Learning AI Early: A Meta-Synthesis of Systematic Reviews on AI Education at the Elementary Level

Audrey Marie DeHoog, Virginia Polytechnic Institute and State University

Audrey DeHoog has received a bachelor's and a master's degree in computer science from the University of Florida Herbert Wertheim College of Engineering in Gainesville, Florida. She is currently pursuing an engineering education PhD at Virginia Tech. She is interested in CS education, cross-cultural engineering, and interdisciplinary research.

Dr. Qin Zhu, Virginia Polytechnic Institute and State University

Dr. Zhu is an Associate Professor in the Department of Engineering Education at Virginia Tech, with additional affiliations in the Department of Science, Technology & Society, the Department of Philosophy, the Center for Human-Computer Interaction, and the Center for Future Workplaces and Practices. He serves as Associate Editor for Science and Engineering Ethics, Studies in Engineering Education, and Editor for International Perspectives at the Online Ethics Center for Engineering and Science. Additionally, Dr. Zhu is a member of the Board of Directors for the Association for Practical and Professional Ethics (APPE). His research investigates how culture both shapes and is shaped by the formation of socially responsible engineers; the ethical design and deployment of emerging technologies such as AI, robotics, and quantum computing; and innovative approaches to teaching responsible AI and robot literacy in K–12 education. He directs the LANCSET (Laboratory for the Advancement of Normative, Cultural, and Societal Engagement with Emerging Technologies) Research Lab, where further information about his projects and publications is available.

Learning AI Early: A Meta-Synthesis of Literature Reviews on AI Education at the Elementary Level

Abstract

In recent years, there has been a growing push for artificial intelligence (AI) education in response to the widespread impact of AI in society, particularly at the elementary education level (K-5). Many efforts focus on AI literacy, or teaching students the knowledge and critical awareness needed to understand technologies embedded in their everyday lives. A major goal is to inspire future interest in AI-related careers while supporting the development of informed and responsible citizens. Although K–12 learners are often treated as a homogeneous group, elementary students differ from older learners in developmental readiness and ability to absorb complex AI and machine learning ideas. Educators therefore must balance accessibility and conceptual rigor when designing AI learning experiences for younger audiences. Rather than conducting another systematic review, this paper draws on existing literature syntheses on elementary AI education to identify patterns, gaps, and tensions in how AI is introduced to elementary students. We coded these studies based on three questions: (1) How is AI literacy defined and operationalized in elementary education? (2) In what ways do these programs differ from traditional computing education initiatives? (3) What adjustments have been made to adapt AI literacy content for younger audiences? Findings from this meta-synthesis contribute to ongoing efforts to study AI education at the elementary level and offer guidance for researchers and instructors focused on AI literacy for younger learners.

Keywords: AI education; K-12; Meta review; Literature review; Elementary education

Introduction

In recent years, there has been a push for artificial intelligence (AI) education as a response to the increasingly widespread impact of AI in society, particularly within the K-12 context. Efforts to advance AI education in K-12 settings focus on AI literacy, teaching students the knowledge and critical awareness needed to make sense of the technologies embedded in their everyday life. A major goal of these efforts is to inspire the next generation to pursue AI related careers while cultivating AI literacy among all students as informed and responsible citizens in an increasingly digitalized world. While K-12 students are considered a homogeneous group by researchers, there is a notable difference in learning abilities and developmental needs between elementary school students (grades K-5) and middle (grades 6-8) and high school students (grades 9-12). Younger audiences such as elementary students may struggle to understand the complexities of AI and machine learning (ML) concepts. When designing AI courses and programs for elementary students, educators and researchers must balance the accessibility of content and the rigor and depth of AI concepts.

Rather than conducting another systematic review, this paper leverages existing literature syntheses on K–12 AI education to identify patterns, gaps, and tensions in how AI is taught to elementary students. More specifically, this paper adopts a *child-centered* lens to examine how AI literacy is defined and enacted within elementary-level AI education programs, and to analyze the efforts documented in the existing literature to make AI learning *developmentally appropriate* for young learners. The findings of this meta-synthesis contribute to ongoing efforts to systematically study AI education at the K-12 level and are especially relevant for instructors and researchers focused on AI literacy education for younger audiences such as elementary school students.

The Computer Science Teachers Association (CSTA) and Artificial Intelligence for K-12 initiative (AI4K12) provide a glossary of key terms in their AI learning priorities for K-12 students (CSTA & AI4K12, 2025). We will be utilizing their definitions of AI, generative AI, and ML for this meta-analysis as they represent how AI concepts are represented in K-12 education. AI refers to a system that uses training data to produce outputs like predictions, recommendations, or decisions that are considered similar to actions that reflect "intelligence" in humans. While AI is often used as an umbrella term, generative AI and ML are distinct categories of AI technologies. Generative AI refers specifically to technologies that can generate new text, images, video, and/or audio in response to a prompt, and ML is a subfield of AI that combines learning algorithms with training data to create tools that can be used to complete tasks. These aspects of AI education are often implemented in K-12 through activities that encourage students to interact with generative AI applications, classroom discussions of AI ethics and societal implications, and activities that involve students in the various stages of developing machine learning models.

