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THE ROLE OF ARTIFICIAL INTELLIGENCE (AI) IN THE EARLY YEARS EDUCATION: A QUALITATIVE RESEARCH

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ABSTRACT

This research critically analyses the incorporation of artificial intelligence (AI) in education into early childhood curricula's pedagogy, and the impact of how AI encourages computational and inquiry thinking, and ethical reasoning among young learners. A systematic review of 30 peer-reviewed articles from the past five years reveals several key themes: early exposure to AI significantly enhances cognitive skills like abstraction, pattern recognition, and algorithmic thinking; meanwhile, inquiry-driven AI activities foster questioning, hypothesis testing, and critical interpretation. Yet critical ethical and developmental hurdles remain, in particular concerning young children's nascent understanding of algorithmic bias, privacy and fairness. Based on the research, the Early AI Literacy Model is proposed, consisting of computational skills, inquiry methods, and built-in ethical education as foundational pillars of early education. The recommendations for curriculum include the integration of modular stories and gamified activities, and introduction of early ethics early on. It recommends the development of standardized international frameworks for AI and the implementation of AI literacy training that is mandatory. However, future research must focus on longitudinal studies that would examine the cognitive and ethical impact over time. Public-private partnerships are suggested as the way to democratise access to affordable AI educational tools to be implemented in the real world. This study as a whole highlights that early AI literacy is not optional but is a key civic competence for children to be able to sift through and shape an increasingly algorithmic world responsibly.

Keywords: *Children, artificial intelligence, education, early year education, AI literacy.*

INTRODUCTION

Background of the Study

Artificial intelligence (AI) is the science and engineering of making machines intelligent (Su et al., 2023). It is a scientific discipline of computer science and is based on machine learning, algorithm creation and natural language processing. As of now, the focus on the use of AI in development has mostly been in secondary and higher education, rarely taking place at the kindergarten level (Yi et al., 2024). The younger generation today has robots in their homes and intelligent agents in their pockets and children within their first years interact with tablets and toys that have orders of magnitude more computing power than personal computers of a

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few years ago (Su & Yang, 2022). The studies on early childhood AI education have increased in these days, for example, providing them with PopBots, knowledge-based systems, supervised machine learning, and generative AI, while there are no sufficient studies of AI curricula in early childhood education in the existing literature (Wang et al., 2024). AI in kindergarten has little in common with AI in secondary and higher education (Yang, 2022). The main topic of AI in kindergarten is about basic concepts and simple AI activities (drawing concept maps and AI framing). However, AI in secondary and higher education at present mostly serves programs (e.g. "Scratch, Google Teachable Machine"), and complex concepts. AI is a need for kindergarten children to learn, since learning AI brings many benefits to (Su & Zhong, 2022). For instance, children can strengthen computational thinking skills or problem-solving skills using AI activities and increased AI knowledge through the use of an AI curriculum. Additionally, AI proved to be useful in helping young children understand inquiry literacy skills, such as creative inquiry, emotional inquiry, as well as collaborative inquiry skills. Therefore, it is recommended that kindergarten children should be taught AI (Zhai et al., 2021). The term curriculum is defined as "the sum of all direct and indirect experiences, activities, and events in any setting designed to provide learning and development opportunities for children". The four dimensions of a curriculum are in terms of goals or objectives, "content or subject matter, methods or procedures and evaluation and assessment" (Michell, 2021).

Furthermore, with the surge of AI into daily life, more AI-savvy workers will be in demand shortly. Given that society is dealing with large public policy questions around the use of AI technologies, citizens who are informed about the fundamentals of AI are needed (Chui et al., 2023). To prepare the children with the competencies needed to lead their lives in the rapidly transforming and tech-led world, and to ensure that children will have the means to be employable and achieve career potential in the future to ensure their employability, children should be educated enough to work with and use AI (Hunter et al., 2022).

Research Objectives

1. To explore and synthesize existing literature on AI education in early childhood, identifying key benefits, challenges, and effective strategies for incorporating fundamental AI concepts into kindergarten curricula.

2. To review and analyse secondary qualitative studies and literature regarding the current state of AI education in early childhood settings.

3. To identify the benefits and challenges, such as the development of computational thinking, inquiry literacy and ethical concerns, that arise when introducing AI concepts at the kindergarten level.

4. To propose actionable strategies and guidelines for integrating basic AI activities and tools into kindergarten curricula, ensuring that young learners can build a foundational understanding of AI in an age-appropriate and ethically informed manner.

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Research Question

How can the integration of basic artificial intelligence concepts in kindergarten curricula enhance computational thinking and inquiry skills among young children, while addressing potential ethical and developmental challenges?

Significance of the Study

With artificial intelligence becoming an everyday thing in everyday lives, there is a need to introduce foundational AI concepts early to prepare children for the technology-dependent world. Current literature suggests that there is a large void in early childhood education, but for some reason, AI curricula are less developed than other levels of education. The problem addressed by this research involves the integration of new technological concepts in kindergarten settings, preserving the ideological ethical principles of kindergartens. The study analyses the predicaments when particular curricular foundations are distributed, alongside the duty to consolidate technological innovation with moral concerns in early education. This research is significant as it has the potential to shape curriculum development and educational policies and thus increase computational thinking and inquiry skills among young learners and prepare future generations for their digital engagement and contributions in such a world.

