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Teaching Machines, Learning to Teach: AI Literacy Education in K-12 Schools

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Abstract

This article examines the current state of artificial intelligence (AI) literacy education in K–12 schools, with particular attention to its conceptual foundations, pedagogical practices, tools, and learning outcomes. Drawing on recent systematic and scoping reviews, it highlights that AI literacy encompasses not only technical understanding but also application, critical evaluation, and ethical reasoning. Existing programmes largely emphasize hands-on, constructivist approaches using tools such as machine learning platforms and programmable devices, yet often lack strong theoretical grounding and consistent assessment frameworks. Evidence suggests positive short-term outcomes, including improved conceptual understanding, computational thinking, and student interest in AI-related fields. However, most studies rely on immediate post-intervention self-reports, offering limited insight into long-term learning retention. Significant gaps persist in areas such as equity, teacher preparedness, and contextual implementation particularly in developing regions like India, where policy initiatives such as NEP 2020 advocate digital and computational competencies but empirical classroom evidence remains scarce. The review underscores the risk of privileging technical skills over critical and ethical understanding, potentially resulting in incomplete AI literacy. It concludes that effective AI education requires sustained teacher training, integration across disciplines, and robust, long-term evaluation methods to ensure inclusive and meaningful learning outcomes.

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Introduction

The arrival of artificial intelligence in everyday life has created a straightforward but genuinely hard question for school systems: should students learn about AI, and if so, how? Over the past five years this question has shifted from a conference discussion to an active policy concern in dozens of countries. Governments and curriculum bodies in the United States, China, the United Kingdom, and India have begun placing AI-related content into national frameworks for school education. At the international level, UNESCO has published guidance calling on member states to integrate AI literacy into national curricula as a matter of educational equity and civic preparedness (Pedro et al., 2019; Miao et al., 2021). The practical question, though, is what actually happens when AI education enters a classroom.

This article examines what is currently known about AI literacy education at the K-12 level. It draws on recent systematic reviews and scoping studies that have mapped how AI is being taught, what tools teachers are using, and what students appear to be learning. The aim is not to produce another argument for why AI education matters but to look carefully at the evidence for what it currently looks like in practice and where the gaps are.

For India, this conversation is particularly pressing. The National Education Policy 2020 explicitly calls for the integration of coding and computational thinking at the secondary level (Ministry of Education, Government of India, 2020), and the National Curriculum Framework for School Education 2023 reinforces digital literacy as a core competency. Yet there is little systematic evidence from Indian school classrooms about how AI-related content is being implemented, which is itself a finding that points toward a need for more action research within the Indian educational context.

What AI Literacy Actually Means

The phrase "AI literacy" is used loosely in both policy documents and research papers, which makes it difficult to evaluate evidence about whether it is being achieved. At the most basic level, AI literacy refers to a set of competencies that allow a person to understand, critically evaluate, and work with AI systems (Long & Magerko, 2020). But the specific skills included under this umbrella vary considerably across studies and programmes. Ng et al. (2021) conducted an exploratory review of the AI literacy literature and identified four intersecting dimensions: knowing and understanding AI, using and applying AI, evaluating and creating with AI, and reasoning ethically about AI a framework that reflects the complexity of genuine competency in this domain.

Holmes and Tuomi (2022) conducted a review of AI in education and developed a typology of AIED systems, showing that different categories of educational AI rest on different pedagogical and educational assumptions. Their typology distinguishes between student-facing AI (intended to support learning), teacher-facing AI (intended to support teaching), and system-facing AI (intended to support institutional administration and management). The distinction matters because each category demands different things from students and teachers, and embeds a different view of what education itself is for. A student using an AI-driven tutoring system to practice mathematics the kind of system described in early influential analyses of intelligent tutoring (Luckin et al., 2016) is not necessarily developing the capacity to reason about how that system was built or what its limitations are.

Touretzky et al. (2019) established the first K-12 AI education framework for United States schools. The framework identifies five essential concepts which serve as fundamental components for teaching artificial intelligence across all academic levels. The framework has received multiple citations while its content has been modified by various researchers and it shows the same battle between technical knowledge and critical understanding which exists in recent academic works.

The K-12 AI education research reviewed by Lee and Kwon (2024) found that topics covered in school-based AI programmes fell broadly into four categories. The first category included AI awareness together with its operational functions. The second category included various AI fields which encompassed machine learning and natural language processing. The third category included everyday situations where AI technologies are used. The fourth category included various ethical challenges that AI technologies present. The ethical dimension is the newest addition to

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curricula and the least systematically taught. Most programmes spend the majority of time on technical concepts and hands-on activities, with ethical reflection appearing as an add-on rather than a thread running through the full programme.

