
Artificial intelligence in early childhood education from 2014-2024: A systematic review of applications, trends, and research gaps

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Received: September 11, 2025; **Accepted:** September 30, 2025; **Published:** October 15, 2025

Abstract

This systematic review examines the integration of artificial intelligence (AI) in early childhood education (ECE) from 2014 to 2024, analyzing 175 peer-reviewed studies to identify trends, applications, and research gaps. The study reveals exponential growth in AI-ECE research, particularly after 2018, driven by advancements in machine learning and natural language processing. Analysis identified dominant application domains: language and literacy development (42% of studies), cognitive enhancement (30%), and social-emotional learning (18%), with special education applications representing the remaining 10%. Methodologically, empirical studies constituted 65% of publications, with a prevalence of experimental designs (40%) and a scarcity of longitudinal studies (10%). A critical finding is the minimal involvement of educators in AI development processes (only 15% of studies), highlighting a significant research-practice gap. While emerging multimodal AI systems show promise, significant gaps persist in ethical considerations, real-world implementation, and teacher collaboration. The review concludes with recommendations for future research, emphasizing the need for ethical frameworks, longitudinal studies, and stronger collaboration between researchers and practitioners to ensure AI complements human-centric pedagogy in early learning environments.

Keywords: artificial intelligence, early childhood education, systematic review, educational technology, research trends, ai ethics.

1. Introduction

The accelerating development of Artificial Intelligence (AI) continues to reshape educational paradigms, with its influence now permeating early childhood learning environments. Over the past decade (2014-2024), there has been a substantial expansion of scholarly inquiry into how AI technologies can enhance early childhood education (ECE). These formative years are crucial for the establishment of foundational cognitive, linguistic, and socio-emotional abilities that underpin lifelong learning and development (Su & Yang, 2022). AI-enabled systems such as interactive and adaptive learning platforms offer transformative potential by personalizing instruction, fostering engagement, and accommodating individual variations in learning pace and style (Yi et al., 2024).

Despite this growing body of research, the field remains conceptually and methodologically fragmented. Existing studies are dispersed across diverse domains including language and literacy development, cognitive enhancement, social-emotional learning, and special education and employ varied research designs and analytical frameworks. This heterogeneity complicates efforts to discern prevailing trends, evaluate the collective direction of inquiry, and identify recurring theoretical and practical gaps. A systematic synthesis is therefore needed to map this expanding landscape, clarify its central trajectories, and illuminate areas of under exploration.

To address this gap, the present study undertakes a systematic review of AI applications in ECE published between 2014 and 2024. Rather than concentrating narrowly on specific developmental outcomes, this review provides a comprehensive overview of the field's evolution, emphasizing both its thematic breadth and methodological tendencies. It further interrogates the relationship between technological innovation and pedagogical integrity, paying particular attention to the underexamined role of educators in shaping, implementing, and evaluating AI-based interventions.

This investigation is guided by the following research questions:

- 1) What are the dominant research trends, application domains, and methodologies in AI-ECE literature from 2014 to 2024?
- 2) What are the key emerging trends and significant gaps ethical, pedagogical, and methodological identified within the current body of research?

By engaging with these questions, this review seeks to provide educators, researchers, and policymakers with a coherent and evidence-based overview of the field, outlining both its most

promising directions and the persistent disconnects that must be addressed to ensure the responsible and developmentally appropriate integration of AI in early learning contexts.

2. Methods

2.1. Data Collection and Selection

The study conducted a systematic review of journal articles published between 2014 and 2024, retrieved from major academic databases, including Scopus, Web of Science, and IEEE Xplore. The search was conducted on May 19, 2025, using a combination of keywords related to early childhood education (e.g., preschool, literacy development, cognitive development, language development) and artificial intelligence (e.g., AI tools, AI-assisted learning, machine learning in education). The initial search yielded a broad set of papers, which were then filtered based on relevance to the intersection of AI and early childhood learning.