LITERATURE REVIEW

Global Initiatives for Standardizing AI Education in K-12

As many countries like China, the United Kingdom, Thailand, Korea and the European Union create the curriculum for teaching artificial intelligence to their students, they are busy trying to standardize what students should learn at different levels (Roll et al., 2021). There are many such criteria by which AI should be taught to students in grades K-12. In May 2018, the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) formed a joint working group, from which the two organizations created national guidelines for artificial intelligence education for K-12 students (Gunning et al., 2021). The AI for K-12 recommendations, in line with the CSTA's national standards for K-12 computer education, laid out what students should know on the topic of artificial intelligence, machine learning, and robotics in each grade band. Online videos, demo software and description activities can be included in the teachers' lesson plans from the working groups' resource directory of AI-related videos, demos and activity descriptions (Sheikh et al., 2023). These issues were noticed by other organizations like AI4ALL and the International Society for Technology in Education (ISTE). On the other hand, years of academic debate continue about the definitions and components of literacy (Lim, 2024). Of the organizations, AI4K12 proposed the Five Big Ideas framework that covers the breadth of the area and makes the area approachable to teachers: "Perception, Representation and Reasoning, Learning, Natural Interaction, and Societal Impact" (Su & Yang, 2024). In addition to definitions and examples for each principle, the framework provides a longer explanation of what K12 students should perform in each category. For instance, perception corresponds with the notion of extracting meaning from sensory inputs (Crawford, 2021).

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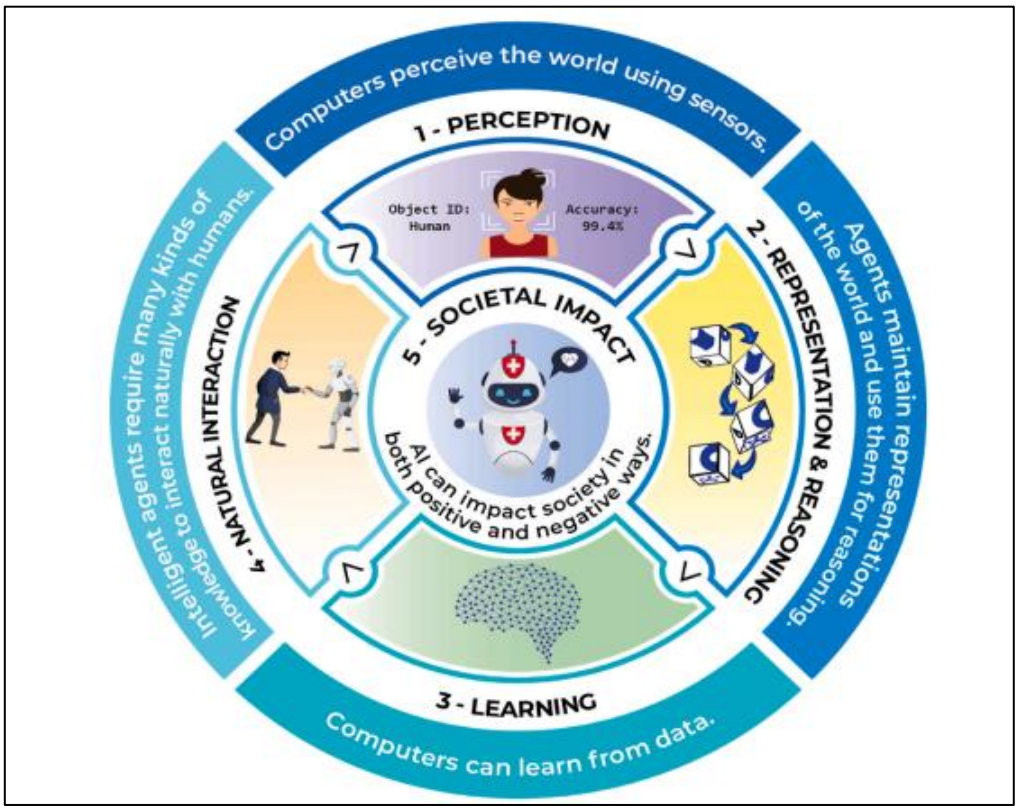

Figure 1: AI4K12 proposed the Five Big Ideas framework. (Source: Kim et al., 2021)

Solving problems using the right AI tools is referred to as 'Using AI Tools'. It is called 'Computational Thinking and Programming', and it means that students can develop simple AI applications to improve their computational thinking. In Kim et al. (2021), the AI competence framework of ReadyAI is developed to foster computational thinking and programming. Lee and Qiufan (2021) indicate that computational thinking implies that a student can solve problems, construct systems and understand human behaviour under the influence of computer science. Computational Thinking emphasizes students' critical analytical skills by thinking at various levels of abstraction in a world where computers are seen everywhere. Since computer science is about AI, AI literacy is considered to be a necessary skill for a student to grasp and become AI literate (Ford et al., 2023).

