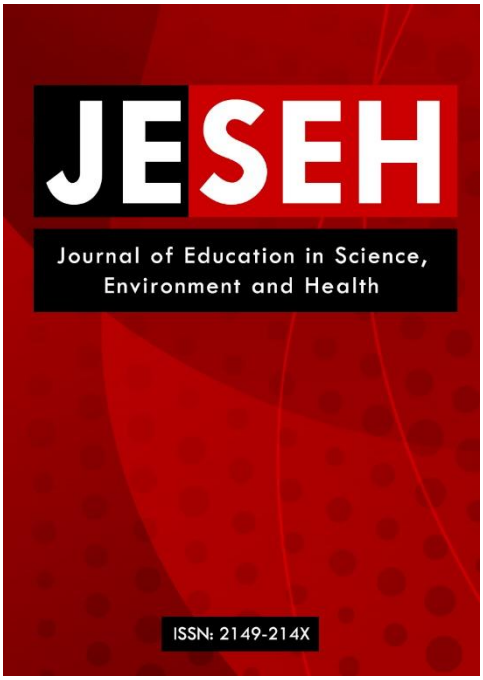

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Abstract

This study examines the pedagogical, ethical, and political dimensions of artificial intelligence (AI) in early childhood STEM education from a theoretical perspective. As digital technologies become increasingly prevalent in education, AI applications offer significant opportunities in areas such as personalized learning experiences, game-based education, and data analytics. However, they also pose critical ethical concerns, including data security, algorithmic bias, and privacy, while influencing children's cognitive, linguistic, and social development. Drawing on Piaget's theory of active discovery and learning, Vygotsky's emphasis on social interaction and teacher guidance, and Bronfenbrenner's ecological systems theory, this study explores how AI-supported learning environments can enrich children's natural developmental processes. A qualitative literature review and theoretical analysis reveal the necessity of achieving a balanced integration between the individualized educational opportunities offered by AI and the potential risks it entails. The findings highlight the critical importance of developing human-centered, ethically sound, and inclusive educational models for educators, policymakers, and researchers in the face of technological transformation. In this context, teacher training, parental collaboration, and interdisciplinary strategies are identified as fundamental prerequisites for the sustainable and effective integration of AI in early childhood education.

Introduction

The rapid advancement of digital technologies is reshaping education systems and introducing new paradigms in learning processes (Selwyn, 2019). Artificial intelligence (AI) presents significant opportunities in areas such as personalized learning, student performance analytics, and the adaptability of educational materials (Luckin, 2017). While research on AI in education has largely focused on higher education and K-12 levels, its pedagogical implications in the context of early childhood education remain insufficiently explored (Ng, 2021). However, early childhood is a critical period for cognitive, social, and emotional development, and pedagogical approaches implemented during this stage have long-term effects on learning processes (Shonkoff & Phillips, 2000). Therefore, examining how AI can be utilized in early childhood education, under what conditions, and what ethical and policy-related questions it raises is of particular significance for both academic and applied research.

Recent studies indicate that AI-assisted tools are being integrated into early childhood education in various ways. For instance, robot-assisted teaching environments (Tanaka & Matsuzoe, 2012), adaptive learning systems (Zhu & Xie, 2021), and natural language processing-based storytelling applications (Chambers et al., 2019) have been shown to positively influence children's cognitive and linguistic development. However, ongoing debates persist regarding AI's long-term effects on children and its appropriate positioning within pedagogical processes (Holmes et al., 2021). Key areas requiring further research include how AI affects teacher-child interactions, shapes learning processes, and transforms children's play-based learning experiences (Zhao et al., 2022).

From a pedagogical paradigm perspective, a fundamental research question concerns the extent to which AI-supported educational applications reinforce or transform traditional teaching approaches. In constructivist learning theories (Piaget, 1952; Vygotsky, 1978), active participation and exploration play a central role in children's learning processes. However, how AI facilitates or constrains these processes remains inadequately understood (Blikstein, 2018). Additionally, AI applications based on behaviorist teaching models have been criticized for potentially promoting rote and mechanical learning rather than fostering deeper cognitive engagement (Papert, 1980; Resnick, 2017). Thus, determining which educational philosophies align with AI and how AI can be effectively integrated into pedagogical processes is a key focus of this study.

AI-supported learning environments also raise significant ethical and policy-related concerns. Issues such as child privacy, data security, and algorithmic bias are among the primary ethical concerns regarding AI in education (Borenstein & Howard, 2021). For example, AI-based learning systems that analyze children's behaviors and collect large-scale data pose substantial risks in terms of child rights and data security (Livingstone & Stoilova, 2020). Furthermore, the widespread implementation of AI in early childhood education may exacerbate educational inequalities (Eynon & Williamson, 2020). Schools with limited access to resources may struggle to benefit from AI technologies, deepening the digital divide in education (Falcer & Selwyn, 2013). Therefore, shaping educational policies to address both the pedagogical and ethical dimensions of AI is another critical aspect of this study.

In this context, this study aims to examine the use of AI in early childhood education through the lens of pedagogical paradigms, ethical issues, and policy implications within a theoretical framework. By systematically analyzing contemporary perspectives in the literature, this research seeks to determine how AI can be effectively utilized in early childhood education and within which ethical and policy frameworks its application should be evaluated. Ultimately, this study aims to contribute to the academic discourse and educational policy development by highlighting the pedagogical potential, limitations, and future directions of AI in early childhood education.

Method

Research Design

This study adopts a qualitative literature review and theoretical analysis approach to comprehensively examine the pedagogical, ethical, and policy dimensions of artificial intelligence (AI) in early childhood education. The primary aim of the research is to explore the impacts of AI on early childhood education and to analyze its implications for pedagogical approaches, data security, ethical concerns, and educational policies. Through a systematic review and critical synthesis of contemporary perspectives in the literature, this study seeks to integrate theoretical contributions from various disciplines (Okoli & Schabram, 2010; Webster & Watson, 2002). The central assumption of the research is that AI applications exert a broad influence on early childhood education, affecting multiple dimensions ranging from pedagogical practices to data security and ethical values. Accordingly, this study adopts a comprehensive and interdisciplinary perspective (Merriam, 2009; Yin, 2014).

