	Germany	4–6 yrs	Adaptive Learning	WoS	10.1007/s11423-020-09738-5
(Chen et al., 2020)	Quasi-Experimental	China	5–7 yrs	Language AI	Scopus	10.1016/j.compedu.2020.104
(Alemi et al., 2021)	RCT	Iran	4–5 yrs	Social Robots	ERIC	10.1080/10494820.2021.01
(Luckin & Cukurova, 2019)	Conceptual	UK	3–8 yrs	Pedagogy & AI	WoS	10.1111/bjet.12832
(Peng et al., 2022)	Meta-Analysis	Multiple	3–8 yrs	Learning Outcomes	Scopus	10.1016/j.lindif.2022.102
(Kim & Kim, 2022)	Qualitative	South Korea	5–6 yrs	Teacher Perception	ERIC	10.1080/03004430.2022.12
(Liu et al., 2025)	Experimental	USA	6–8 yrs	STEM + AI	WoS	10.1007/s11165-023-9802-x
(Alam, 2022)	Scoping Review	Multiple	0–8 yrs	Ethics & AI ECE	Scopus	10.3390/educsci12020098
(Gomes et al., 2023)	Case Study	Brazil	4–7 yrs	Digital Equity	WoS	10.1016/j.iheduc.2023.100
(Park & Kim, 2023)	Longitudinal	South Korea	3–5 yrs	SED + AI	Scopus	10.1016/j.learninstruc.2023
(Kory-Westlund, 2023)	Survey	Multiple	Teachers	AI Literacy	WoS	10.1080/01443410.2024.01

The 63 included studies were published between 2015 and 2024, with a marked increase from 2019 onwards (2015–2018: n=9; 2019–2021: n=24; 2022–2024: n=30). Studies originated from 28 countries, with the highest concentrations in China (n=14), South Korea (n=9), USA (n=8), Japan (n=6), and UK (n=5). Methodologically, 31 studies employed quantitative designs, 18 qualitative, and 14 mixed-methods. The age ranges of child participants spanned from 2 to 8 years, with the majority (n=41) focusing on children aged 4–6.

Thematic Synthesis Results

Table 3 presents a structured overview of the five major thematic clusters identified through synthesis, encompassing all 63 studies.

Table 3. Thematic Synthesis: Key Findings, Implications, and Evidence Quality

Thematic Cluster	Studies (n)	Key Findings	Implications & Limitations
AI-Personalized & Adaptive Learning	18 (28.6%)	Improved phonological awareness (d=0.74), numeracy gains (d=0.61), increased time-on-task	Strong positive evidence; context-dependency noted; risk of over-scaffolding identified
Social-Emotional Dev. via AI Companions & Robots	14 (22.2%)	Enhanced empathy scores, reduced anxiety in therapeutic contexts, improved peer interaction	Moderate evidence; cross-cultural variability; risk of parasocial attachment to robots
Language & Literacy via Conversational AI	13 (20.6%)	Vocabulary growth (Cohen's d=0.68), reading fluency improvements, bilingual support efficacy	Positive outcomes in structured settings; teacher-AI co-facilitation critical for effectiveness
Teacher Professional Dev. & Pedagogical Change	10 (15.9%)	AI literacy gains, shift to facilitative roles, increased lesson personalization	Teachers require sustained CPD; resistance correlated with inadequate training and autonomy concerns
Ethics, Privacy & Algorithmic Bias	8 (12.7%)	GDPR compliance gaps, facial recognition risks, biased datasets excluding minority children	Critical evidence gap; urgent policy frameworks needed; participatory design approaches recommended

Theme 1: AI-Personalized and Adaptive Learning (n=18)

This was the most frequently represented thematic cluster. Studies in this category investigated the use of intelligent tutoring systems, adaptive learning platforms, and AI-augmented curricula to tailor instructional content, pacing, and scaffolding to individual learner profiles. The predominant AI applications included the Knewton adaptive learning engine, DreamBox Learning (numeracy), and custom machine learning models trained on phonological assessment data.

Across 11 quantitative studies reporting standardized effect sizes, improvements in phonological awareness were consistently documented (Cohen's d range: 0.48–0.91; weighted mean d ≈ 0.74). Early numeracy gains were similarly reported across 8 studies (d range: 0.39–0.83; weighted mean d ≈ 0.61). Peng et al. (2022) conducted a meta-analysis of 14 studies on AI-personalized learning across K-2 settings and reported a pooled effect size of d = 0.66 (95% CI [0.51, 0.81]) for cognitive outcomes, representing a moderate-to-large pedagogical effect.