Unlike most existing reviews that treat K–12 AI education as a single group, this paper focuses specifically on elementary students. By bringing together findings from multiple literature reviews, this study clarifies what we actually know and what we still do not know about AI literacy for young children. This focus offers a clearer picture of how AI education should be designed for early learners and highlights the gaps that future research needs to address.

Context

Due to the ever-evolving nature of AI and its significant implications for economic competitiveness and societal well-being, countries around the world are increasingly investing in AI research, development, and educational initiatives to prepare a future workforce and citizenry capable of engaging responsibly with AI. In particular, the United States has issued presidential executive orders and more recently established major funding programs such as those at the National Science Foundation to promote K-12 AI education and research (Office of the Federal Register, 2025). These efforts are further complicated by the pace of AI technological advancement, which often surpasses the timelines of curriculum development and instructional design (Miao et al., 2021). Despite the burgeoning literature on K-12 AI education, there have been certain challenges that limit the effective translation of educational research into instructional practice and policy guidance (Adil, 2025). Furthermore, access to high quality AI learning opportunities remains unequal across schools and communities, which raises concerns that shape how AI literacy can be developed in K-12 contexts (Bouakaz & Khalid, 2025).

Most notably, there has been a lack of a consistent definition or comprehensive framework for AI literacy, which further complicates the development of coherent learning outcomes and pedagogical strategies (Linde et al., 2025). It has made it even more difficult to design learning outcomes and pedagogies that are responsive to the unique needs and learning styles of K-12 students at different developmental stages, considering they are not a *homogeneous* group. Lacking consistent definitions and frameworks has also led to other negative outcomes. For instance, most existing AI literacy frameworks and programs lack a balanced representation of technical, and ethical and societal skills, with technical skills often prioritized over ethical and societal dimensions (Yue et al., 2025). In addition, due to the absence of consistent frameworks, there has been limited research into effective strategies for teaching AI literacy, especially at the elementary level (Yue et al., 2025). Further complicating these issues, many elementary educators report limited confidence or preparation to teach AI-related content, which highlights the need for clearer instructional frameworks and sustained professional learning support (Philippakos & Rocconi, 2025).

More recently, scholars have proposed the idea of “child-centered AI” places children's voices and rights at the heart of AI education. Technological and pedagogical designs influenced by such a philosophy often addresses questions such as how children perceive the impact of AI on their own learning futures and how these designs can expand the capabilities of children in expressing their own ideas (Wilson et al., 2025). In other words, a child-centered approach to AI literacy in the context of K-12 needs to consider adjusting the existing AI literacy frameworks (which may be made by adults for adults) to meet children’s needs. A child-centered approach therefore requires aligning AI literacy goals with children’s cognitive, social, and emotional development, rather than solely simplifying adult-oriented AI concepts. Such a transformation requires careful examinations. More specifically, this paper critically examines the three following research questions in the existing literature on K-12 AI education, particularly at the elementary level while educators and researchers are designing programs to support children’s AI literacy development:

(1) How is AI literacy defined and operationalized in elementary education?
(2) In what ways do these programs differ from traditional computing education initiatives?
(3) What adjustments have been made to adapt AI literacy content for younger audiences?

Methods

This study conducts a meta-synthesis on review articles covering K-12 AI education. In this section, we describe the protocol to select relevant reviews, including the databases and search terms used, exclusion criteria applied, and the screening process for excluding irrelevant articles.

To identify relevant reviews, we searched Web of Science, EBSCO, and Scopus using combinations of keywords related to AI literacy and AI education ("AI literacy" OR "artificial intelligence literacy" OR "AI education" OR "artificial intelligence education") together with educational level terms ("elementary" OR "K–12" OR "primary") and review type terms ("systematic review" OR "scoping review" OR "literature review"). After identifying relevant reviews, we applied a consistent set of inclusion and exclusion criteria to select individual studies from those reviews for analysis. Included studies were peer-reviewed journal or conference papers, published between 2018 and December 2025, written in English, and available in full text. Articles were excluded if the article was not related to K-12 AI education, the review was not the focus of the article, the article did not address AI literacy, or the findings of the review were not relevant to the research question. We then coded these selected studies focusing specifically on the following questions: (1) how these programs differ from traditional computing education; (2) what conceptual depth or rigor may be lost when adapting content for younger audiences; and (3) how AI competency is defined and operationalized in elementary education.

Initially, Google Scholar was chosen to provide a more extensive literature search; however, Google Scholar lacked the filter options necessary to effectively search using the exclusion criteria and returned far too many articles to manually filter the results of the keyword search. Scopus was instead used to ensure a quality literature search with relevant journal articles and conference papers. Web of Science and EBSCO provided additional peer-reviewed articles to ensure the search was inclusive. For each database, date range, language, and document type filters were used to apply the exclusion criteria to the search results to reduce the number of irrelevant articles returned. The search of the Web of Science database using the keywords by topic and applying the filters produced 28 results. The search of the EBSCO database using the keywords within all fields and applying the filters produced 14 results. Finally, the search of the Scopus database using the keywords within the article title, abstract, or keywords and applying the filters produced 43 results. Almost all of the articles from Web of Science and EBSCO were present in the Scopus search results, with the exception of one article from the EBSCO database. The article D. Lee & Kwon (2024) was available on the Scopus database but did not include some of the keywords in the title, abstract, or keywords, so it was not returned in the Scopus search results.