This process aims to identify gaps in the literature and highlight innovative approaches. To achieve this, the literature review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2021). Initially, a systematic search was performed in international academic databases, including Web of Science, Scopus, ERIC, ProQuest, TRDizin, EBSCO, and Google Scholar, using key terms such as "early childhood education," "artificial intelligence," "pedagogical paradigms," "ethical issues," and "educational policies". Boolean operators and filtering techniques (Okoli & Schabram, 2010; Webster & Watson, 2002) were applied to prioritize peer-reviewed articles, reports, and conference proceedings published after 2010.

Data Collection

The data collection process was based on a systematic review of relevant peer-reviewed articles, books, reports, and conference proceedings. The study primarily relied on international academic databases such as Web of Science, Scopus, ERIC, ProQuest, TRDizin, EBSCO, and Google Scholar. Additionally, reports and policy documents published by international organizations such as the OECD, UNESCO, and the European Commission were also included in the analysis. The selection criteria prioritized peer-reviewed journal articles published after 2010, recent books, and international reports. A comprehensive search strategy was applied using Boolean operators and filtering techniques with key terms such as "early childhood education," "artificial intelligence," "pedagogical paradigms," "ethical issues," and "educational policies".

The initial search identified 283 studies related with artificial intelligence among early childhood period, which were then assessed based on their titles, scope, and abstracts. Following this evaluation, 112 studies were selected for detailed content analysis. Subsequently, 75 studies that did not directly contribute to the study’s objectives or provided only limited discussions within the broader context of educational technology were excluded. Ultimately, 37 studies were subjected to in-depth content analysis. In other words, studies focusing on AI, early childhood education, pedagogical paradigms, ethical concerns, and educational policies were included, while

those with only a general focus on educational technology were excluded. As a result, 37 studies were found to be directly relevant to the objectives of this research.

Data Analysis

The content analysis process employed thematic coding, identifying three main categories: pedagogical approaches, ethical concerns, and educational policies. In this process, reliability measures for content analysis proposed by Miles and Huberman (1994) were followed, achieving an inter-coder agreement of 85%. This ensured a transparent and replicable structure for the systematic review and thematic analysis (Merriam, 2009;Yin, 2014).

Initially, the collected data were categorized thematically using qualitative analysis techniques. Subsequently, the relationships between pedagogical theories, AI technologies, and ethical principles were systematically synthesized. This synthesis facilitated the development of a multidimensional theoretical model explaining AI integration in early childhood education. Furthermore, comparative analyses were conducted between traditional educational models and AI-assisted approaches, evaluating their respective strengths and weaknesses from a theoretical perspective. These comparisons reinforced the arguments regarding the applicability of the proposed model (Chen et al., 2020; Luckin et al., 2016).

The collected data underwent a two-stage analysis process. In the first stage, prominent pedagogical approaches, ethical issues, and policy recommendations in the literature were examined using content analysis. Each study was systematically coded according to specific themes, following the methodological principles outlined by Miles and Huberman (1994). In the second stage, the identified thematic findings were synthesized through a critical review. This synthesis process focused on evaluating similarities, differences, and contradictions across studies, thereby enabling a comprehensive interpretation of the multidimensional impacts of AI in early childhood education (Cooper,1988; Webster & Watson, 2002).

Validity and Reliability

In qualitative research, validity and reliability play a crucial role in interpreting findings (Yin, 2014). Therefore, this study employed strategies such as a systematic approach and critical review. Comparative analysis of diverse data sources ensured consistency in findings, while the rigorous application of inclusion and exclusion criteria enhanced the replicability and reliability of the study's results (Okoli & Schabram, 2010). Furthermore, critically evaluating sources allowed for a careful consideration of methodological limitations and potential biases (Merriam, 2009). Nonetheless, the methodological approach acknowledges that qualitative analyses based on literature reviews are inherently subject to subjective interpretations. The limitations of the inclusion criteria and search strategies used in source selection may introduce potential biases that could influence the study’s overall conclusions. However, efforts were made to minimize these limitations by utilizing a broad and interdisciplinary data pool (Yin, 2014).

Model Development Process and Methodological Foundations

The primary aim of this study is to develop a theoretical model addressing the integration of artificial intelligence (AI) into early childhood education from pedagogical, ethical, and policy perspectives. The development of this model is based on a systematic literature review and thematic content analysis. The process of constructing the model involved the following key stages:

The first stage focused on literature review and theoretical framework identification. The model was built upon an extensive review of existing theoretical approaches in early childhood education and AI. The foundational theories incorporated into the model include Piaget’s theory of discovery-based learning, Vygotsky’s social interaction and guided learning approach, and Bronfenbrenner’s ecological systems theory.

The second stage involved systematic literature analysis and thematic coding. The literature review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Initially, 283 studies were identified, out of which 75 studies that did not meet the inclusion criteria were excluded. Consequently, a total of 37 key studies were selected for in-depth content analysis.

In the third stage, data analysis and thematic model construction were carried out. The thematic analysis identified three core dimensions: pedagogical approaches, ethical concerns, and educational policies. Coding methods by Miles and Huberman (1994) were employed, ensuring an inter-coder reliability rate of 85%, thus enhancing the consistency of the content analysis.

The fourth stage focused on structuring the model and defining the conceptual framework. The final model highlights the integration of AI in early childhood education across three critical dimensions:

- Pedagogical Paradigms (Discovery-based learning, AI-supported social interaction, game-based learning)
- Ethical Issues (Data privacy, algorithmic bias, equity in education)
- Policy and Strategic Approaches (AI-driven education policies, teacher training, regulatory frameworks)

To enhance the validity and reliability of the model, comparative analyses with existing AI-based educational models were conducted. The proposed model was compared with AI education frameworks developed by Chen et al. (2020) and Luckin et al. (2016), highlighting both similarities and differences. This methodological approach ensures that the model is both theoretically grounded and practically applicable, reinforcing its contribution to the academic literature. Future research should focus on empirical validation of the model through experimental and applied studies in early childhood education settings.