AI attitude

With an AI attitude, students become more prepared to take in all sides of AI as a unified social phenomenon. It was assumed that AI Attitude includes 'Social Impact' and 'Collaborate with AI' (Cao et al., 2023). The AI Attitude competency evaluates students who can discern both the positive and negative consequences of AI on society and their implacable attitude towards the use of AI. If citizens are AI literate, they should be able to use AI for the sake of goodness. AI is a major source of innovation, but is also a threat to the privacy, safety and security of children's rights. Most AI initiatives and guidelines, however, barely mention children, and little thought is given to the impact of AI systems on children and their rights (Chen et al., 2022). Given that AI technology involves some level of complexity that young people cannot understand comprehensively and cannot express clearly, as well as a deficit of ability to

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properly express themselves and a deficit of proper advocates to back them up, this is especially concerning (Zhao, 2025). Because children do not have the resources, they cannot respond to incidents of bias or correct any false data interpretations. Incorporating AI in the human decision-making process is problematic on ethical grounds (Yang et al., 2024) of its incorporation as applied in enforcing a commercial gender-biased face classifier by Kutz (2022) and "word embedding with encoded racial stereotypes". A balanced view of the ethical issues of AI is necessary for students to reflect on themselves and see out their different points of view. In this regard, AI literacy competencies should ensure that students know how to use AI (Su, 2025).

Tools and resources for AI at the kindergarten level

To encourage K-12 students and instructors to explore AI and understand the basics, auxiliary tools are suggested to aid the understanding. Surge in AI tools democratizes advanced techniques for younger students. Multiple tools and useful resources are identified in the literature for students and teachers to learn about AI education (Opesemowo, 2025). Cognimates is a Scratch add-on enabling users to use "APIs for voice production, speech recognition, text classification, object identification and robot control". Another website is Machine Learning for Kids, which has online demonstrations in which children can train classifiers using web applications or Scratch extensions (Butler & Starkey, 2024). The Cozmo robot is a low-cost mobile manipulator with integrated computer vision that supports objects, "custom markers, face recognition, object handling, path planning and speech production" (Yi et al., 2024). "Calypso for Cozmo is a rule-based visual programming language for Cozmo, with speech recognition, landmark-based navigation, a visible global map and state machine programming abilities" (Kolemen & Yildirim, 2025). Google has also released several free AI experiments, including Teachable Machine and QuickDraw, which use a neural net to figure out what children are drawing. To make these easy and cheap to implement, Google's AIY (AI and You) vision and voice kit uses the Raspberry Pi Zero to provide low-cost image and speech recognition (Marienko et al., 2024). The voice kit links to the cloud-based Google Assistant, while the vision kit employs a neural network classifier. TensorFlow Playground is a graphical application which enables high school students and university undergraduates to play with neural networks and backpropagation learning (Beisly, 2025).

Integrating age-appropriate AI in early childhood cultivates computational-inquiry skills, ethics, and empowers children to navigate and invent the digital world.

RESEARCH METHODOLOGY

Research Design

The research design is grounded on secondary data analysis. This design creates a framework for an approach to systematically review scholarly articles, case studies and policy documents that touch upon the topic of early childhood AI education. The qualitative design provides an interpretive understanding of current literature, serves to delineate gaps in the literature, and identifies themes both for the benefits and challenges of integrating AI into kindergarten curricula.

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Research Approach

The study has a qualitative approach supported by thematic analysis to extract, categorize and synthesize key concepts from selected literature. Supporting the broad exploration of theoretical perspectives, curricular models and pedagogical practices is a critical review of academic sources. The main outcome of this approach is that it allowed for identifying recurring themes, namely computational thinking, inquiry literacy, as well as ethical concerns concerning early encounters with AI concepts among educators. Moreover, the approach allows a comparison of national and international curriculum standards, making early childhood AI education part of the larger global view.

Data Collection

Data collection involves a systematic review of secondary sources. Relevant databases like academic journals, conference proceedings, policy repositories, and reputable organizational reports are used to search for information extensively. Such keywords as “early childhood AI education,” “kindergarten AI curriculum,” “computational thinking in early education,” and “ethical AI in early years” facilitate searching for literature. This guarantees that peer reviewed as well as grey literature is included, for a broader sphere of opinions to be brought in within the subject matter. 30 papers were reviewed to synthesize the research findings.

Inclusion and Exclusion Criteria

The literature selected for review adheres to clearly defined inclusion and exclusion criteria, as summarized in the table below:

Table 1: Inclusion and exclusion criteria of the literature

Criteria	Inclusion	Exclusion
Publication Date	Publications from 2016 to the present	Publications before 2016
Type of Study	Peer-reviewed articles, policy documents and case studies	Non-scholarly articles and unsupported opinion pieces
Relevance to Topic	Studies focused on early childhood AI education and computational thinking	Studies centred solely on secondary or higher education
Methodological Rigor	Qualitative studies with clear methodological frameworks	Studies lacking transparency in methodology

Data Analysis

Thematic synthesis of the selected literature is done for data analysis. The patterns describe the recurring themes that are based on curriculum development patterns, pedagogical strategies, ethical considerations, and technology integration in early childhood education. Findings organization into distinct themes and subthemes in the data is supported by manual coding of the data. This analytical process helps the interpretation of the complex data and consequent implications for developing future curricula. Insights on best practices, challenges and

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opportunities for introducing AI concepts to kindergarten learners from the synthesis of findings help in a holistic understanding of the research problem.

The qualitative method of thematic analysis is used to identify, analyze, and report patterns (themes) from data. This study involved the coding of the data from the selected literature that identified the themes related to curriculum design, pedagogical strategies, ethics and learning outcomes. This method offers greater insight into more detailed information of complicated text and what lies beneath. The thematic analysis is completed by manually coding segments of text according to how they relate to the research question. Using this method, the viewer creates a set of data that can be closely analyzed and the most relevant themes can be generated naturally from the analysis. More specifically, manual coding enables the organization of the findings into consistent themes which respond to the research questions. Engaging in a structured, exhaustive search across scholarly databases and other sources that are relevant to the question of interest is the systematic literature review. This ensures that arbitrary decisions are not made within the review process, as criteria for inclusion and exclusion should be pre-determined.