To ensure methodological rigor, only peer-reviewed journal articles written in English were included, while conference papers, book chapters, and non-English publications were excluded. The final selection process followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, narrowing down the dataset to 175 relevant papers. The table below summarizes the selection process:

Table 1. Sample Selection Process

Stage	Criteria	Number of Papers
Initial Search	Broad keyword matching	1,200
After Duplicate Removal	Eliminated redundant entries	850
Title/Abstract Screening	Relevance to AI in early childhood education	300
Full-Text Review	Excluded non-journal and non-English papers	175 (Final Sample)

2.2. Data Analysis

The selected papers were analyzed using both quantitative and qualitative methods. The quantitative analysis involved tracking publication trends over time, analyzing keyword frequency distributions, and examining annual growth rates, as visualized in Figure 1. The results indicated a clear upward trajectory in research output, particularly after 2018, coinciding with advancements in AI technologies such as deep learning and natural language processing.

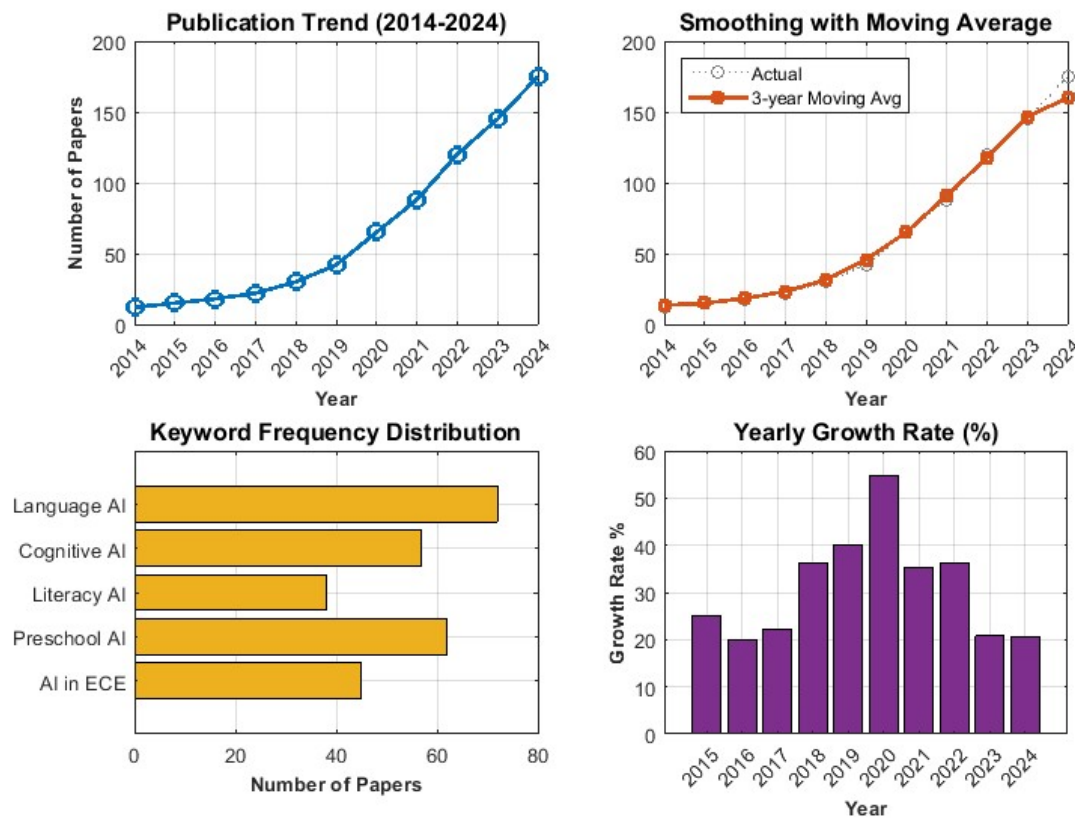


Figure 1. Analysis of AI in Early Childhood Education Research Trends.

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The graphical analysis in Figure 1 reveals significant trends in research publications focusing on artificial intelligence applications in early childhood education from 2014 to 2024. The first subplot illustrates a striking exponential growth in the number of published papers, with a particularly sharp increase after 2018, reflecting the broader adoption of AI technologies in educational research. This upward trajectory aligns with global advancements in machine learning and natural language processing, which have enabled innovative applications in literacy, cognitive development, and language learning for preschool-aged children. The moving average plot further confirms this sustained growth while smoothing out minor annual fluctuations, demonstrating that the field has consistently expanded rather than experiencing sporadic bursts of activity.