Findings

The findings of this study were constructed using systematic literature review and critical synthesis methods. The role of artificial intelligence (AI) in early childhood education, its integration into pedagogical practices, concerns related to data privacy and ethics, and the frameworks of national and international policies were examined across different dimensions in the literature. The data obtained indicate that AI provides both positive contributions and certain risks to pedagogical paradigms. Furthermore, the study revealed that at the ethical and political levels, there are ongoing multi-layered debates, with significant gaps, especially regarding data security, algorithmic bias, and digital inequality.

Thematic Model: AI-Supported Early Childhood STEM Education

Some models developed within the political framework aim to strengthen collaboration among government institutions, educators, technology providers, and parents. These strategies are structured around the principles of transparency, participation, and accountability, with the goal of aligning AI applications with pedagogical and ethical dimensions. To clarify this aspect of the study,

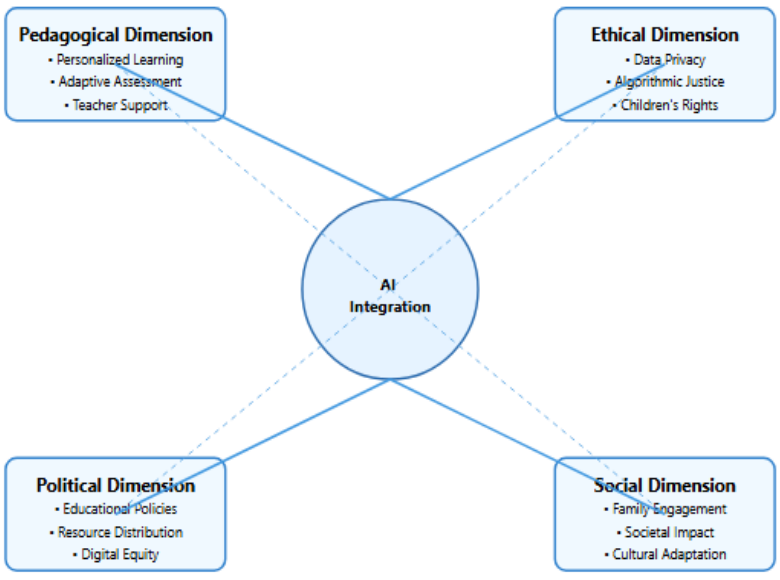

Figure 1. Conceptual framework: integration of artificial intelligence in early childhood education - a multi-dimensional interaction model

Figure 1 presents a conceptual model showing the interaction between policy, pedagogical practices, and ethical principles in AI integration in early childhood education, based on the data collected in this study. This model visualizes the challenges faced by policymakers and practitioners, along with proposed solutions, while also indicating areas for strategic intervention. In Figure 1, the conceptual model illustrates how AI integration interacts with pedagogical practices in early childhood education, while also considering the ethical concerns, policies, strategic orientations, and teacher-parent relationships. This model visualizes the interrelations and feedback loops among all dimensions, summarizing the multilayered effects of technology on the educational field.

To systematically analyze the integration of artificial intelligence (AI) in early childhood education, a thematic model was developed (Figure 2). This model conceptualizes AI integration across three critical dimensions: pedagogical paradigms, ethical and data security issues, and educational policies and strategies. The pedagogical paradigms dimension draws upon established educational theories, including Piaget's discovery-based learning approach, Vygotsky's emphasis on social interaction, and Bronfenbrenner's ecological systems theory. These theoretical perspectives provide insight into how AI-enhanced learning environments can either support or challenge traditional early childhood education (ECE) practices.