RESEARCH FINDINGS AND DISCUSSION

Overview of the Selected Literature

This study systematically reviewed 30 published peer-reviewed articles on AI in education in early childhood settings. The papers encompass qualitative methodologies, thematic content analysis, case studies and policy reviews. The inclusion criteria were rigorous and emphasized methodological transparency, educational relevance, and a contemporary thematic focus on computational thinking, inquiry literacy, ethical considerations, and the suitability of the project for teacher training. A defining strength of the selected studies was the methodological rigor, as many employed triangulated methods using interviews, classroom observations and curriculum design evaluation (Yang, 2022; Sperling et al., 2024). Additionally, the research objectives were well aligned with the thematic contributions in that they offered an evolving space of AI in early childhood education that is neither solely for cognitive skill development nor for ethical reflection. Indeed, Su and Yang (2022) point out in their review of the scoping review of adoption of AI in early childhood that there is a large distance between the theoretical potential of AI in education and the actual practice in early learning classrooms. It reinforces the imperative of conducting further research, development, and cross-disciplinary work to close the gap between policy and the classroom.

Major Themes Identified from Thematic Analysis

Enhancement of Computational Thinking Skills

The literature reviewed shows that the integrated activities of AI, if robustly applied, hold a consistent finding in fostering computational thinking (CT) among children. Cotino-Arbelo and González-González (2024) mentioned that early engagement with AI-based activities allows children to organically develop key skills such as pattern recognition, abstraction, and algorithmic reasoning, which are foundational to later computer science learning. Repeatedly mentioned were great practical tools such as Cognimates, Machine Learning for Kids, and

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Cozmo. For example, Druga (2018) showed that five-year-old children or older could train simple classifiers using Cognimates, helping them obtain a hands-on understanding of AI logic structures.

Even basic AI concepts, often embedded within storytelling or playful activity, can help a child to deconstruct a complex problem into smaller logical steps, said Kim et al. (2023). In their landmark paper, Lye and Koh (2014), in their delivery, indicated that computational thinking is not something that's available, but rather something that one experimentally learns through practicing; it is both about programming, as well as thinking systematically and algorithmically, thus apprehending the importance of early AI exposure.

Importantly, as Biagini (2025) emphasized, computational thinking skills in teamwork, such as literacy skills and civic literacy, are essential for early AI education and should not be divorced from technical skills but instead embedded into broader social contexts. Consequently, AI-based activities are recently regarded as a bridge between playful learning and the building block of computational logic as a part of the 21st-century skills.

Development of Inquiry Literacy

In addition, inquiry literacy became another dominant theme. AI tools will serve children's ability to pose questions, to seek evidence and to develop explanations (Yang, 2022). According to multiple researchers (Sperling et al., 2024; Su & Yang, 2022), enablers for inquiry-based exploration were applications such as QuickDraw, Teachable Machine and AIY Vision Kits. The inquiry competencies were developed naturally through the tools, which invite children to generate hypotheses and iterate on problem-solving. Bers (2018) captured this thought: coding, robotics and AI education should be modern playgrounds focused on inquiry-driven exploration and vice learning. Concepts like categorization, feedback loops and prediction models drawn from scientific inquiry were found to spark genuine wonder among children.

Kidman and Kewalramani (2021) argued that the AI learning environments equip children with an inquiry literacy that enables children to become future citizens who will demand to question and validate outputs from the AI that we are now making. On that account, AI is not only a technological tool, but a way in which critical scientific thinking is grown from a young age.

Ethical and Developmental Challenges

While benefits are compelling, ethical and developmental concerns surfaced strongly across the literature. Scholars like Chen et al. (2022) and Zhao (2025) highlighted the cognitive limitations of young children in fully grasping AI's intricacies, cautioning against overexposure without scaffolded guidance. A recurring concern was bias in AI systems. Kautz (2022) reported that without critical literacy, young children might uncritically accept biased outputs from AI systems as truth, thus necessitating early intervention to foster critical thinking.

Livingstone and Third (2017) emphasized children's vulnerability in digital spaces, arguing, children's rights must be central to any AI integration strategy, given their inability to advocate for themselves effectively in algorithmically mediated environments. Additionally,

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recent research by Adams et al. (2023) stresses that the ethical literacy of both teachers and students must evolve concurrently, or ethical violations risk becoming normalized in the digital learning landscape. Addressing these challenges requires designing AI curricula that do not merely teach functional use but embed critical ethical reasoning from the outset.

Effectiveness

Cognimates, Teachable Machine and TensorFlow Playground were found to be mixed in their effectiveness for tools. As Druba (2018) points out, such platforms are the perfect avenue for introducing an idea, but they typically involve adult scaffolding to make sense of how and when AI fits into society. Yi et al. (2024) noted that children liked interactive AI toys, yet there was often a difference between playful engagement and true understanding of underlying AI concepts. In some scenarios, children would be able to operate interfaces without really understanding the algorithms that lie behind them. Ozturk (2025) also found that playful engagement with AI interfaces without structured inquiry prompts can become superficial interaction that falls short of deep cognitive engagement. Consequently, the deployment of the tool must be purposefully designed as it should include narrative, guided inquiry and adult facilitation to bring the interaction into durable cognitive growth.