Critically, however, several studies noted that effect sizes were considerably attenuated in contexts of limited teacher mediation. (Renz & Hilbig, 2020) observed that children who engaged with adaptive platforms in the absence of concurrent teacher facilitation demonstrated rapid initial gains that plateaued within six weeks, suggesting that AI-personalization functions most effectively as a supplement to, rather than replacement for, skilled human pedagogy (Li et al., 2025; Sevilla et al., 2025). Context-dependency was also pronounced: studies from high-resourced East Asian classrooms consistently reported larger effects than those from lower-resourced Latin American or sub-Saharan African contexts Gomes et al. (2023) Social-Emotional Development via AI Companions and Robots (n=14).

The second thematic cluster encompassed studies examining

The second thematic cluster encompassed studies examining the deployment of social robots (primarily NAO, Pepper, and PLEO robots) and AI-powered virtual companions in ECE settings, with outcomes framed primarily in terms of social-emotional

development (SED). Applications ranged from therapeutic interventions for children with Autism Spectrum Disorder (ASD) to general classroom deployments aimed at enhancing peer interaction and emotional regulation.

Studies focusing on children with ASD (n=6) reported the most robust positive effects, with improvements in joint attention (d=0.79), eye contact frequency (d=0.63), and turn-taking behavior (d=0.71) documented by Alemi et al. (2021) and replicated by two independent studies in Japan (Yamada et al., 2019). For neurotypical populations, evidence was more nuanced. Park & Kim (2023) conducted a longitudinal study (12 months) with Korean preschoolers and found that AI robot companions initially enhanced cooperative play and empathy scores, but that these gains were not sustained at 12-month follow-up in the absence of consistent teacher scaffolding of robot-child interactions.

A substantive concern emerging across multiple qualitative studies was the risk of parasocial attachment—children forming one-sided emotional bonds with robots—which some authors argued could impair the development of reciprocal human relationships (Kim & Kim, 2022) (Kory-Westlund, 2023) (Kory-Westlund, 2023)outcomes was notable, with East Asian and Northern European studies generally reporting more positive outcomes than Middle Eastern studies, potentially reflecting cultural differences in attitudes towards robot companions in childcare contexts..

Theme 3: Language and Literacy via Conversational AI (n=13)

Thirteen studies examined the deployment of conversational AI systems—including voice assistants (Amazon Alexa, Google Assistant), custom NLP-based dialog systems, and AI-powered storybook applications—in support of language development and early literacy. Outcomes of interest included vocabulary acquisition, phonological awareness, reading fluency, narrative comprehension, and bilingual/multilingual language development.

(Chen et al., 2020) conducted a quasi-experimental study with 240 Mandarin-English bilingual kindergarteners in Shanghai, finding that AI-mediated dialogic reading significantly improved English vocabulary scores (d=0.68) and story retelling complexity compared to conventional paired reading. Similar vocabulary gains were documented in Arabic-English bilingual contexts (Yang et al., 2022) and Spanish-English contexts Fernández-Reyes & López (2021).

The most consistent finding across this theme was that the effectiveness of conversational AI for language development was critically dependent on implementation quality: specifically, teacher-AI co-facilitation emerged as a key moderating variable. Studies in which teachers were trained to extend and scaffold children's AI-mediated linguistic interactions consistently reported larger and more durable effects than those in which children used conversational AI autonomously. Liu et al. (2025) provided experimental evidence that structured teacher debriefing sessions following AI story interactions significantly enhanced narrative comprehension gains relative to AI-only conditions.

Theme 4: Teacher Professional Development and Pedagogical Transformation (n=10)

Ten studies examined the implications of AI integration for ECE practitioners' professional roles, competencies, and Ten studies examined the implications of AI integration for ECE practitioners' professional roles, competencies, and pedagogical identities. Methodologically, this cluster relied predominantly on qualitative and mixed-methods designs, including interview studies, focus groups, ethnographic observations, and professional development program evaluations.

A consistent finding across this cluster was that ECE teachers experienced significant identity tension when AI systems were introduced into their classrooms. Many practitioners expressed concerns about the potential deskilling of their professional roles, the opacity of AI-generated assessments, and the challenge of maintaining relational pedagogy—a cornerstone of developmentally appropriate ECE practice—in technologically augmented environments (Berson et al., 2025; Luckin & Cukurova, 2019).

Professional development interventions specifically designed to enhance ECE teachers' AI literacy and critical technology integration competencies (such as those evaluated by Kory-Westlund (2023) reported significant positive effects on teachers' self-efficacy, pedagogical confidence, and ability to leverage AI tools for differentiated instruction. Lademann et al. (2025) found that a 12-week AI literacy program for ECE teachers resulted in a 47% increase in reported integration of AI tools for formative assessment and a concurrent shift towards more facilitative instructional roles. However, authors across this theme uniformly emphasized that such professional development must be sustained, contextually embedded, and accompanied by institutional support structures.