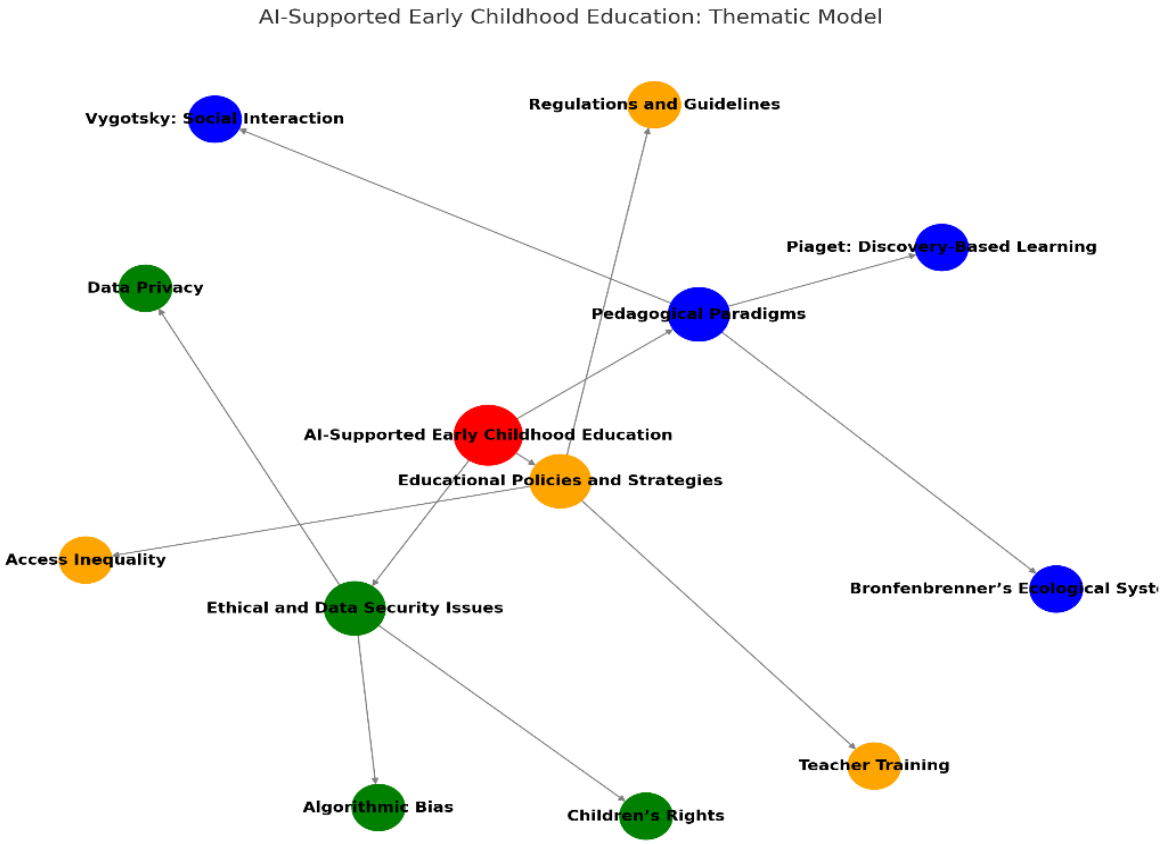

Figure 2. Thematic model of AI-supported early childhood education

The ethical and data security issues dimension highlights key concerns related to AI implementation in ECE, including algorithmic bias, data privacy, and children's rights. As AI-based educational tools increasingly collect and process large amounts of data, ensuring transparency, security, and fairness in their design and application becomes imperative.

The educational policies and strategies dimension underscores the need for structural frameworks to regulate AI adoption in early childhood settings. It includes essential policy considerations such as teacher training, access inequality, and regulatory guidelines. Given the potential disparities in AI accessibility across different educational contexts, strategic policymaking is required to bridge digital divides and foster equitable AI integration.This thematic model offers a multidimensional perspective on AI's role in ECE, demonstrating the interconnectedness of pedagogical, ethical, and policy-related factors. The conceptual framework serves as a foundation for discussing the opportunities and challenges of AI implementation in ECE and provides insight into future directions for research and practice. The overall assessment of the findings reveals that AI applications in

early childhood education have multidimensional effects. These effects can be optimized through the integration of pedagogical efficiency, ethical responsibilities, and strategic policymaking processes. The data suggests that, with careful planning and regulatory frameworks in place, AI's potential can lead to innovative educational practices; otherwise, the technological adaptation process might produce unintended side effects.

In this study, based on international databases and recent reports, three main dimensions of AI applications in early childhood education—pedagogical paradigms, ethical issues, and political orientations—were systematically examined. The critical synthesis of the studies in the literature resulted in the following key findings, presented below with their subdimensions.

Pedagogical Paradigms

The reviewed studies indicate that AI applications play a significant role in enriching learning processes in early childhood. Research highlights that AI-supported tools foster individualized learning experiences, contributing to children's cognitive, linguistic, social, and emotional development. For instance, Aslan et al. (2024) and Kewalramani et al. (2021) focus on interactive and play-based models to support learning processes, while Jin (2019) and Liu and Kromer (2019) emphasize the pedagogical value of exploration and problem-solving approaches in early childhood. Furthermore, Masturoh et al. (2024) and Solichah and Shofiah (2024) demonstrate that increasing children's digital literacy and collaborative learning skills through digital games and activities positively contributes to learning processes.

Findings on the pedagogical impact of AI in early childhood education suggest that, in most related studies, technology-supported learning environments create individualized educational opportunities. Experimental research by Shin et al. (2020) reports significant increases in problem-solving skills and cognitive flexibility in children when they are exposed to AI-supported interactive, game-based learning environments. Similarly, studies by Mubin et al. (2013) show that robotic applications strengthen social interaction and collaboration skills. However, some research also indicates that if AI is not integrated within an appropriate pedagogical framework, it may restrict children's creative thinking abilities (Holmes et al., 2021). The data gathered suggests that, when supported by the right methods and tools, AI applications can enrich not only traditional classroom interaction but also individualized learning experiences. The comparative analysis of the main pedagogical findings from various studies is presented in Table 1, illustrating the multidimensional nature of the pedagogical impact area, evaluated in terms of both positive contributions and potential risks.

Table 1. Comparative summary of pedagogical contributions, ethical considerations, and policy/strategic ımplications of artificial ıntelligence applications in early childhood education (N=37)

Research	Method / Application Used	Pedagogical Findings	Ethical Findings	Policy/Social Strategic Implications
Aslan et al. (2024)	Multimodal, speech-based AI applications; case study	Personalized learning experiences; interactive and game-based approaches	Data privacy risks; need for greater attention to children's privacy	Innovative teacher training programs; strengthening digital infrastructure
Atabey& Scarff (2023)	Theoretical analysis; focus on the principle of justice	Emphasizes the importance of integrating fairness in educational settings	Ethical standards and regulatory framework recommendations for children's rights	Development of regulatory frameworks; policy recommendations
Berson et al. (2023)	Multimodal creative inquiry approach	Enhancing cognitive and creative processes; enriching learning experiences	Protection of children's data; ethical guidance for fair AI use	Development of ethical standards in education
Bielova & Byelov (2023)	Review; critique of children's rights and AI development	Highlights the need for careful consideration in innovative educational applications	Risks associated with algorithmic bias and lack of fairness	Emphasis on equality and transparency principles
Charisi et al. (2020)	Research; model promoting critical reflection	Supports children's development of critical thinking through AI and robotics	Need for ethical awareness in the use of technology	Ethical integration recommendations in education policies