Curriculum Design and International Standards

Globally, efforts like AI4K12, ISTE standards, and various EU frameworks are converging on standardizing AI education. However, Yang (2022) criticized that while frameworks provide excellent scaffolding, actual classroom adaptation remains sparse and inconsistent across countries. Long and Magerko (2020) argued that AI literacy must move beyond technical proficiency to encompass social and ethical dimensions. AI literacy must not simply mean 'knowing AI' but critically engaging with how AI shapes the world.

Zhong and Su (2022) also emphasized that AI curricula should prioritize human-centred design principles to mitigate risks of depersonalization and technocentrism in early childhood education. The lack of coherence between frameworks and real-world applications is particularly acute in early education, where curriculum overcrowding, lack of teacher training, and ethical caution limit adoption. Moreover, Adams et al. (2023) propose a values-based curriculum model that embeds children's rights, democratic values, and civic responsibility within early AI education frameworks.

Teachers' Perceptions and Preparedness

Teacher preparedness was identified as a critical bottleneck in scaling AI education. Edwards (2023) in their scoping review found that most early childhood educators express interest in teaching AI concepts but feel unequipped due to a lack of training, resources and professional development pathways. Kim and Kwon (2023) emphasized that AI education must be supported by targeted professional development programs that demystify AI concepts for teachers, building both technical and ethical fluency. Similarly, Bae et al. (2022) demonstrated that pre-service teachers' perceptions of AI are significantly influenced by their digital literacy levels and self-efficacy.

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Sperling et al. (2024) pointed out that teachers' ethical knowledge is often underdeveloped, highlighting the need for frameworks that incorporate digital ethics explicitly into educator training. Likewise, Lim (2023) stressed the importance of embedding AI literacy within initial teacher education, rather than treating it as an optional add-on skill. This gap in teacher preparedness signals an urgent call for systemic reforms integrating AI literacy into early childhood teacher education programs worldwide. Without such interventions, AI education risks being implemented inconsistently or inadequately, undermining its transformative potential.

Discussion

However, the integrated analysis shows that early contact with AI-centred activities promotes the core cognitive faculty necessary to build a career that is ready for the future. Based on the work of Cotino-Arbelo and González-González (2024), they found that promoting computational thinking (CT) in the early years speeds up pattern recognition, problem decomposition and abstract reasoning, which is a cognitive starting point for subsequent STEM fields. Similarly, Zhong and Su (2022) highlighted how inquiry-based AI activities not only encourage scientific thinking but also foster adaptability and creativity, two precursor skills to the evolving digital economy.

But technical competencies are not all. According to scholars like Ng et al. (2023), AI curricula need to incorporate ethical considerations into the curriculum, not as addenda. “Ethical engagement with technology should not be an afterthought, such as an add-on to the end of the project—the farther we get into completing the project, the later it comes into focus, which was one of the co-ops that I participated in" (Ng et al., 2023). Fundi et al. (2024) also claimed that children ought to be exposed early to the ideas of bias, transparency and fairness in order to avoid uncritical acceptance of algorithmic output. This study puts forward a more holistic framework that recommends an early AI literacy model formed of computational thinking, inquiry literacy and ethical reasoning as pillars. This model is designed in line with the SIACC framework (Luo et al., 2024), where safety, cognitive competence and ethical consciousness are stressed from the beginning of AI education. Studies like Lakshmi and Paulin (2024) encouraged the use of inquiry-based methods, such as those that allow students to question and test AI systems critically to intertwine technical exploration with questioning of ethics. Badawy et al. (2025) also suggested that computational thinking activities can be relevant to socio-emotional learning to nurture empathy with technical skill, in line with human-centred AI conception. In line with Biagini (2025), it is about developing critical computational literacies and seeing AI’s political, social and ethical impacts, instead of simply technical working. Finally, the curriculum designed with the Early AI Literacy Model prepares children for technical careers and digital citizenship. Kafai and Proctor (2022) asserted that critical, situated computational literacies that include ethical, civic and cultural dimensions are literacies we need for future-ready education.

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CONCLUSION AND RECOMMENDATIONS

Conclusion

This study critically integrates AI research and offers how data integrated in early childhood curricula dramatically amplifies computational thinking and inquiry literacy. Across the reviewed literature, a consistent theme emerged in randomized controlled experiments on age-appropriate AI activities like training simple classifiers, interacting with visual machine learning models and interacting with AI-enabled robots. Activities such as abstraction, pattern recognition, algorithmic design, as well as hypothesis testing are developed. In parallel to the inquiry-driven training design approaches, inquiry-driven AI tasks motivate young learners to create questions, do iterative exploration and interpret predictive outputs to internalize the logic and the uncertainty that is inherent in computational systems. With the roots of future career readiness in a data-driven, algorithmic world established very early, with these twin capacities to think computationally and to take an investigative approach to finding meaning in the world, a future is laid out for these children to thrive. However, it also revealed important ethical and developmental challenges. Empirical experience suggests that young children's cognitive limitations in complete understanding of socio-technical issues related to bias, transparency, privacy and algorithmic fairness make them vulnerable to early and unqualified exposure to AI systems.

Recommendations

Curriculum Recommendations

Therefore, AI curricular innovation must prioritize the modular and developmentally appropriate integration of AI concepts. Storytelling, gamification and tangible learning tools like AI-enabled toys, machine learning art activities are a few that should be incorporated into early modules in storytelling and constructivist as well as experiential learning theories. The critical digital citizenship curricula must be embedded with ethical instruction from the start, covering algorithmic fairness, empathy in interaction with AI, transparency in a system of decision making and critical awareness about bias. Systematically, techniques such as ethical case-based reasoning, isocratic questioning and value-sensitive design activities should be incorporated. Consolidating technical understanding with ethical reflection requires inquiry-driven project-based modules, such as training an AI to recognize different emotions, designing a robot which treats all users equally (Ng et al., 2023).