A PRISMA diagram (Fig. 1) presents an overview of the search protocol. The initial search returned 85 articles in total. After removing duplicates, we screened 49 articles by reviewing the title and abstract, and 12 articles were removed for irrelevance. Next, we examined the complete text of the 32 articles we were able to retrieve. Of those articles, four were removed for not containing information relevant to the research questions, three were removed because the literature review was not central to the paper, and one article was removed because it did not address AI literacy for K-12 students. This yielded a final collection of 24 articles for meta-synthesis.

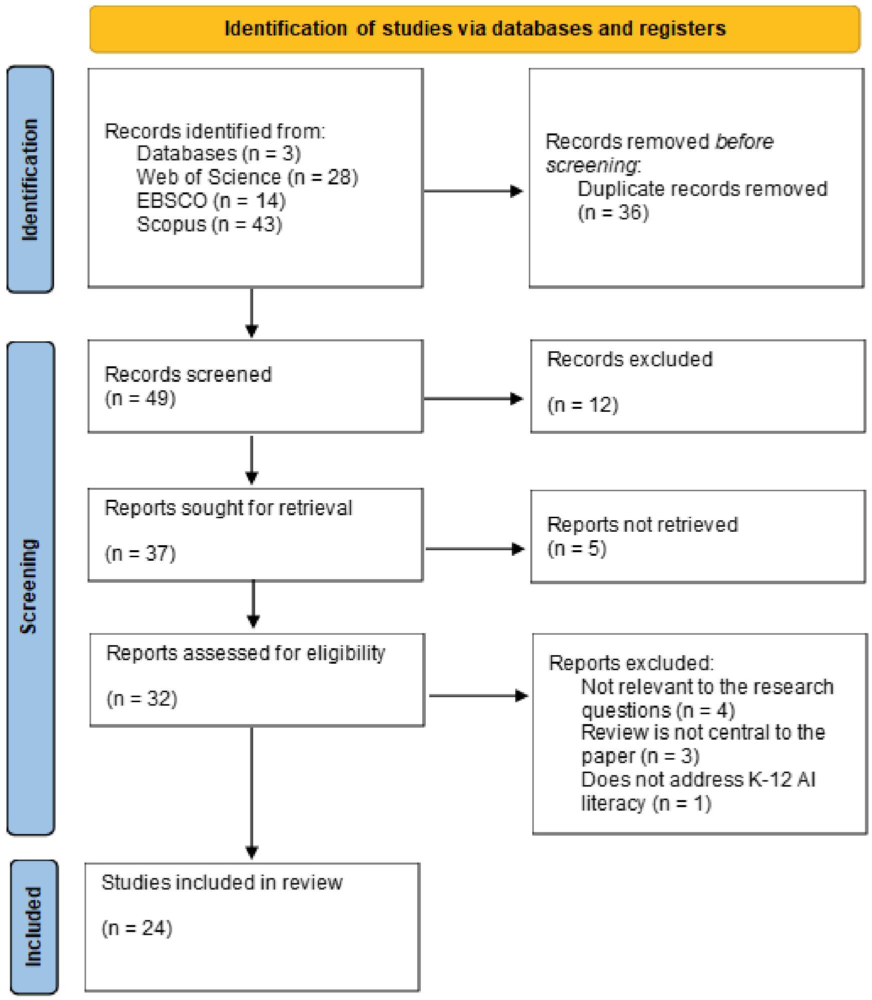

Fig 1. PRISMA diagram showing the process of selecting eligible studies.

Findings

How AI Literacy is Defined and Operationalized

Few reviews clearly define AI literacy or specify the competencies students need to be considered AI literate, and even fewer do so with attention to elementary school learners. Despite the emergence of several AI literacy frameworks in recent years, most were developed for general K–12 audiences or older students. For example, Yim (2024) identified 17 AI literacy frameworks, and yet only four explicitly address K–12 contexts and none are tailored to elementary education. Across these frameworks, AI literacy is defined as a multidimensional construct that integrates conceptual understanding, practical skills, and ethical awareness. A particularly dominant framework shaping how these conceptual components are understood is the AI4K12 Initiative, which identifies five core ideas (Perception, Representation & Reasoning, Learning, Natural Interaction, and Societal Impact) as foundational to K–12 AI literacy (Li et al., 2024). The Five Big Ideas have become the de facto major framework in the field of AI literacy for determining what young learners should know about AI.

Across these reviews, AI literacy is conceptualized as requiring students to develop (1) foundational knowledge of core AI ideas (e.g., data, models, learning, and representation); and (2) the ability to interact with, apply, and reason about AI systems through hands-on activities, computational thinking practices, or model exploration tasks (Yim, 2024). In addition, nearly all frameworks emphasize the importance of understanding the societal and ethical implications of AI. Casal-Otero et al. (2023) further argue that AI literacy in K–12 spans three intertwined dimensions: learning about AI, learning how AI works, and learning to live ethically and critically with AI. Yet they also note that few studies systematically assess whether young learners truly understand AI concepts.