This is a problem worth naming. Students who can train a machine learning model using an online platform but who have not thought carefully about what data was used to train it, who built it, or what happens when it is wrong are not fully AI-literate. They have technical skills without critical understanding. In the Indian context, where AI systems are increasingly used in government services and financial products that directly affect people at the lower end of the economic spectrum, the ethical dimension of AI literacy seems especially important.

What K-12 Schools Are Actually Teaching

Lee and Kwon (2024) conducted a systematic review of 25 peer-reviewed studies on AI education in K-12 classrooms published between 2018 and 2023. Some patterns in the findings are worth noting. First one, the majority of studies (approx 80%) focused on secondary school students, that means the evidence base for primary-level AI education is thin. The second one, the uneven distribution geographically. Most of the studies came from the United States, China, Thailand, and a small number of European countries. Third, programme duration ranged from a single 90-minute session to a full semester, which makes it almost impossible to compare outcomes across studies.

Yue, Jong, and Dai (2022) reviewed the pedagogical designs of K-12 AI education programmes and found that hands-on activities, project-based learning, and design challenges were the most frequently used teaching approaches. Direct instruction in AI concepts was almost always paired with some form of activity in which students built or trained a simple AI system. This approach reflects a constructivist philosophy: students learn about AI by doing things with it a principle whose roots stretch back to Papert's (1980) foundational work on constructionist learning, in which children were understood to build knowledge most effectively when they build shareable artifacts. The authors noted, however, that most programmes did not report on how the pedagogical design decisions were made or what learning theories informed them. A lot of AI teaching is happening by trial and error.

The research conducted by Lee and Kwon (2024) presents a crucial element for teacher educators in India which demonstrates the significance of teacher involvement within those educational programs. The studies which were analyzed showed that AI education was taught to students through the collaborative efforts of researchers and curriculum developers who worked with classroom teachers instead of teachers using regular curriculum materials to teach. The current system of AI education depends on external experts who provide the necessary knowledge. The implementation of this program requires extensive teacher training which exceeds the need for only curriculum updates according to international policy recommendations (Miao et al., 2021).

The Tools Being Used

The scoping review conducted by Yim and Su in 2024 examined 46 studies which they gathered from multiple conferences and journals to identify the educational tools that K-12 schools use to teach AI literacy. The results demonstrate that all age groups show distinct separation from one another. For the youngest learners kindergarten and early primary the most frequently utilised tools are physical, embodied objects: programmable robots such as PopBots, platforms based on LEGO Mindstorms, and robots that students design and assemble themselves. The tools enable children to understand abstract AI concepts because they transform these concepts into physical objects which children can touch and control. The field of early childhood computing research has shown that tangible and embodied interactions with objects enable children to learn new concepts (Bers 2018) and this knowledge serves as the foundation for AI education research.

The software-based tools serve as the primary educational resources for secondary students. The three most common platforms include Google Teachable Machine Machine Learning for Kids and Scratch based machine learning environments. The platforms enable students to build basic classifiers which use visual and audio and text data without requiring them to learn any programming skills. Upper secondary students begin to learn Python programming through computer science programs that focus on advanced computer science studies. AI education connects to core computational thinking development according to the literature (Wing 2006) which has led educators to select teaching materials that support both skills for their curriculum development process.

Yim and Su (2024) describe Teachable Machine and Machine Learning for Kids as age-appropriate entry points into AI literacy at the secondary level tools that lower the barrier to a first hands-on experience with machine learning. Whether such tools, on their own, support the deeper conceptual understanding that AI literacy ultimately requires is a separate question, and one their scoping review explicitly flags as under-evaluated: few of the studies they reviewed included measures of conceptual understanding beyond immediate post-activity assessments. A student can train a model to recognise gestures in under twenty minutes, which makes for a satisfying activity and demonstrably introduces a learner to how a classifier behaves; what is less clear is what students retain about why it behaves that way once the activity ends. Selwyn (2019) has raised a broader version of this concern, arguing that enthusiasm for digital tools in education often outpaces evidence for their effectiveness, and that the interests of technology developers do not always align with the interests of learners. Teachers need to address this issue because it affects their work. Students become interested in a lesson when teachers use exciting digital tools. Students create something which has both real value and actual existence. The lesson delivered to students through AI showed them that the technology consists of two basic functions. The tools need to be paired with explicit instruction and discussion about the concepts behind them.

What Students Learn from AI Education

The learning outcomes reported across studies reviewed by Lee and Kwon (2024) fell into three broad groups. The first group relates to AI literacy and conceptual understanding: students showed improvement in their ability to define AI concepts and identify AI applications in daily life and explain machine learning functions through basic terminology. The second group covers thinking skills: several studies reported gains in computational thinking and problem-solving and logical reasoning skills that Wing (2006) identified as essential for success in the automated future. The third group is affective: students in multiple programs demonstrated greater interest in artificial intelligence and developed better attitudes toward technology and some students showed interest in technology-related professional fields.