Policy Recommendations

It is urgent for policymakers to begin developing international standards and unified frameworks for artificial intelligence (AI) literacy, starting at the level of pre-primary and primary education. Technical competencies of these frameworks should draw comparisons to civic/ethical literacies, such as bias recognition and privacy protection (Bers, 2018).

The professional development programs for early childhood educators regarding AI education should be mandated and based on the TPACK (Technological Pedagogical Content Knowledge) and the Ethical AI Literacy model. A certification system should be introduced to

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certified teachers who can deliver AI concepts ethically and appropriately. In addition, governments need to legislate regular audits of AI education programmes, because inclusivity, fairness, and alignment of education and AI should constantly change with the developing AI technologies and societal needs.

Recommendation for future research

Future work must focus on longitudinal, mixed-methods studies that track how early AI literacy impacts cognitive, ethical, and socio-emotional development over time. Longitudinal research would also establish the degree to which early engagement cultivates or stifles sustained critical computational literacies or technocentric biases. Additionally, empirical studies need to be done related to the children's current understanding of algorithmic bias, systemic fairness, ethical use of AI, and social justice issues while dealing with various AI systems. To examine how ethical reasoning develops in AI-mediated early learning environments, the researchers should use protocol analysis, concept mapping techniques and qualitative ethnographic observation. Such critical comparative studies between socio-economic and cultural contexts, as well as national contexts, would also provide some insight into such disparities and serve as a basis for inclusive AI education design (Cao et al., 2023).

Practical Implementation Recommendations

It needs to be bridged by public-private partnerships to create low-cost, customizable and distinct from other kits, which are targeted to kindergarten environments. It is important to collaborate with organizations such as the Raspberry Pi Foundation, Google AI Experiments and OpenAI Educational Initiatives to build such kits. Teachers should be able to use these kits to receive ethically designed interaction tasks, visual machine learning models and guidance modules.

Public-private innovation consortia that hire (edtech) companies, AI researchers, early childhood specialists and ethicists to co-design scalable, affordable interventions in AI education should be part of educational systems. Specific examples include a national government tech giant and NGO powered AI for Kids consortia like the ones piloted. Furthermore, age-appropriate open access repositories of machine learning ethics lesson plans, child-centred machine learning interfaces and virtual sandbox platforms of inquiry-driven exploration should also be developed to democratize access to high-quality AI education around the world (Chui et al., 2023).

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REFERENCES

Badawy, H. R. I., Alkaabi, A. M., & Qablan, A. M. (2025). *Nurturing future innovators: Integrating computational thinking, AI, and STEM in early education*. IGI Global. https://www.igi-global.com/chapter/nurturing-future-innovators-integrating-computational-thinking-ai-and-stem-in-early-education/361663

Beisly, A., & Abeyrathna Herath Mudiyanselag, D. (2025). Teachers can use it with their littles: Using case studies to explore preservice teachers' perceptions of technology. *Education Sciences, 15*(3), 366. https://www.mdpi.com/2227-7102/15/3/366

Baskara, F. R. (2023). Chatbots and flipped learning: enhancing student engagement and learning outcomes through personalised support and collaboration. *IJORER: International Journal of Recent Educational Research*, *4*(2), 223-238. https://journal.ia-education.com/index.php/ijorer/article/view/331

Bers, M. U. (2018). *Coding as a playground: Programming and computational thinking in the early childhood classroom*. MIT Press. https://www.taylorfrancis.com/books/mono/10.4324/9781003022602/coding-playground-marina-umaschi-bers

Biagini, G. (2025). Towards an AI-literate future: A systematic literature review exploring education, ethics, and applications. *Journal of Artificial Intelligence in Education*. Springer. https://doi.org/10.1007/s40593-025-00466-w

Butler, L., & Starkey, L. (2024). OK Google, help me learn: An exploratory study of voice-activated artificial intelligence in the classroom. *Technology, Pedagogy and Education, 33*(2), 135–148. https://doi.org/10.1080/1475939X.2024.2311779

Cao, Y., Li, S., Liu, Y., Yan, Z., Dai, Y., Yu, P. S., & Sun, L. (2023). A comprehensive survey of AI-generated content (AIGC): A history of generative AI from GAN to ChatGPT. *arXiv* Preprint arXiv:2303.04226. https://arxiv.org/abs/2303.04226

Chen, X., Zou, D., Xie, H., Cheng, G., & Liu, C. (2022). Two decades of artificial intelligence in education. *Educational Technology & Society, 25*(1), 28–47. https://www.jstor.org/stable/48647028

Chui, M., Hazan, E., Roberts, R., Singla, A., & Smaje, K. (2023). *The economic potential of generative AI*. McKinsey & Company. http://dln.jaipuria.ac.in:8080/jspui/bitstream/123456789/14313/1/The-economic-potential-of-generative-ai-the-next-productivity-frontier.pdf

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Reviewed: 6 May 2025
Accepted: 16 May 2025