A growing body of literature on elementary education expands this multidimensional understanding. Yim and Su's (2025) review conceptualizes AI literacy for young children as a blend of computational thinking, critical data literacy, AI–human interaction competencies, and early ethical awareness. Their analysis shows that elementary AI literacy builds not only on conceptual knowledge but on skills to collaborate with AI agents, interpret simple data patterns, and reflect on AI's social implications. Su et al.'s (2025) scoping review reinforces this expanded view by identifying four assessable components (AI knowledge, ethical understanding, affect toward AI, and AI use) and highlighting that AI literacy involves dispositions and practices as well as conceptual understanding.

Recent literature also shows that elementary AI literacy is most effectively operationalized through developmentally appropriate, hands-on, and concrete learning activities that make abstract AI concepts visible and manipulable for young children (S. J. Lee & Kwon, 2024). These activities, often embedded within familiar school subjects such as science, literacy, social studies, and the arts, help young learners explore core ideas like perception, classification, learning, and fairness through simplified model-building, structured experimentation, embodied simulations, or guided ethical reflection. Reviews of K–12 AI learning tools further indicate that AI literacy at the elementary level is commonly implemented through intelligent agents, block-based programming environments, and visual ML platforms such as PopBots, Machine Learning for Kids, Scratch-based ML extensions, and Teachable Machine (Yim & Su, 2024). These tools enable children to understand foundational concepts such as perception and classification without requiring formal programming knowledge, supporting early experimentation with training data, model behavior, and simple algorithmic reasoning.

Beyond tools, several reviews also highlight specific instructional strategies that support elementary students' conceptual and ethical development in AI. Algorithmic demystification activities that teach how AI processes input data help young children recognize where bias, error, or unfairness may arise (Ma et al., 2025; Tagare et al., 2025). Age-appropriate approaches include perspective-taking activities in which students adopt the role of an AI system to simulate decision-making processes (Lin et al., 2025), and analogy-based instruction that maps abstract AI concepts onto familiar real-world experiences (Arranz-Garcia et al., 2025). These strategies make algorithmic logic more accessible and reduce cognitive load for young children encountering complex ideas for the first time.

Hands-on, project-based learning also plays a central role in operationalizing elementary AI literacy. Through simplified ML tasks such as collecting and labeling small datasets, training or testing models, and examining model errors students gain firsthand experience with how data quality and model design influence outputs (Lin et al., 2025; Ma et al., 2025; Tagare et al., 2025). These activities help students identify how biased or unrepresentative data can lead to unfair or harmful outcomes. Doing so will cultivate critical data literacy and ethical reasoning early in the learning process. Many of these projects are interdisciplinary, reflecting how real-world AI development requires combining knowledge from multiple domains (Zhou et al., 2025). For elementary students specifically, AI literacy instruction is often connected to arts, music, storytelling, and maker-centered learning, allowing children to integrate creativity with foundational problem-solving skills (Álvarez Ariza et al., 2025; Bal & Öztürk, 2025). Drawing-based ML tools such as Google Quick, Draw! and AutoDraw are often used as they cultivate creativity and encourage students to critically examine the limitations and underlying mechanisms of AI tools, contributing to their AI literacy (Lin et al., 2025).

Ethics education is also central to elementary AI literacy. Reviews show that teachers commonly facilitate discussions about fairness, harm, and appropriate AI use by drawing on students' everyday experiences and local community contexts (Álvarez Ariza et al., 2025; Zhou et al., 2025). Activities such as comparing outputs from different AI systems, examining biased examples, or analyzing AI-mediated stories help students reflect on how AI affects their lives and the lives of others. Such early ethical engagement helps students build empathy and recognize the social and cultural dimensions of AI. Additionally, teachers can foster a deeper understanding of the implications of AI in society by posing challenging questions and by encouraging students to seek answers through experimentation and exploration of AI technologies. This inquiry-based approach promotes curiosity, critical thinking, and independent learning that helps students develop the skills necessary to navigate complex AI topics (Abulibdeh, 2025).

Finally, elementary AI literacy emphasizes the importance of understanding human agency in AI interactions. Young learners are encouraged to see AI systems not as authoritative sources but as tools shaped by human choices, intentions, and values (Ma et al., 2025). Activities that promote play, exploration, and guided experimentation—such as interacting with conversational AI, giving simple prompts, or comparing system responses—support self-directed learning and increase students' interest in understanding how AI works (D. Lee & Kwon, 2024). Several reviews also suggest that prompt-based interactions with generative AI tools can strengthen students' digital literacy and early AI literacy skills when implemented in structured, age-appropriate ways (Álvarez Ariza et al., 2025; Dimeli & Kostas, 2025). For example, activities where students act as co-creators with generative AI tools, such as students using image generation tools to reimagine their hand-drawn sketches. This allows students to explore AI tools through interactive play and creative exploration (Lin & Tan, 2025).