Chu (2022)	In-depth analysis of ethical issues	Discusses AI's role in education and its integration	Proposes the development and implementation of ethical standards	Recommendations for regulatory and ethical frameworks
Druga et al. (2019)	Experimental study; inclusive AI literacy approach	Supports the early learning of AI concepts	Emphasis on inclusive education policies and ethical frameworks	Policy recommendations for practitioners
Durrani et al. (2024)	Scoping review	Outlines the general framework of AI applications in early childhood education	Summarizes ethical and technical challenges encountered in practice	Development of regulatory mechanisms
Familyarskaya (2024)	Case analysis; practical application example	AI-supported learning models in preschool settings	Warnings on technological inequality, data security, and privacy	Local-level policy recommendations; regulatory approaches
Honghu et al. (2024)	Systematic evaluation of AI tools and technological infrastructure	Innovative learning approaches; focus on children's cognitive and linguistic development	Algorithmic bias; need for fair access and transparency	Identification of innovative integration strategies in education policies
Jin, L. (2019)	Experimental application; exploration of AI potential	Support for discovery-based learning models; enrichment of learning processes	Systematic measures for child data security and privacy	Development of school-based implementation models; local policy recommendations
Kahila et al. (2024)	Development of pedagogical framework	Promotes children's data agency and creativity	Ethical data use; importance of digital rights and security	Digital equity and innovative curriculum proposals
Kanders et al. (2024)	Perspective study; effects of generative AI	Evaluates generative AI's contributions to learning in early education	Ethical boundaries; recommendations for regulations and implementation standards	Development of regulatory frameworks and policy recommendations
Kewalramani et al. (2021)	Experimental study; robotic toy applications	Supports social and emotional development; interaction-enhancing pedagogical applications	Privacy, data protection, and security concerns	Parent-teacher collaboration; establishment of regulatory mechanisms
Lian (2024)	Application analysis; ChatGPT-focused model	Contributions to designing interactive and supportive learning environments	Discussions on AI limitations, security, and ethical use	Regulatory dimensions of technological integration
Liu & Kromer (2019)	Methodological review; evaluation of AI-based tools	Encourages problem-solving, creativity, and critical thinking skills	Secure online interactions; implementation of data management standards	Curriculum integration; importance of educator guidance and strategic planning
Liu (2024)	Ethical research; evaluation of AI education systems	Highlights the importance of child-centered AI educational approaches	Ethical guidance, regulatory standards, and implementation strategies	Strengthening ethical standards in education
Masturoh et al. (2024)	AI-supported digital games and activities	Supports cognitive and social development through game-based learning environments; promotes digital literacy	Digital data management; focus on online security and privacy	Strengthening teacher-parent collaboration strategies; expansion of game-based instructional models

Mitchell et al. (2024)	Robot theater in informal learning environments	Raises awareness of AI and robotics ethics	Ethical AI design; development of implementation standards	Recommendations for regulatory and ethical frameworks
Ng et al. (2022b)	AI literacy curriculum design	Proposes curricula for early AI education	Emphasis on digital equity; ethical education approaches and policy recommendations	Curriculum integration; improvement of digital competence
Okeke (2022)	Case study; AI in professional preschool education	Example of teacher digital transformation practices	Findings on digital transformation and ethical practices in education	Policy reforms; local implementation models
Review on AI & Robots (2022)	Literature review (STEAM-focused)	Summarizes pedagogical contributions of AI and robotics integration	Application risks; ethical concerns; recommendations for regulatory frameworks	Development of regulatory frameworks and policy recommendations
Salloum (2024)	Ethical analysis	Discusses risks and opportunities of AI in educational environments	Importance of developing security, privacy, and ethical standards	Implementation of ethical educational policies and regulatory measures
Samara & Kotsis (2024)	Case study; AI use in science education	Proposes innovative AI-supported teaching methods in science education	Need for security and ethical implementation measures	Recommendations for technological integration and regulatory frameworks
Sharma et al. (2022)	Ethical call; analysis of AI interaction with children	Strategic approaches for AI integration into learning	Ethical AI design; protection of children's rights; safe usage	Policy recommendations for the establishment of ethical standards in education
Sharma et al. (2023)	Ethical design and implementation research	Pedagogical recommendations for responsible AI applications	Child safety; fair use; establishment of ethical standards	Development of regulatory frameworks and policy reforms
Shawky et al. (2023)	Comprehensive ethical evaluation	Discusses the role of pedagogical approaches in AI use in education	Data security; regulatory gaps; ethical concerns	Strengthening ethical and regulatory measures
Siraj-Blatchford (2023)	Perspective article	Evaluates AI's transformative potential in early childhood education	Equality, transparency, and accountability principles	Policy recommendations; regulatory approaches
Solichah & Shofiah (2024)	Scoping review	Identifies pedagogical models for fostering AI literacy in early childhood	Need for the establishment of ethical guidelines and data protection standards	Multi-stakeholder policy approaches; development of comprehensive curriculum recommendations
Su & Yang (2022)	Scoping review	Provides a general framework for AI applications in early childhood education	Ethical and technical challenges in implementation	Development of innovative regulatory mechanisms
Su & Zhong (2022)	Curriculum design research	Proposes AI-based educational programs	Establishment of regulatory frameworks and ethical standards	Curriculum integration; emphasis on policy reforms
Su et al. (2023)	Literature analysis	Evaluates AI literacy approaches in early education	Recommendations for fair and ethical AI applications	Comprehensive recommendations for education policies

Su et al. (2024)	Experimental study; cooperative game and direct instruction models	Supports cognitive, computational, and social skills in kindergarten	Emphasis on data security, privacy, and teacher digital competencies	Integration into early education curricula; strengthening teacher digital competencies; policy reforms
Tazume et al. (2020)	Multi-modal interactive AI robot applications	Contributes to the enrichment of interactive learning processes	Importance of security, privacy, and ethical awareness	Recommendations for regulatory and ethical frameworks
Williams et al. (2019)	Curriculum design; pilot implementation	AI-supported learning environment design and implementation	Ethical dimensions of technological integration	Regulatory recommendations; implementation strategies
Yang (2022)	Theoretical analysis; curriculum recommendations	Discusses why, what, and how AI education should be taught	Need for curriculum reform and establishment of ethical standards	Innovative curriculum proposals; policy reforms
Yusof et al. (2024)	Application analysis; generative AI-supported model	Supports AI integration into teacher education	Security, transparency, and accountability-based policy recommendations	Technological integration; regulatory policy recommendations

Table 1 summarizes the research focus and contributions of thirty-seven studies directly related to the main areas of the study: pedagogical paradigms, ethical issues, and policy/strategic recommendations. The methods and findings of each study are addressed in a way that reveals the multidimensional effects of AI applications in early childhood education. AI-supported tools and applications are seen to offer potential benefits in developing children's cognitive and social skills. However, more research is needed regarding the limitations and long-term effects of these applications. These findings indicate that the integration of AI in early childhood education presents both opportunities and points that need careful consideration. Educators and policymakers must implement a thoughtful planning and execution process to ensure the effective and ethical use of these technologies. The pedagogical opportunities, ethical responsibilities, and strategic policy requirements offered by AI applications in education are reflected in a more comprehensive and detailed manner. The data gathered from both experimental and theoretical studies suggest that a multidimensional approach is needed for the successful integration of AI in early childhood education.