Cotino-Arbelo, A. E., & González-González, C. S. (2024). Promoting computational thinking and AI literacy in early childhood education: A gender-based analysis. *ResearchGate*. https://www.researchgate.net/profile/Carina-Gonzalez-Gonzalez/publication/387644729_Promoting_Computational_Thinking_and_AI_Literacy_in_Early_Childhood_Education_A_Gender-Based_Analysis/links/6775a3b1117f340ec3eabcb7/Promoting-Computational-Thinking-and-AI-Literacy-in-Early-Childhood-Education-A-Gender-Based-Analysis.pdf

Crawford, K. (2021). *The atlas of AI: Power, politics, and the planetary costs of artificial intelligence*. Yale University Press. https://books.google.com/books?hl=en&lr=&id=XvEdEAAAQBAJ&oi=fnd&pg=PP1&dq=Crawford,+K.+(2021).+The+atlas+of+AI:+Power,+politics,+and+the+planetary+costs+of+artificial+intelligence.+Yale+University+Press&ots=MpLARl31Cw&sig=gVSl7BWpotPDM-PUpiSXVBrw9yA

Druga, S. (2018). *Growing up with AI: Cognimates* (Master's thesis). Massachusetts Institute of Technology. https://dspace.mit.edu/handle/1721.1/120691

Edwards, S. (2023). Concepts for early childhood education and care in the postdigital. *Postdigital Science and Education*, *5*(3), 777-798. https://link.springer.com/article/10.1007/s42438-022-00356-7

Ford, E., Milne, R., & Curlewis, K. (2023). Ethical issues when using digital biomarkers and artificial intelligence for the early detection of dementia. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, 13*(3), e1492. https://wires.onlinelibrary.wiley.com/doi/abs/10.1002/widm.1492

Fundi, M., Sanusi, I. T., Oyelere, S. S., & Ayere, M. (2024). Advancing AI education: Assessing Kenyan in-service teachers' preparedness. *Computers in Human Behavior Reports*. https://www.sciencedirect.com/science/article/pii/S2451958824000459

Gunning, D., Vorm, E., Wang, Y., & Turek, M. (2021). DARPA's explainable AI (XAI) program: A retrospective. *Authorea* Preprints. https://doi.org/10.22541/au.162126895.06091106/v2

Hunter, B., Hindocha, S., & Lee, R. W. (2022). The role of artificial intelligence*, 14*(6), 1524.

Kafai, Y. B., & Proctor, C. (2022). A revaluation of computational thinking in K–12 education: Moving toward computational literacies. *Educational Researcher*. https://journals.sagepub.com/doi/abs/10.3102/0013189X211057904

Submitted: 4 May 2025
Reviewed: 6 May 2025
Accepted: 16 May 2025

Kaluarachchi, T., Reis, A., & Nanayakkara, S. (2021). A review of recent deep learning approaches in human-centered machine learning. *Sensors*, *21*(7), 2514. https://www.mdpi.com/1424-8220/21/7/2514

Kautz, H. (2022). The third AI summer: AAAI Robert S. Engelmore Memorial Lecture. *AI Magazine, 43*(1), 105–125. http://ojs.aaai.org/aimagazine/index.php/aimagazine/article/view/19122

Kelso, M. (2024). *Bridging the Gap: Preparing Delaware K-12 Teachers for AI Integration* (Doctoral dissertation, Wilmington University (Delaware)). https://search.proquest.com/openview/0eab4a062bf425a66cb41943e907ffe8/1?pq-origsite=gscholar&cbl=18750&diss=y

Kim, K., & Kwon, K. (2023). Exploring the AI competencies of elementary school teachers in South Korea. *Computers and Education: Artificial Intelligence, 4*, 100164. https://www.sciencedirect.com/science/article/pii/S2666920X23000164

Kölemen, E. B., & Yıldırım, B. (2025). A new era in early childhood education: Teachers' opinions on the application of artificial intelligence. *Education and Information Technologies*, 1–42. https://link.springer.com/article/10.1007/s10639-025-13478-9

Lakshmi, T. K., & Paulin, M. S. (2024). Early curriculum for artificial intelligence enhancing quality of education. In *Advances in Consumer Research* Association for Consumer Research. https://acr-journal.com/article/early-curriculum-for-artificial-intelligence-ai-enhancing-the-quality-of-education-862/

Lee, K. F., & Qiufan, C. (2021). *AI 2041: Ten visions for our future*. Crown Currency.

Liu, L. (2024). Impact of AI gamification on EFL learning outcomes and nonlinear dynamic motivation: Comparing adaptive learning paths, conversational agents, and storytelling. *Education and Information Technologies*, 1-40. https://link.springer.com/article/10.1007/s10639-024-13296-5

Lim, E. M. (2024). Metaphor analysis on pre-service early childhood teachers' conception of AI education for young children. *Thinking Skills and Creativity, 51*, 101455. https://www.sciencedirect.com/science/article/pii/S1871187123002225

Livingstone, S., & Third, A. (2017). Children and young people's rights in the digital age. *New Media & Society, 19*(5), 657–670. https://journals.sagepub.com/doi/abs/10.1177/1461444816686318

Submitted: 4 May 2025
Reviewed: 6 May 2025
Accepted: 16 May 2025

Long, D., & Magerko, B. (2020). What is AI literacy? In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (Paper CS07). https://doi.org/10.1145/3371836.3371869

Luo, W., & Li, H. (2024). Safety, identity, attitude, cognition and capability: The SIACC framework of early childhood AI literacy. *Education Sciences*. https://researchers.mq.edu.au/en/publications/safety-identity-attitude-cognition-and-capability-the-siacc-frame