While elementary AI literacy is typically implemented in formal classroom settings, reviews highlight that informal learning environments—such as after-school programs, robotics clubs, family learning activities, and community events—play a significant role in shaping young children's early AI understandings (Kim & Kwon, 2025; D. Lee & Kwon, 2024; Ma et al., 2025). These environments are particularly influential because participation is voluntary and interest-driven, enabling children to engage with AI tools in personally meaningful ways.

Overall, across all these reviews, AI literacy in elementary education emerges as a multidimensional and developmentally grounded competence that combines foundational AI concepts, hands-on engagement with intelligent tools, critical and ethical reasoning, and opportunities for creative expression. It is operationalized through playful, project-based, and culturally responsive learning activities that help young children understand, interrogate, and responsibly use AI systems in ways appropriate for their developmental stage.

How AI Programs Differ from Traditional Computing Education Initiatives

A reoccurring AI literacy learning outcome for K-12 students is developing their fundamental coding skills to better understand AI systems. Similar to introductory computing education, block-based programming tools, cell-based programming environments, and educational programming languages are often used to provide younger learners with an accessible entry point to build interactive AI systems (D. Lee & Kwon, 2024; Lin et al., 2025). ML and AI tools tailored for beginners such as visual model training platforms and simplified dataset interfaces are also used to provide an accessible method to explore AI through hands-on development, training, and evaluation of AI models (Lin et al., 2025). For example, Google Teachable Machine (GTM) is a popular choice for enhancing interactive learning as it allows students to create machine learning models without coding (Yim & Su, 2025; Zhou et al., 2025). Students can use GTM to develop personalized models based on their interests, which can foster engagement and motivation among younger audiences (Lin et al., 2025). Multiple reviews have found that the development of students' computational thinking and programming skills in AI education is crucial for developing student AI literacy, digital skills, and self-efficacy (Arranz-Garcia et al., 2025; D. Lee & Kwon, 2024; Lin et al., 2025).

However, these reviews also emphasize that AI education cannot be treated as the same as traditional computing education, and it is insufficient to solely rely on coding. AI education at the K-12 level cannot solely focus on coding as it is difficult for general teachers with little computer science knowledge to teach in-depth coding concepts (D. Lee & Kwon, 2024). Furthermore, several reviews note that coding-intensive AI learning activities often assume programming prerequisites that younger learners do not yet possess and draw on constructionist approaches for which young learners may lack the intellectual ability to benefit (Ng et al., 2023; Yim, 2024). As a result, these reviews recommend designing AI learning experiences that provide flexible and accessible entry points and increase accessibility for students without a technical background, therefore reducing the technical demands associated with computing-oriented approaches (Song et al., 2024; Yim & Su, 2025).

While traditional computing education focuses more on teaching rule-based programming (e.g., writing explicit instructions for a machine to follow), recent AI education efforts increasingly encourage a shift toward data-driven approaches (Yim & Su, 2024). AI education requires helping students better understand how models learn from examples, how training data shape system behavior, and how algorithms function under uncertainty. AI learning activities often involve data-driven learning designs, including activities such as data labeling, model evaluation, exploration of misclassifications, and the analysis of sources of bias which are practices rarely found in introductory programming courses (Casal-Otero et al., 2023; Ng et al., 2023). A reoccurring example in reviews was AI for Oceans, an interactive web-based activity designed to teach kindergarteners the fundamentals of machine learning concepts, such as the importance of quality training data and the impact of training data on algorithm bias, by enabling students to train an AI model to identify images of fish and garbage (S. J. Lee & Kwon, 2024; Lin et al., 2025).

Additionally, computing activities require comprehensive programming skills (D. Lee & Kwon, 2024). They are also about learning other factors such as “AI dispositions” (Yue et al., 2022), computational thinking (Bilstrup et al., 2022), and stakeholders affected by AI. To truly understand ML systems, students must not only engage with the technical components of ML models, but also with how they are designed and the context related to their development and deployment. AI education programs also emphasize understanding and evaluating the ethical and social implications of AI (Kong et al., 2024; Su et al., 2025; Yim & Su, 2024). Teachers may achieve this by leading discussions on the ethical and legal implications of AI in real-life scenarios, such as how AI may affect students’ parents and their jobs, or by assigning individual writing assignments that encourage students to reflect critically about AI and how it relates to issues such as fake news (Tagare et al., 2025).

Adjustments to Adapt AI Literacy Content for Younger Audiences

To better facilitate AI literacy amongst children, educators find it useful to simplify AI concepts to make it easier for children to understand them. However, it is not always possible to effectively translate these complex ideas, and conceptual depth or “rigor” may be lost when adapting content for younger audiences.

A common approach to making AI algorithm functionality easier for younger audiences to understand is to allow students to interact with a simplified AI tool, such as an AI-driven robot, to “open the black box” of AI systems. While this allows students to explore a system with AI components and provides AI concepts with a level of transparency, this approach often lacks the mathematically rigorous content related to ML algorithms (Rizvi et al., 2023). Instead of algorithmic depth, learning activities at the elementary level emphasize behavioral exploration such as observing how a model changes when data are added or removed or examining simple misclassifications to develop intuitive understandings of model limitations.