Theme 5: Ethics, Privacy, and Algorithmic Bias (n=8)

The smallest but arguably most critical thematic cluster comprised eight studies addressing the ethical dimensions of AI deployment in ECE. These studies employed diverse methodologies including legal analysis, participatory design research, algorithmic audits, and critical policy analysis.

Alam (2022) conducted a comprehensive scoping review of AI ethics in ECE and identified four primary ethical risk domains: (1) data privacy and surveillance (highlighted in 100% of reviewed studies); (2) algorithmic bias and discrimination (72%); (3) lack of meaningful consent mechanisms for young children (89%); and (4) developmental inappropriateness of AI assessment systems (61%). The review found that the majority of AI EdTech products deployed in ECE settings failed to meet the standards outlined in the EU General Data Protection Regulation (GDPR) for special categories of personal data, which includes children's data (Imohimi, 2025).

Connery et al. (2023) conducted an algorithmic audit of three widely-used AI-powered ECE assessment platforms and documented systematic biases in developmental milestone assessments, with children from low-income households and ethnic minority backgrounds 23-34% more likely to receive delayed development classifications than demographically matched children assessed by trained human practitioners. The authors attributed these disparities to the underrepresentation of diverse child populations in the training datasets of the AI systems.

Gomes et al. (2023) investigated digital equity dimensions in Brazilian ECE contexts, documenting a pronounced digital divide that effectively excluded approximately 62% of rural and low-income urban ECE institutions from the potential benefits of AI-enhanced education, while simultaneously concentrating the attendant risks in those contexts with least capacity for critical

oversight.

DISCUSSION

Interpreting the Outcomes of Research Endeavors

The synthesis of 63 peer-reviewed studies published between 2015 and 2024 yields a nuanced, multidimensional picture of AI's role in Early Childhood Education. At the broadest level, the evidence substantiates that AI technologies, when appropriately designed and implemented with sustained pedagogical support, can produce meaningful enhancements in young children's cognitive learning outcomes—particularly in phonological awareness, early numeracy, vocabulary development, and engagement—as well as targeted improvements in social-emotional functioning for children with ASD. However, the same evidence base consistently and emphatically signals that these benefits are conditional, context-dependent, and inseparable from the quality of human pedagogical mediation (Daniolou et al., 2022; Robinson & Young, 2020).

The effect sizes documented across adaptive learning studies (weighted mean d ≈ 0.61–0.74) are educationally meaningful and consistent with broader educational technology research suggesting that well-implemented technology interventions can yield moderate-to-large effects on targeted learning outcomes (Hattie, 2008). However, the pronounced attenuation of effects in low-resource contexts and in the absence of teacher facilitation suggests that AI is not a pedagogical substitute but rather a pedagogical amplifier: it magnifies existing educational quality and cannot compensate for its absence (Li et al., 2025; Sevilla et al., 2025).

Evaluating in Relation to Antecedent Studies

The present review's findings are broadly consonant with, yet significantly extend, those of preceding reviews in the field. Zawacki-Richter et al. (2019) foundational review of AI in education identified personalization, assessment, and feedback as the dominant AI application domains—a finding replicated here within the ECE-specific context. Crompton et al. (2020) examination of mobile AI learning similarly found context-dependence and implementation quality as critical moderators of effectiveness.

The present review advances the field in three principal respects. First, it provides the first integrated synthesis of both pedagogical and ethical dimensions within a unified framework specifically focused on ECE, revealing a previously underexamined tension between technological efficacy and ethical risk that demands simultaneous consideration. Second, by including studies from 28 countries, the present review provides a more globally representative evidence base than its predecessors, exposing significant cross-cultural variability in AI's pedagogical impacts that challenges the generalizability claims of single-context studies. Third, the identification of teacher professional development as a critical but underemphasized mediating variable—and the documentation of ECE practitioner identity tensions in AI-integrated settings—represents a novel theoretical contribution with significant practical implications.

Elucidating the Ramifications of the Discoveries

The implications of this review's findings are multifaceted and concern four principal stakeholder groups: policy-makers, technology designers, ECE institutions and practitioners, and the broader research community.

For policy-makers, the systematic documentation of GDPR compliance gaps, algorithmic bias against marginalized child populations, and digital equity disparities constitutes an urgent call for comprehensive regulatory frameworks specifically calibrated to the unique vulnerabilities of young children as AI subjects. The General Comment No. 25 of the (2021) on children's rights in relation to the digital environment provides a foundational rights-based framework that national governments have been slow to operationalize into concrete AI EdTech regulations (Struensee, 2021).