Marienko, M. V., Semerikov, S. O., & Markova, O. M. (2024). Artificial intelligence literacy in secondary education: Methodological approaches and challenges. http://ds.knu.edu.ua/jspui/handle/123456789/5479

Mosha, N. F. (2025). The role of artificial intelligence tools in enhancing accessibility and usability of electronic resources in academic libraries. *Library Management*. https://www.emerald.com/insight/content/doi/10.1108/lm-08-2024-0088/full/html

Mitchell, M. (2021). Why AI is harder than we think. *arXiv* Preprint arXiv:2104.12871. https://arxiv.org/abs/2104.12871

NeuralMinds. (2024, October 27). Personalized learning: How AI is changing education. *NeuralMinds Blog*. https://blog.neuralminds.io/personalized-learning-how-ai-is-changing-education/

Ng, D. T. K., Su, J., & Chu, S. K. W. (2023). Artificial intelligence (AI) literacy in early childhood education: The challenges and opportunities. *Computers and Education: Artificial Intelligence, 4*, 100124. https://www.sciencedirect.com/science/article/pii/S2666920X23000036

Opesemowo, O. A. G. (2025). Artificial intelligence in mathematics education: The pros and cons. In *Encyclopedia of Information Science and Technology* (6th ed., pp. 1–18). IGI Global. https://www.igi-global.com/chapter/artificial-intelligence-in-mathematics-education/349931

Roll, I., McNamara, D., Sosnovsky, S., Luckin, R., & Dimitrova, V. (2021). *Artificial intelligence in education*. Berlin: Springer International Publishing. https://link.springer.com/content/pdf/10.1007/978-3-030-78270-2.pdf

Sheikh, H., Prins, C., & Schrijvers, E. (2023). Artificial intelligence: Definition and background. In *Mission AI: The new system technology* (pp. 15–41). Springer International Publishing. https://link.springer.com/chapter/10.1007/978-3-031-21448-6_2

Submitted: 4 May 2025
Reviewed: 6 May 2025
Accepted: 16 May 2025

Su, J. (2025). Kindergarten parents' perceptions of the use of AI technologies and AI literacy education: Positive views but practical concerns. *Education and Information Technologies, 30*(1), 279–295. https://link.springer.com/article/10.1007/s10639-024-12673-4

Su, J., & Yang, W. (2022). Artificial intelligence in early childhood education: A scoping review. *Computers and Education: Artificial Intelligence, 3*, 100049. https://www.sciencedirect.com/science/article/pii/S2666920X22000042

Su, J., & Zhong, Y. (2022). Artificial intelligence in early childhood education: Curriculum design and future directions. *Computers and Education: Artificial Intelligence, 3*, 100072. https://www.sciencedirect.com/science/article/pii/S2666920X22000273

Su, J., Ng, D. T. K., & Chu, S. K. W. (2023). Artificial intelligence literacy in early childhood education: The challenges and opportunities. *Computers and Education: Artificial Intelligence, 4*, 100124. https://www.sciencedirect.com/science/article/pii/S2666920X23000036

Tapalova, O., & Zhiyenbayeva, N. (2022). Artificial intelligence in education: AIEd for personalised learning pathways. *Electronic Journal of e-Learning*, *20*(5), 639-653. https://eric.ed.gov/?id=EJ1373006

Tang, M., Liu, S., & Zhou, R. (2023). Trends in AI-supported e-learning: A systematic review. *Educational Innovations Quarterly, 14*(1), 45–67. https://www.tandfonline.com/doi/abs/10.1080/10494820.2021.1875001

Yang, W. (2022). Artificial intelligence education for young children: Why, what, and how in curriculum design and implementation. *Computers and Education: Artificial Intelligence, 3*, 100061. https://www.sciencedirect.com/science/article/pii/S2666920X22000169

Yang, W., Hu, X., Yeter, I. H., Su, J., Yang, Y., & Lee, J. C. K. (2024). Artificial intelligence education for young children: A case study of technology-enhanced embodied learning. *Journal of Computer Assisted Learning, 40*(2), 465–477. https://onlinelibrary.wiley.com/doi/abs/10.1111/jcal.12892

Yadav, S. (2025). *Empowering educators for the artificial intelligence era: Strategies and challenges in integrating computational thinking*. IGI Global. https://www.igi-global.com/chapter/empowering-educators-for-the-artificial-intelligence-ai-era/365561

Submitted: 4 May 2025
Reviewed: 6 May 2025
Accepted: 16 May 2025

Yi, H., Liu, T., & Lan, G. (2024). The key artificial intelligence technologies in early childhood education: A review. *Artificial Intelligence Review, 57*(1), 12. https://link.springer.com/article/10.1007/s10462-023-10637-7

Zhai, X., Chu, X., Chai, C. S., Jong, M. S. Y., Istenic, A., Spector, M., … & Li, Y. (2021). A review of artificial intelligence in education from 2010 to 2020. *Complexity, 2021*, 8812542. https://doi.org/10.1155/2021/8812542

Zhang, H., & Aslan, D. (2021). Connecting pedagogy with AI advancements: Opportunities for transformative learning. *Future of Education and AI, 15*(4), 299–315.

Zhao, Y. (2025). Artificial intelligence and education: End the grammar of schooling. *ECNU Review of Education, 8*(1), 3–20. https://journals.sagepub.com/doi/abs/10.1177/20965311241265124