Ethical Issues

The findings regarding ethical issues, another significant dimension of the research, reveal that AI-based educational applications raise serious discussions about children's data privacy, security, and individual rights (see Table 1). Additionally, analyses by Livingstone and Stoilova (2020) emphasize that the collection and processing of personal data during the use of AI technologies at a young age present significant privacy and security risks. Similarly, researchers such as Borenstein and Howard (2021) have pointed out that observed biases in AI algorithms could lead to inequalities in educational opportunities, particularly having more significant outcomes for disadvantaged groups. In this context, the lack of ethical guidelines and regulatory frameworks increases the potential risks of AI systems, while also raising questions about the reliability and inclusiveness of these applications. Based on the findings, some studies offer recommendations for the establishment of ethical standards and regulatory mechanisms. However, they also reveal ongoing uncertainties regarding the scope and impact of these proposals (see Table 1). This situation introduces risk factors that could deepen the digital divide in education, especially in low-income areas and schools lacking technological infrastructure.

The use of AI applications in early childhood education brings significant ethical issues such as data privacy, algorithmic bias, and children's privacy. Studies stress the need for transparency and security standards during the collection and processing of children's personal data. Researchers such as Akhtar et al. (2023), Borenstein & Howard (2021) and Liu (2024) argue that algorithmic biases and the misuse of digital tools increase the risk of creating inequality and injustice in education. This demonstrates the inevitability of establishing child-centered ethical frameworks for AI applications targeted at early childhood.

Policy, Social, and Strategic Orientations

From a policy perspective, international organizations (such as OECD, UNESCO) and experimental applications highlight the need for multi-stakeholder strategies to ensure that AI integration in early childhood education is sustainable and inclusive. The study by Su et al. (2024) argues that cooperative games and direct teaching models should be applied in parallel with curriculum reforms to enhance teachers' digital competencies. Policymakers should focus on creating regulatory mechanisms based on transparency and accountability that strengthen teacher-parent collaboration.

Analyses of policy and strategic orientations reveal the necessity of comprehensive and multi-stakeholder strategies for the successful integration of AI in early childhood education. Reports published by international organizations, particularly those from OECD, UNESCO, and the European Commission, indicate the need for the development of new regulatory frameworks to effectively use AI technologies in education. A pilot study by Zhao et al. (2022) showed positive results from AI-supported educational applications, yet significant gaps remained in teacher training and digital literacy. These findings suggest that policymakers should prioritize strategic planning to maximize the potential benefits of AI technologies in education while minimizing inequalities and ethical risks during the widespread adoption of these technologies.

Overall Trends in Scientific Research on the Integration of AI in ECE

The integration of artificial intelligence (AI) into early childhood education presents both pedagogical opportunities and ethical considerations. This graphic (Figure 3) provides a structured analysis of AI's pedagogical benefits, ethical risks, and associated pedagogical models based on the related literature review.