The results show overall positive outcomes. The results require detailed examination. The program used self-report surveys as its main outcome assessment tool which were given to participants

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immediately after program completion. Only a small number of research projects tracked students over multiple weeks or months to assess whether their AI knowledge and interest had persisted. The evidence for enduring educational results from K-12 AI education programs remains extremely weak. The statement serves as a defense of AI education programs. The statement represents a call for improved research design methods which should assess the effectiveness of AI education programs through research studies.

The issue exists of determining which students achieve advantages from the program. Yim and Su (2024) observed that AI education programs which emphasize coding and computational thinking show more significant student progress when students possess previous technology skills. Students from lower-income households or rural backgrounds, who may have less access to devices at home, begin their program with an unaddressable disadvantage which the program fails to resolve. The OECD (2021) has identified this issue as a systemic threat which affects all countries implementing AI educational programs because such programs will create educational divides without design approaches that intentionally promote fairness. The equity question in India exists as a concrete issue. Gujarat has established clear evidence of the digital divide which separates urban and rural students, thus any school-based AI education program which fails to address this divide will increase learning gaps instead of decreasing them.

What We Still Do Not Know

Research publications have expanded but researchers still identify specific research gaps which require attention. Holmes and Tuomi (2022) demonstrated that technology developers and edtech companies control the majority of AI development for education while educational researchers and teachers maintain limited control. The process defines which products receive development funding and which items undergo evaluation to determine their success. The AI tutoring platform developer needs to support research efforts which demonstrate the platform's effectiveness. Luckin et al. (2016) made a similar observation, noting that optimistic claims about intelligent systems in education often rest on proprietary evaluations rather than independent replications. The existing system requires independent evaluations which require extended testing periods and superior evaluation methods.

The other major gap is teacher preparation. Every review of K-12 AI education demonstrates that teachers lack adequate preparation to teach the subject. This situation appears to be expected. AI education has recently emerged as a field and teacher training programs have yet to incorporate it as a standard requirement because most teachers lack any AI knowledge from their own educational experiences. UNESCO's policy guidance stresses that effective AI education requires investing in teacher capacity, not just curriculum materials (Miao et al., 2021). Teachers need extended professional development which includes hands-on experience with AI tools to practice their skills and grow their knowledge before they can guide students through similar learning experiences.

Implications for Classroom Practice

This research provides practical implications which teachers can use in their work with Indian school systems. The educational system needs to treat AI education as a compulsory subject which should be taught to all students. The implementation needs to start from the beginning of the project. When students create an image classification system through model training they should demonstrate their understanding of three elements. Long and Magerko (2020) explicitly include "critical appraisal of AI" as a core competency in their framework, not a supplementary one.

The learning goals should determine tool selection for educational activities because tools serve as learning resources in the educational process. Teachers must define their desired student outcomes before selecting between Teachable Machine, physical robot, or Scratch-based activities. The tool that creates the most interest for users does not always lead to the most effective learning outcomes. Bers (2018) shows that creative construction tools enable students to learn more effectively than tools which focus on consumption and novelty.

AI education needs its present form to operate successfully with multiple academic disciplines. The programs which Lee and Kwon (2024) reviewed integrated AI education into science, mathematics, and social studies. The cross-curricular approach produced better conceptual results than the AI modules which functioned as standalone units. The STEM or science classroom enables students to understand how AI connects with data collection and hypothesis testing and pattern recognition which occurs in nature This integration also helps address the computational

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thinking goals embedded in frameworks like NEP 2020 (Ministry of Education, Government of India, 2020) without requiring entirely new timetable space.

Conclusion

The existing research proves AI literacy education in K-12 schools is expanding but still shows gaps. The information we possess includes details about taught subjects and utilized educational resources. The research shows two areas which need study because it lacks knowledge about learning retention and equity gap resolution and teacher training methods for effective content delivery. The research base includes short-term studies which focus on wealthy urban areas and show technology developers' agendas instead of meeting classroom teachers and students' requirements.

For education systems working to implement the ambitions of NEP 2020 and the National Curriculum Framework for School Education 2023, AI literacy is not a luxury add-on. The process prepares students for a future which already uses AI systems to make important choices. Schools must provide complete solutions which require more than installing new computer lab equipment. The process needs teachers who possess deep understanding of concepts and requires curriculum design which incorporates ethical learning together with technical skill development and needs assessment methods which measure actual understanding through direct evidence instead of survey data. The basic UNESCO report by Pedro et al. (2019) established that educational institutions must involve AI technology based on principles of inclusion and equity and human dignity, which curriculum designers and teacher educators and policymakers need to follow.

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