AI literacy and AI ethics education is more frequently employed and studied in AI education for high school students compared to other K-12 levels as younger students, especially elementary schoolers, struggle to grasp the complex underlying principles and mechanisms of AI systems (Bal & Öztürk, 2025; Kim & Kwon, 2025; Lin et al., 2025). Additionally, younger audiences find it difficult to fully grasp the ethical and societal implications of AI. Therefore, AI literacy education at that level often lacks in-depth discussion about these concepts (Lin et al., 2025; Rizvi et al., 2023).

To make AI instruction more accessible to younger learners, it is also crucial to provide well-designed scaffolding, individualized facilitation, and guidance that helps children connect new ideas with their previous experiences (Song et al., 2024). Young learners can benefit when teachers guide their information processing, support planning and monitoring, and provide learning structures that align with their developing reasoning skills (Song et al., 2024; Su et al., 2025). As children often struggle with underlying assumptions and algorithms, teachers rely on pedagogical approaches that emphasize conceptual exploration, hands-on demonstrations, and guided activities that build understanding gradually (Yim & Su, 2025; Li et al., 2024).

In addition to simplifying AI concepts, AI education for young children incorporates age-appropriate pedagogical approaches to support their cognitive and developmental needs. AI education for younger learners often integrates methods such as storytelling, role-playing, embodied learning, unplugged activities, robotics-supported narratives, and interactive visualizations to introduce foundational ideas such as perception, classification, pattern recognition, and model behavior (Li et al., 2024; Yim & Su, 2025). These activities are designed to be developmentally appropriate and emphasize helping children observe and reason about how AI systems behave, instead of expecting young learners to design and program full AI systems on their own (Yim & Su, 2025). In addition, it is also critical to leverage concepts and principles from Human–Computer Interaction (HCI) and Universal Design for Learning (UDL) to promote accessibility, diverse means of representation, and culturally responsive design in AI education (Song et al., 2024).

Discussion

As indicated in these reviews, elementary AI literacy is understood as a multidimensional competence that integrates foundational AI concepts, hands-on interaction with intelligent tools, and early (or age appropriate) ethical reasoning. In addition to clarifying which aspects of AI are developmentally appropriate for elementary learners, the literature frequently points to teacher preparation as a critical condition for effective AI education. Across these reviews, limited teacher confidence and preparation emerge as barriers to effective elementary AI education. Rather than expecting elementary educators to become experts on advanced technical content, the literature emphasizes professional learning models that highlights conceptual understanding, pedagogical scaffolding, ethical reflection, and the use of low-threshold AI tools integrated into existing curricula. Although many AI literacy frameworks exist, few are designed for young children, and elementary-focused studies emphasize developmentally appropriate, concrete learning experiences (e.g., simplified model-building, embodied simulations, and creative, interdisciplinary projects) that help students understand how AI works, recognize its limitations, and reflect on its social implications.

Having basic computing knowledge is fundamental for understanding how AI systems are developed. Therefore, it is important to assess how AI education differs from traditional computing education. K-12 AI literacy education and introductory computing education have some overlap in key ideas and teaching approaches. Introductory programming tools tailored for beginners allow younger audiences to engage with coding concepts that are fundamental to understanding AI systems, without the potentially overwhelming complexities of traditional programming languages and environments. Younger audiences lack technical background knowledge and intellectual development to understand AI system development, so it is important for educators to utilize age-appropriate tools and activities to develop their students' computational thinking skills and problem-solving skills. However, unlike traditional computing education, AI literacy education is more than just learning to code. For instance, AI literacy education requires students to be mindful of training data and to understand the potential impact it can have on AI system behavior.

To better facilitate AI literacy amongst children, educators find it useful to adapt AI content to make it easier for younger audiences to understand it. However, it is not always possible to effectively translate these complex ideas, and conceptual depth or "rigor" may be lost. Younger students struggle to understand in-depth computing or ethical AI concepts; therefore, AI literacy education for elementary students instead focuses on the broader social and ethical implications of AI to make AI literacy education more aligned with their intellectual and moral development levels. Younger audience friendliness and making AI concepts more accessible is also greatly emphasized in K-5 AI literacy education (e.g. introductory programming tools tailored for beginners, demystification exercises, etc.). Furthermore, early K-12 AI literacy education appears to focus more on laying foundation for future AI literacy education by introducing basic concepts, developing students' interest in AI-related topics, and developing students' critical thinking skills to engage with AI more responsibly.

However, there are still several important questions that have not yet been addressed. We still know little about how young children *actually think about AI*, how their understanding develops over time, and which pedagogical strategies work best for different ages. There is also limited research on how teachers can be prepared to teach AI confidently, especially those without computing backgrounds. Finally, very few studies examine how cultural, linguistic, or socioeconomic differences shape children's early experiences with AI. These gaps highlight the need for more empirical research on early AI learning.