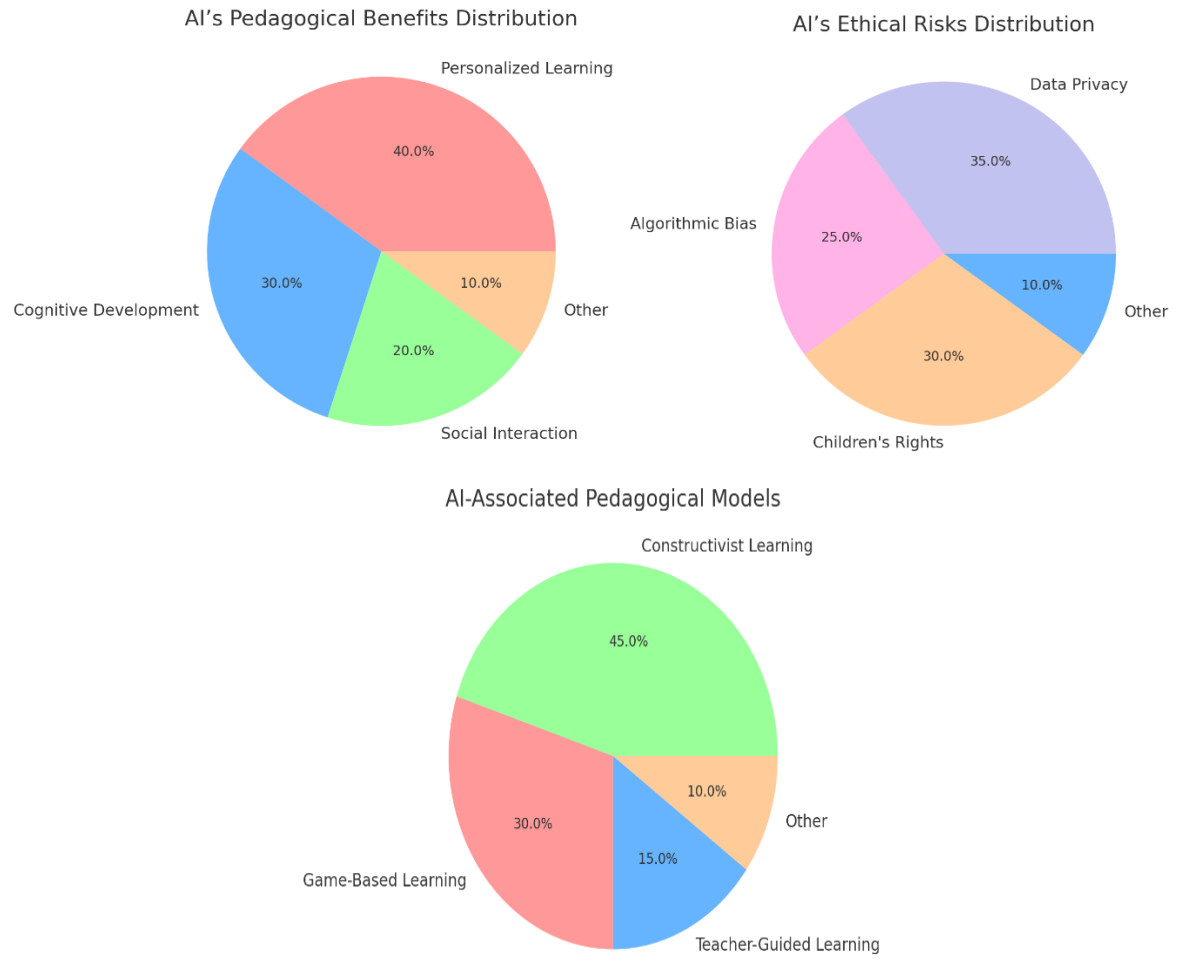

Figure 3. The role of artificial intelligence in early childhood education: pedagogical benefits, ethical risks, and associated learning models

AI-driven educational technologies contribute significantly to early childhood learning experiences. The distribution of AI's pedagogical benefits reveals that personalized learning (40%) is the most recognized advantage, as AI enables tailored educational pathways that adapt to individual students' needs. Cognitive development (30%) is another key benefit, as AI-assisted tools enhance problem-solving abilities and critical thinking. Furthermore, social interaction (20%) is supported through AI-driven interactive learning environments, such as robot-assisted education and adaptive learning systems. However, other benefits (10%), such as engagement in digital literacy and improved motivation, are also noted in the literature.

Despite its potential benefits, AI in education raises serious ethical concerns. The most prominent issue is data privacy (35%), as AI-based systems collect and process large amounts of personal data, raising questions about security and child protection. Algorithmic bias (25%) is another critical risk, as AI models trained on biased datasets may reinforce existing inequalities in education. Children's rights (30%) are also a major concern, particularly regarding consent, autonomy, and fair access to AI-driven learning tools. Additionally, other ethical risks (10%), such as digital dependency and the diminishing role of human teachers, require further investigation.

The adoption of AI in early childhood education aligns with various pedagogical models. The findings suggest that constructivist learning (45%) is the most frequently associated model, emphasizing active exploration and discovery-based learning. Game-based learning (30%) is another prominent approach, leveraging AI to create immersive and interactive educational experiences. Teacher-guided learning (15%) highlights the role of AI as a supportive tool rather than a replacement for human educators. Finally, other models (10%), including hybrid approaches that combine AI-driven and traditional methods, are emerging in educational research.

To sum up, the findings indicate that, in addition to the pedagogical opportunities AI offers in early childhood education, there are many important ethical and policy issues that need to be carefully considered. From a pedagogical perspective, AI-supported learning environments contribute positively to children's cognitive, linguistic, and social development by providing individualized learning experiences. However, these technologies could also have restrictive effects on fundamental skills like creative thinking and originality if not integrated into an appropriate pedagogical framework. From an ethical standpoint, issues such as data privacy, algorithmic bias, and digital inequality have become even more critical with the widespread use of AI applications. In this context, the establishment of regulatory and ethical guidelines has become necessary. From a policy perspective, strategic models developed at both national and international levels reveal that the pedagogical and ethical dimensions of AI integration must be addressed integrally. These findings lay the foundation for further research and policy recommendations and emphasize the need for multidisciplinary approaches to ensure that AI technologies are used more effectively and fairly in early childhood education.

Discussion and Conclusion

The use of artificial intelligence (AI) in education has multifaceted effects, particularly in early childhood education, a delicate and crucial developmental stage. This study comprehensively examines how AI can be integrated into pedagogical practices, the ethical risks associated with it, and how educational policies should be shaped in response. The findings suggest that while AI has the potential to enrich learning processes in early childhood education, it also raises significant ethical and strategic questions.

Jean Piaget's cognitive development theory (1952) emphasizes the importance of children actively interacting with their environment during the learning process. AI-supported learning environments offer personalized experiences that allow children to progress at their own pace and deepen their exploration processes. This presents a significant opportunity, particularly for children with learning differences. AI-based educational platforms can adapt to children's learning styles and provide personalized content, making education more inclusive. However, a key point is that AI should not only be viewed as a tool but also as a complementary and supportive element in pedagogical processes.

On the other hand, Lev Vygotsky's social interaction theory (1978) suggests that the potential effects of AI on children's social development need careful consideration. Vygotsky posits that peer interaction and teacher guidance play critical roles in cognitive development. Therefore, a key research question is how AI-supported learning environments shape children's interactions with teachers and peers. While there are positive findings suggesting that robot-assisted educational tools can enhance social interaction skills (Kewalramani et al., 2021), it is also crucial to be cautious about AI potentially distancing children from human-centered learning experiences.

From the perspective of Bronfenbrenner's Ecological Systems Theory (1979), AI's transformation of interactions among children, teachers, parents, and policymakers is also an important aspect. AI-based educational tools directly impact children's learning processes while redefining teachers' pedagogical roles and altering parents' roles in education. In this context, teachers' and parents' digital literacy significantly influences children's interactions with AI. Findings indicate that teachers require more guidance on how to use AI-supported educational materials in the classroom, and parents have concerns regarding data security and digital addiction.
Ethically and in terms of data privacy, the findings underscore the need to address issues such as algorithmic bias, data security, and privacy to fully harness AI's potential in education. Protecting children's personal data and making the decision-making mechanisms of AI-based systems transparent continue to be among the biggest debates in educational AI (Berson et al., 2023; Bielova & Byelov, 2023). While AI in education can promote equality of opportunity, it also risks deepening socioeconomic disparities. In areas with limited access, the opportunities offered by AI-supported education become harder to utilize, exacerbating the digital divide.

Another area of debate is the long-term impact of AI on pedagogical approaches. The tension between behaviorist and constructivist approaches in education is reshaped in the context of AI integration. Some AI-supported systems may encourage children to learn within specific patterns, potentially limiting the exploration and experiential learning processes offered by constructivist environments. This raises the question of which pedagogical frameworks AI in education aligns with. Will AI lead children toward rote learning, or will it support discovery-based learning?