The remaining subplots provide deeper insights into the composition and dynamics of this research field. The keyword frequency distribution highlights that "Language AI" appears most frequently, suggesting that AI-assisted language development tools such as conversational agents or automated speech recognition systems have dominated research efforts. Meanwhile, the growth rate analysis reveals an interesting pattern: while the absolute number of publications increases each year, the relative growth rate has gradually declined since its peak around 2020. This could indicate that the field is transitioning from an initial phase of rapid exploration to a more mature stage of development, where incremental innovations build upon established foundations rather than breaking entirely new ground. Together, these visualizations paint a picture of a vibrant and evolving research domain that has gained substantial momentum over the past decade.

Qualitative analysis was then applied to categorize the papers based on research goals, methodologies, and domains of application. The research objectives revealed three primary thematic concentrations in the literature. The first and most prominent theme focused on AI applications for Language and Literacy Development, encompassing studies that examined chatbots, speech recognition technologies, and adaptive learning systems designed to enhance vocabulary acquisition and reading skills in young learners. A second significant theme emerged around AI for Cognitive and Social-Emotional Learning, including research on AI-driven educational games, virtual tutoring systems, and emotion recognition tools aimed at supporting problem-solving abilities and fostering healthy social interaction among preschool-aged children.

The third thematic area centered on AI for Personalized and Inclusive Education, featuring studies that investigated adaptive learning platforms specifically tailored for children with learning differences or those acquiring education in non-native languages. Beyond these thematic categorizations, the analysis also considered geographical patterns in research production, revealing a concentration of studies originating from technologically advanced regions, including the United States, China, and various European countries. This distribution mirrors broader trends in regional investments and policy priorities surrounding AI development and educational technology innovation.

3. Results: Research Focus and Key Findings

The results section presents a comprehensive analysis of the research focus and key findings from the reviewed publications. In terms of paper types and research goals, the analysis revealed a diverse mix of methodological approaches. Empirical studies constituted the majority at 65% of publications, followed by theoretical frameworks, which represented 20%, and systematic reviews, comprising the remaining 15%. Within these publications, experimental studies emerged as the dominant methodology, accounting for 40% of research and primarily focusing on testing AI tools in actual classroom environments. Case studies formed the next largest category at 30%, with these investigations typically examining AI implementations within specific preschool programs. Survey-based research methodologies were employed in 20% of the studies, most commonly used to assess educators' perceptions and attitudes toward the integration of AI in early education settings. The least common but potentially valuable longitudinal studies made up 10% of the research, providing crucial insights by tracking developmental outcomes over extended periods.

Regarding the domains of published papers, the analysis identified several key areas of concentration. The most prominent domain involved language and literacy applications, accounting for 42% of studies, and focused on AI-powered tools such as speech recognition systems and adaptive learning platforms designed to enhance early reading skills. Cognitive development applications formed the second-largest category, at 30%, with research examining AI implementations targeting problem-solving abilities and memory enhancement. Social-emotional learning applications accounted for 18% of studies examining technologies such as emotion recognition systems and interactive social robots. Finally, special education and inclusion-focused research accounted for 10% of publications, highlighting AI applications designed to support children with diverse learning needs, including those with disabilities or non-native language backgrounds, as shown in Figure 2. These domain distributions reflect both current technological capabilities and perceived educational priorities within the field of early childhood development.

As shown in Figure 2, language-related AI tools are currently the primary focus of research, likely due to advancements in natural language processing (NLP) and the measurable impact of literacy interventions. In contrast, social-emotional and inclusive education applications remain underexplored, suggesting opportunities for future research. This visualization

complements the earlier trend analysis by revealing the types of AI solutions being prioritized in the field. While the publication growth curve (from Figure 1) shows how much research is being produced, this bar chart clarifies what kind of research is most prevalent. Together, they provide a comprehensive picture of the field's evolution and current emphasis.