Conducting this meta-synthesis highlighted a clear lack of literature focusing specifically on elementary AI literacy education. Despite using "elementary" and "primary" as search terms, it was necessary to broaden the search to include K–12 articles as many reviews lump all grade levels together, making it difficult to isolate findings about young children. This meta-synthesis also has certain limitations. As it summarizes findings from existing reviews rather than primary empirical studies, it depends on how those reviews selected and interpreted the literature. It is possible that some newer or less visible studies were not included in the reviews we analyzed. These limitations call for more firsthand and systematic research with young children to better understand how they develop AI literacy over time.

Conclusion

This meta-synthesis demonstrates that elementary AI literacy represents a distinct and underexamined area within K–12 AI education. It is a field that requires developmentally grounded learning goals, pedagogies, and frameworks rather than adaptations of frameworks designed for adults. Within existing literature, AI literacy for young children is often characterized as a multidimensional competence integrating foundational AI concepts, hands-on and playful engagement with intelligent tools, early ethical awareness, and opportunities for creative expression. Yet the literature also indicates critical gaps: few frameworks are tailored to elementary learners, conceptual rigor can be sacrificed for accessibility, and research frequently conflates K–12 despite meaningful developmental differences. Addressing these gaps will require designing child-centered AI literacy frameworks, strengthening teacher preparation, and expanding empirical studies that examine how young learners *actually* develop AI literacy over time. By emphasizing the unique needs of elementary students, this paper highlights the importance of building AI education that is cognitively appropriate, ethically informed, and capable of supporting children's long-term growth as critical and responsible citizens in an AI-enabled world.

References

Abulibdeh, A. (2025). A systematic and bibliometric review of artificial intelligence in sustainable education: Current trends and future research directions. *Sustainable Futures*, *10*, 101033. https://doi.org/10.1016/j.sftr.2025.101033

Adil, J. J. G. (2025). AI in Education: A Systematic Literature Review of Emerging Trends, Benefits, and Challenges. *Seminars in Medical Writing and Education*, *4*, 795–795. https://doi.org/10.56294/mw2025795

Álvarez Ariza, J., Benitez Restrepo, M., & Hernández Hernández, C. (2025). Generative AI in Engineering and Computing Education: A Scoping Review of Empirical Studies and Educational Practices. *IEEE Access*, *13*, 30789–30810. https://doi.org/10.1109/ACCESS.2025.3541424

Arranz-Garcia, O., García, M. del C. R., & Alonso-Secades, V. (2025). Perceptions, Strategies, and Challenges of Teachers in the Integration of Artificial Intelligence in Primary Education: A Systematic Review. *Journal of Information Technology Education: Research*, *24*, 006.

Bal, M., & Öztürk, E. (2025). The potential of deep learning in improving K-12 students' writing skills: A systematic review. *British Educational Research Journal*, *51*(3), 1295–1312. https://doi.org/10.1002/berj.4120

Bilstrup, K.-E. K., Kaspersen, M. H., Assent, I., Enni, S., & Petersen, M. G. (2022). From Demo to Design in Teaching Machine Learning. *Proceedings of the 2022 ACM Conference on Fairness, Accountability, and Transparency*, 2168–2178. https://doi.org/10.1145/3531146.3534634

Bouakaz, L., & Khalid, S. (2025). AI in education: A sociological exploration of technology in learning environments. *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1700876

Casal-Otero, L., Catala, A., Fernández-Morante, C., Taboada, M., Cebreiro, B., & Barro, S. (2023). AI literacy in K-12: A systematic literature review. *International Journal of STEM Education*, *10*(1), 29. https://doi.org/10.1186/s40594-023-00418-7

CSTA & AI4K12. (2025). AI Learning Priorities for All K-12 Students. *Computer Science Teachers Association*. https://csteachers.org/ai-priorities/

Dimeli, M., & Kostas, A. (2025). The Role of ChatGPT in Education: Applications, Challenges: Insights From a Systematic Review. *Journal of Information Technology Education. Research*, *24*, 2. https://doi.org/10.28945/5422

Kim, K., & Kwon, K. (2025). A systematic review of the evaluation in K-12 artificial intelligence education from 2013 to 2022. *Interactive Learning Environments*, *33*(1), 103–131. https://doi.org/10.1080/10494820.2024.2335499

Lee, D., & Kwon, H. (2024). Meta-analysis on effects of artificial intelligence education in K-12 South Korean classrooms. *Education and Information Technologies*, *29*(17), 22859–22894. https://doi.org/10.1007/s10639-024-12738-4

Lee, S. J., & Kwon, K. (2024). A systematic review of AI education in K-12 classrooms from 2018 to 2023: Topics, strategies, and learning outcomes. *Computers and Education: Artificial Intelligence*, *6*, 100211. https://doi.org/10.1016/j.caeai.2024.100211

Li, L., Yu, F., & Zhang, E. (2024). A systematic review of learning task design for K-12 AI education: Trends, challenges, and opportunities. *Computers and Education: Artificial Intelligence*, *6*, 100217. https://doi.org/10.1016/j.caeai.2024.100217

Lin, X., & Tan, H. (2025). A Systematic Review of Generative AI in K–12: Mapping Goals, Activities, Roles, and Outcomes via the 3P Model. *Systems*, *13*(10), 840–865. https://doi.org/10.3390/systems13100840