AI systems in education are increasingly supporting children's learning processes. However, their potential to reinforce societal biases cannot be overlooked. Since AI algorithms are trained on large data sets, biases present in these data can be directly reflected in the models. For example, AI-based educational tools may incorporate biases related to gender or ethnicity, disadvantaging certain student groups. Additionally, human moderators' conscious or unconscious biases in data labeling can influence decisions on what content is deemed appropriate. This can lead to educational materials being shaped by specific perspectives, potentially hindering children's development of critical thinking skills.

From a pedagogical standpoint, while AI systems offer personalized learning opportunities, they also present risks. Students encountering only algorithm-driven content may experience negative effects on their social interaction skills and cognitive flexibility. Furthermore, excessive reliance on AI could weaken students' problem-solving and critical thinking abilities. Therefore, it is essential to integrate AI into education in line with ethical principles, ensuring algorithmic transparency and increasing data diversity. When designing AI systems for children, a balanced approach to pedagogical strategies is necessary to create policies that minimize biases and promote equality of opportunity in education.

The findings also indicate that educational policies must adapt to this transformation. At both the national and international levels, education policies must encompass multidimensional changes, from teacher training to curriculum reforms, digital infrastructure investments, and data security regulations. The success of AI-supported educational systems depends not only on strengthening technological infrastructure but also on teachers' ability to integrate these tools into pedagogical processes. Therefore, policymakers must support the use of AI through teacher training, ethical regulations, and curriculum reforms.

To sum up, the integration of AI into early childhood education is a complex and multilayered process that affects all components of the education system. AI-supported learning systems offer personalized learning opportunities and pedagogical innovations but also bring significant ethical and policy-related challenges. In line with Piaget, Vygotsky, and Bronfenbrenner's theoretical frameworks, AI holds great potential as a tool to support cognitive development, but it cannot fully replace the human-centered nature of pedagogical processes. Therefore, how AI is positioned in education, the pedagogical and ethical principles guiding its use, and how it is supported through teacher-parent collaboration remain critical questions.

This study provides a comprehensive framework for how AI can be more effectively and responsibly integrated into early childhood education, offering valuable contributions to the literature. The findings provide a solid foundation for further empirical research on the long-term effects of AI integration into educational processes, which is critical for policymakers and practitioners. The role of AI in education is not merely a technological transformation but also a critical factor that reshapes the future educational paradigm, encompassing pedagogical, ethical, and policy dimensions. At this point, the proposed model offers a multidimensional approach to the integration of artificial intelligence (AI) in early childhood education, distinguishing itself from existing AI-based educational frameworks.

Unlike previous models that primarily focus on personalized learning (Chen et al., 2020) or technology-enhanced teaching strategies (Luckin et al., 2016), this model holistically incorporates pedagogical paradigms, ethical concerns, and policy frameworks into a unified structure. By integrating Piaget's discovery-based learning, Vygotsky's social interaction model, and Bronfenbrenner's ecological systems theory, it ensures that AI applications not only support cognitive development but also enhance social and emotional learning through interactive and play-based environments. Moreover, while existing models often consider ethical and data privacy concerns as secondary issues, this study places child rights, algorithmic bias, and AI-driven educational inequalities at the forefront of its analysis. Additionally, the model moves beyond a technocentric perspective, offering strategic policy recommendations that address teacher training, regulatory frameworks, and the accessibility of AI-enhanced education. This comprehensive integration of pedagogical, ethical, and policy dimensions makes it one of the first AI models specifically tailored to early childhood education, ensuring a human-centered, inclusive, and developmentally appropriate approach to AI implementation in educational settings.

Recommendations

This study not only highlights the pedagogical opportunities that artificial intelligence (AI) offers in early childhood education but also reveals the risks it may pose in ethical and political dimensions. Researchers should undertake comprehensive empirical studies to assess the long-term effects of AI on children's cognitive, social, and emotional development. At the same time, they should develop theoretical and practical models that will ensure the integration of this technology in a way that supports personalized learning experiences while preserving human-centered educational values. Educators, in turn, should create continuous professional development programs focused on digital literacy and AI-based pedagogical approaches, exploring ways to use technology effectively and ethically in the classroom. Furthermore, addressing fundamental ethical issues such as data security, algorithmic bias, and children's privacy requires the creation of regulatory frameworks based on interdisciplinary collaboration, valid both locally and internationally. Thus, by supporting AI applications in early childhood education with comprehensive policy reforms, teacher-parent collaborations, and ethical standards, it will be possible to create a sustainable and inclusive learning environment that contributes to children's development.

The findings of this study reveal the potential of AI to enrich personalized learning experiences in early childhood education and positively impact children's cognitive, linguistic, and social development. However, they also provide important warnings regarding data privacy, algorithmic bias, and the importance of human-centered interactions. In this context, future research should empirically examine the long-term effects of AI applications, thoroughly assessing the opportunities and risks presented by the technology. It is crucial that educators, when adopting AI-based pedagogical models, also incorporate approaches that support in-class human interaction and critical thinking. Additionally, teachers' professional development in digital literacy and AI integration is a key element for ensuring that applications are used effectively and within ethical boundaries. Collaboration between policymakers and researchers to establish regulatory frameworks that include data security, algorithmic transparency, and child-centered ethical standards will be an essential step in realizing the potential of AI in early childhood education in a sustainable and inclusive way.

The results of the study show that AI applications support personalized learning experiences in early childhood but cannot replace social interaction and guidance in children's natural developmental processes. In this context, considering Piaget's emphasis on active exploration and learning through experience, Vygotsky's focus on social interaction and teacher guidance, and Bronfenbrenner's approach to evaluating children's development in the context of environmental interactions, AI-supported systems should be designed to allow children to learn at their own pace while also enriching teacher and peer interactions. This recommendation will contribute to creating child-centered, ethically aligned educational environments that integrate the personalized learning opportunities provided by AI with children's cognitive, emotional, and social development. Thus, technological applications can be used as complementary tools that support children's exploration, critical thinking, and social interaction skills, rather than interfering with their natural developmental processes.

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