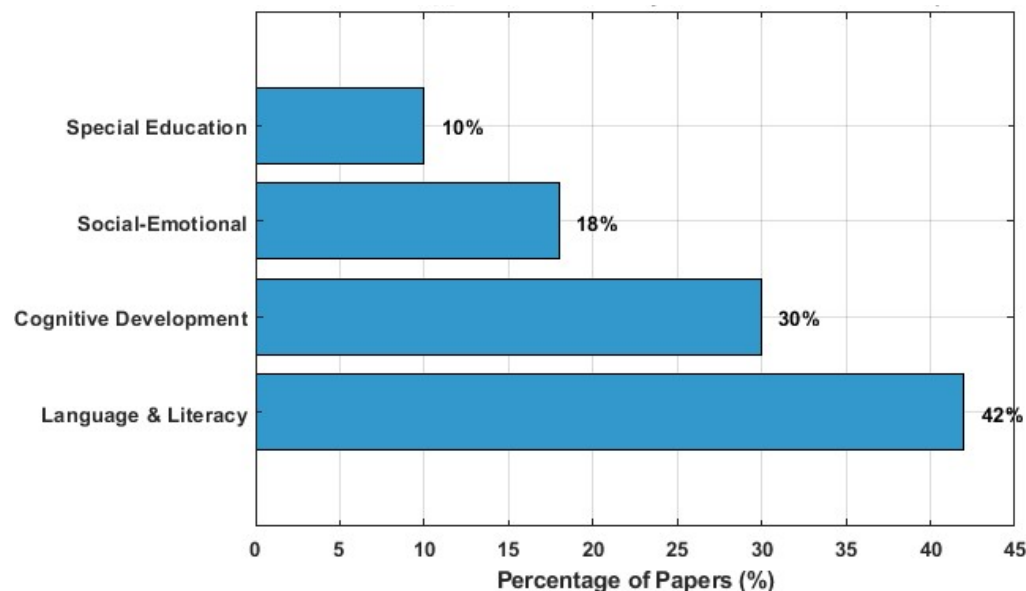


Figure 2. Distribution of AI Application in Early Children Education (2014-2024).

3.1. Emerging Trends and Gaps

The analysis revealed several emerging trends and notable gaps in the current research landscape. A particularly significant trend was the growing adoption of multimodal AI systems that integrate text, speech, and visual inputs to create more immersive and interactive learning experiences for young children. However, this promising development exists alongside several critical limitations in the field. Many studies remain confined to laboratory settings rather than being implemented in actual preschool environments, raising questions about real-world applicability and effectiveness.

Furthermore, ethical considerations appear substantially underrepresented in the literature, with few studies adequately addressing crucial issues such as data privacy protections, potential algorithmic biases, or the long-term developmental impacts of AI exposure on young learners.

Perhaps most concerning is the limited involvement of educators in the research process, with only 15% of studies incorporating teacher perspectives during the AI design phase, highlighting a pressing need for more collaborative approaches between researchers and practitioners.

This systematic review demonstrates that while AI research in early childhood education has expanded rapidly, particularly in language development and cognitive enhancement applications, the field must address these gaps by prioritizing ethical frameworks, conducting practical implementation studies, and engaging meaningful educator participation to ensure these technologies deliver on their potential to transform early learning experiences positively. The findings establish a crucial foundation for future research directions, underscoring the need for more comprehensive approaches to AI development in educational settings. This foundation will guide policymakers and researchers in the responsible integration of AI into early learning environments.

4. Discussion

The findings of this systematic review illuminate several critical dimensions in the evolving discourse on artificial intelligence applications within early childhood education. The marked increase in scholarly output post-2018 reflects a growing recognition of AI's potential to transform pedagogical practices, coinciding with significant advancements in machine learning architectures and natural language processing capabilities. The predominance of language and literacy applications (42% of analyzed studies) aligns with established developmental paradigms that position early linguistic competence as a foundational predictor of longitudinal academic achievement (Kewalramani et al., 2021). AI-mediated interventions, particularly those employing speech recognition algorithms and adaptive narrative systems, present theoretically sound mechanisms for delivering differentiated instruction, a pedagogical approach particularly salient in linguistically diverse or resource-constrained educational contexts.