Lin, Z., Dai, Y., & Ng, O.-L. (2025). Constructionism in K-12 AI Literacy Education: A Systematic Review of Pedagogical Designs, Student Outcomes, and Learning Mechanisms. *Journal of Educational Computing Research*, *63*(7–8), 1748–1781. https://doi.org/10.1177/07356331251360442

Linde, G. van der, Rodriguez-Montoya, C., & Garrido, L. E. (2025). Landscape of AI literacy in education: Approaches, impacts, and challenges for student preparedness—a narrative review. *Discover Education*, *4*(1), 561. https://doi.org/10.1007/s44217-025-00924-6

Ma, M., Ng, D. T. K., Liu, Z., & Wong, G. K. W. (2025). Fostering responsible AI literacy: A systematic review of K-12 AI ethics education. *Computers and Education: Artificial Intelligence*, *8*, 100422. https://doi.org/10.1016/j.caeai.2025.100422

Miao, F., Holmes, W., Ronghuai, H., & Zhang, H. (2021). *AI and education: Guidance for policy-makers*. UNESCO Publishing. https://doi.org/10.54675/PCSP7350

Ng, D. T. K., Lee, M., Tan, R. J. Y., Hu, X., Downie, J. S., & Chu, S. K. W. (2023). A review of AI teaching and learning from 2000 to 2020. *Education and Information Technologies*, *28*(7), 8445–8501. https://doi.org/10.1007/s10639-022-11491-w

Office of the Federal Register, National Archives and Records Administration. (2025, April 23). *DCPD-202500511—Executive Order 14277—Advancing Artificial Intelligence Education for American Youth*. Office of the Federal Register, National Archives and Records Administration. https://www.govinfo.gov/app/details/DCPD-202500511

Philippakos, Z. A. T., & Rocconi, L. (2025). AI Literacy: Elementary and Secondary Teachers' Use of AI-Tools, Reported Confidence, and Professional Development Needs. *Education Sciences*, *15*(9), 1186. https://doi.org/10.3390/educsci15091186

Rizvi, S., Waite, J., & Sentance, S. (2023). Artificial Intelligence teaching and learning in K-12 from 2019 to 2022: A systematic literature review. *Computers and Education: Artificial Intelligence*, *4*, 100145. https://doi.org/10.1016/j.caeai.2023.100145

Song, Y., Weisberg, L. R., Zhang, S., Tian, X., Boyer, K. E., & Israel, M. (2024). A framework for inclusive AI learning design for diverse learners. *Computers and Education: Artificial Intelligence*, *6*, 100212. https://doi.org/10.1016/j.caeai.2024.100212

Su, J., Chen, X., Chu, S. K. W., & Hu, X. (2025). A scoping review of empirical research on AI literacy assessments. *Educational Technology Research and Development*, *73*(5), 3105–3130. https://doi.org/10.1007/s11423-025-10515-9

Tagare, D., Karki, T., & Yu, W. (2025). K-12 teachers' ethical competencies for AI literacy: Insights from a systematic literature review. *Computers & Education*, *239*, 105435. https://doi.org/10.1016/j.compedu.2025.105435

Wilson, C., Atabey, A., & Revans, J. (2025). Towards child-centred AI in children's learning futures: Participatory design futuring with SmartSchool and the co-design stories toolkit. *International Journal of Human-Computer Studies*, *199*, 103431. https://doi.org/10.1016/j.ijhcs.2024.103431

Yim, I. H. Y. (2024). A critical review of teaching and learning artificial intelligence (AI) literacy: Developing an intelligence-based AI literacy framework for primary school education. *Computers and Education: Artificial Intelligence*, *7*, 100319. https://doi.org/10.1016/j.caeai.2024.100319

Yim, I. H. Y., & Su, J. (2024). Artificial intelligence (AI) learning tools in K-12 education: A scoping review. *Journal of Computers in Education*, *12*(1), 93–131. https://doi.org/10.1007/s40692-023-00304-9

Yim, I. H. Y., & Su, J. (2025). Artificial intelligence literacy education in primary schools: A review. *International Journal of Technology and Design Education*, *35*(5), 2175–2204. https://doi.org/10.1007/s10798-025-09979-w

Yue, M., Jong, M. S.-Y., & Dai, Y. (2022). Pedagogical Design of K-12 Artificial Intelligence Education: A Systematic Review. *Sustainability*, *14*(23), NA-NA. https://doi.org/10.3390/su142315620

Yue, M., Jong, M. S.-Y., Dai, Y., & Lau, W. W.-F. (2025). Students as AI literate designers: A pedagogical framework for learning and teaching AI literacy in elementary education. *Journal of Research on Technology in Education*, *0*(0), 1–22. https://doi.org/10.1080/15391523.2025.2449942

Zhou, X., Li, Y., Chai, C. S., & Chiu, T. K. F. (2025). Defining, enhancing, and assessing artificial intelligence literacy and competency in K-12 education from a systematic review. *Interactive Learning Environments*, *33*(10), 5766–5788. https://doi.org/10.1080/10494820.2025.2487538