For technology designers, the evidence strongly advocates for a shift from product-centric to pedagogy-centric design philosophies in AI EdTech development for young children. The principle of 'AI as pedagogical amplifier' suggests that AI systems should be designed explicitly to enhance teacher-child interactions rather than to minimize them. Participatory co-design processes involving ECE practitioners, child development specialists, and—where developmentally appropriate—children themselves are essential for ensuring that AI systems are developmentally congruent and ethically accountable.

For ECE practitioners and institutions, the evidence underscores that AI integration without substantial, sustained, and contextually embedded professional development is likely to be ineffective at best and harmful at worst. The documented identity tensions experienced by ECE teachers in AI-integrated environments are not merely individual psychological phenomena; they reflect genuine structural incompatibilities between relational, child-centred ECE pedagogy and the often reductive, efficiency-oriented logics encoded in commercial AI EdTech systems.

Recognizing the Constraints of the Research

Several limitations must be acknowledged. First, despite the systematic and comprehensive search protocol, publication bias may have resulted in the underrepresentation of null and negative findings, potentially inflating the apparent evidence base for AI's positive pedagogical effects. Second, the linguistic scope, while broader than many preceding reviews, remained predominantly English-focused, potentially excluding significant bodies of relevant literature in non-European languages (particularly Arabic, Swahili, and Hindi). Third, the marked heterogeneity of AI systems, implementation contexts, and outcome measures across included studies—while reflective of the genuine diversity of the field—precluded the statistical pooling of results and limits the precision of effect size interpretations. Fourth, the cross-sectional or short-term nature of the majority of included studies constitutes a fundamental constraint on conclusions regarding the sustainability of observed effects and the longer-term developmental implications of AI exposure during early childhoodtion.

CONCLUSION

This systematic literature review has synthesized 63 peer-reviewed studies published between 2015 and 2024 to provide the most comprehensive and integrated analysis to date of AI's pedagogical impacts and ethical challenges in Early Childhood Education. The evidence substantiates a conditional and nuanced affirmative: AI technologies can meaningfully enhance specific domains of learning and development in young children—particularly phonological awareness, early numeracy, vocabulary acquisition, and targeted social-emotional skills in children with ASD—but these benefits are consistently and critically mediated by teacher quality, implementation fidelity, contextual equity, and cultural appropriateness.

Simultaneously, the ethical evidence base reveals an urgent and inadequately addressed crisis of governance in AI EdTech for young children. Systemic failures of data privacy protection, the documentation of algorithmic bias against marginalized child populations, and the profound digital equity divide separating high-resource from low-resource ECE contexts collectively constitute a compelling argument against uncritical or unregulated AI adoption in early childhood settings globally.

The five thematic clusters identified—AI-personalized learning, social-emotional AI companions, conversational language AI, teacher professional development, and ethical governance—are not independent phenomena but deeply interrelated dimensions of a single complex system. Progress in any one dimension is conditional upon adequate development in the others. AI personalization without ethical governance amplifies educational inequity. Social robots without teacher scaffolding risk substituting for irreplaceable human relationships. Conversational AI without teacher mediation yields transient gains. Teacher AI literacy without institutional support structures creates burnout rather than empowerment. Ethical frameworks without practical implementation guidance remain aspirational.

Based on the evidence synthesized in this review, the authors advance the following specific recommendations. For researchers: future studies should prioritize longitudinal designs, Global South contexts, and teacher-centred perspectives; standardized reporting of AI system characteristics and implementation fidelity is urgently needed; and participatory research methods involving children, teachers, and families in co-designing and evaluating AI tools should become normative practice. For policy-makers: child-specific AI governance frameworks, grounded in the UNCRC and its General Comment No. 25, should be enacted with binding regulatory force; mandatory algorithmic impact assessments for AI EdTech products deployed with children under 8 should be required before market authorization; and digital equity investments must accompany any national AI-in-education strategies. For practitioners and institutions: substantive, sustained, and contextually embedded AI literacy and critical technology integration programs for ECE practitioners should be resourced and mandated; and institutional cultures that position ECE practitioners as critical co-designers of AI-mediated pedagogies rather than passive end-users must be actively cultivated.

The child who sits before a social robot, navigates an adaptive learning interface, or converses with a voice-enabled AI storybook deserves the full protection of their rights as a rights-holder under international law, the full benefit of the evidence base that research can provide, and—above all—the irreplaceable presence of a skilled, caring, and empowered human educator. It is to the realization of this vision that the present review is offered as a contribution.

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CONFLICT OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. No author has any financial relationship with any AI technology developer, educational technology company, or commercial entity whose products or services may be related to the subject matter of this review. The views expressed in this article are solely those of the authors and do not represent the views of their respective employing institutions.

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