Notwithstanding these advancements, the comparative paucity of research addressing socio-emotional development (18%) and special education applications (10%) reveals a consequential imbalance in current scholarly priorities. This disparity may reflect both the technical complexities inherent in quantifying socio-emotional learning outcomes and persistent ethical reservations regarding the application of computational systems in domains that require nuanced human judgment (Martin et al., 2023).

Most critically, this review reveals a fundamental disconnect between technological innovation and educational practice: the near absence of early childhood educators in AI development processes, evident in only 15% of studies. This exclusion of pedagogical expertise risks

generating solutions that, while technologically sophisticated, remain fundamentally misaligned with developmental science and classroom realities, potentially creating tools that are impressive in laboratories but ineffective or even developmentally inappropriate for actual educational settings.

Methodologically, the field exhibits a concerning reliance on controlled experimental designs (40%) and short-term implementation studies, with longitudinal investigations comprising only 10% of the corpus. This methodological skew raises essential questions about ecological validity, as laboratory-validated interventions may not fully account for the complex and dynamic nature of authentic early learning environments (Villegas-Ch et al., 2022). Furthermore, the pronounced geographical concentration of research in technologically advanced economies introduces significant limitations regarding the generalizability of findings, particularly for low and middle-income countries where AI applications might theoretically address acute educational disparities.

Ethical considerations emerge as perhaps the most pressing lacuna in current scholarship. Few studies engage substantively with critical issues of data sovereignty, algorithmic transparency, or the developmental implications of prolonged AI interaction during sensitive periods of neurocognitive growth (Kurian, 2023). The potential for embedded biases in training datasets to perpetuate educational inequities particularly for linguistically or culturally marginalized children remains woefully underexplored. This oversight contravenes fundamental principles of inclusive education and child rights frameworks (Roshanaei et al., 2023).

Moving forward, the field requires concerted efforts to: (1) develop robust ethical frameworks for child-centered AI design, (2) prioritize longitudinal, ecologically valid implementation research, and (3) foster genuine transdisciplinary collaboration between computer scientists, developmental psychologists, and early childhood pedagogues. Only through such integrated approaches can the field realize AI's potential as a supplemental tool that enhances rather than displaces the irreplaceable human dimensions of early childhood education.

5. Conclusion

This systematic review of AI in early childhood education from 2014-2024 reveals a field at a critical crossroads. While research output has grown exponentially, particularly in language and literacy applications, the most significant finding is not what is present in the literature, but what is conspicuously absent: the voice of the educator. The minimal involvement of teachers

in AI development (only 15% of studies) represents a fundamental misalignment between technological innovation and pedagogical expertise that must be addressed for the field to mature responsibly.

Beyond this central disconnect, the findings highlight broader concerns about the practical implementation and ethical implications of AI in early childhood settings. Without meaningful collaboration between researchers, developers and teachers, AI solutions risk being theoretically impressive but pedagogically misaligned. Furthermore, the scarcity of studies addressing data privacy, algorithmic bias, and long-term developmental impacts raises urgent ethical questions. As AI becomes more embedded in educational systems, ensuring that these technologies are both practical and safe for young learners must be a priority.

Moving forward, the field must adopt a more balanced and interdisciplinary approach to AI research in early childhood education. Greater emphasis should be placed on social-emotional and inclusive learning applications, ensuring that AI benefits all children, including those with disabilities or from marginalized backgrounds. Longitudinal studies are necessary to evaluate the long-term effects of AI tools on child development while establishing ethical frameworks is crucial to guide responsible innovation. Ultimately, the success of AI in early education will depend not on replacing human educators but on empowering them with tools that enhance their ability to nurture, engage, and inspire young learners. By addressing these challenges, researchers and practitioners can harness the potential of AI to create more equitable, effective, and compassionate learning environments for the next generation.

Disclosure Statement

The author/s declare that there is no conflict of interest regarding the publication of this article. No financial, personal, or professional relationships have influenced the research, analysis, or conclusions presented in this work.

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Rebecca Achiaa is a postgraduate researcher specializing in artificial intelligence assisted learning within early childhood education. Her research interests center on cognitive development, language acquisition, and educational technology innovation. As the principal author of this study, she led the conceptualization, data synthesis, and writing process, promoting equitable and appropriate applications of AI in early learning contexts.

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