Artificial Intelligence (AI) Literacy in Education: Definition, Competencies, Opportunities and Challenges

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Article

Artificial Intelligence (AI) Literacy in Education: Definition, Competencies, Opportunities and Challenges

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Abstract

Artificial Intelligence (AI) is rapidly being integrated into educational systems globally, making AI literacy a critical educational priority. This paper comprehensively reviews AI literacy, focusing on its definition, essential competencies, integration opportunities, and associated challenges within educational contexts. AI literacy refers to the knowledge, skills, and attitudes necessary to understand AI principles, effectively utilize and create AI tools, and critically evaluate AI technologies' ethical and societal impacts. The review synthesizes existing literature, international policy initiatives, and educational frameworks to conceptualize AI literacy and identify core competencies needed across different educational stages, categorized into knowledge-based, skill-based, and ethical-attitudinal dimensions. Opportunities explored include fostering interdisciplinary learning, preparing students for AI-driven workplaces, leveraging AI educational tools, and driving curriculum and policy innovation. However, significant implementation challenges, such as insufficient teacher training, infrastructure disparities, curriculum integration uncertainties, and ethical concerns related to bias, privacy, equity, and societal impacts, are highlighted. Addressing these challenges requires coordinated efforts among educators, policymakers, researchers, and stakeholders. Future research, policy development, and educational practice should focus on developing comprehensive competency frameworks, equitable access strategies, targeted professional development for educators, and responsible approaches to embedding AI literacy into education.

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1. Introduction

Artificial Intelligence (AI) is rapidly being integrated into education systems worldwide. Different governments have launched initiatives to equip students with AI-related knowledge and skills. For example, a recent UNESCO report identified eleven countries – including China, India, and the Republic of Korea – implementing national K–12 AI curricula, with many others developing AI education plans [1]. Countries like the United States, Finland, the United Kingdom, Canada, Turkey, and Argentina have all introduced AI topics into their school programs or policies [1]. In Singapore, the Ministry of Education piloted an interactive AI learning program in schools, though its expansion has been hindered by a lack of trained teachers [2]. Canada has designed a high school AI course to empower students with AI knowledge, covering foundational concepts, societal implications, and hands-on projects solving real-world problems [2]. These global efforts reflect a broad recognition

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that students will live and work in an AI-powered world, making AI literacy an essential new educational objective.

Amid this trend, the concept of "AI literacy" has emerged as a focal point for educational innovation. AI literacy refers to individuals' competencies to effectively understand and engage with AI technologies. It extends beyond traditional digital literacy to encompass understanding how AI systems work, how they impact society, and how to use them responsibly. Researchers have underscored the urgency of promoting AI literacy for all learners: as AI becomes ubiquitous, the ability to understand, evaluate, and use AI is "quickly becoming an essential skill for participating in modern society" [3]. Accordingly, governments and institutions worldwide are beginning to treat AI literacy as a foundational goal alongside basic literacies like reading, writing, and mathematics [2].

This study provides a comprehensive review of AI literacy in education. We examine how AI literacy is defined and conceptualized, outline its core competencies, and discuss opportunities for integrating AI literacy into curricula. We also identify key challenges and risks – from teacher readiness to ethical concerns – that must be addressed. Finally, we highlight future directions for research, policy, and practice to support the effective integration of AI literacy in education. The aim is to offer educators, researchers, and policymakers a structured understanding of AI literacy and a roadmap for harnessing its potential in teaching and learning.

2. Defining AI Literacy

2.1. Conceptual Foundations of AI Literacy

AI literacy is a relatively new concept, and recent literature has proposed multiple definitions. AI literacy generally refers to the knowledge, skills, and dispositions that enable individuals to critically understand and engage with artificial intelligence. Long and Magerko [4] offer a frequently cited definition: AI literacy is "a set of competencies that enable individuals to evaluate AI technologies critically; communicate and collaborate effectively with AI; and use AI as a tool" in various contexts. This definition highlights that AI-literate people should not only know what AI is but also be able to work alongside AI tools and make informed judgments about AI outputs.

Other scholars emphasize similar elements. For instance, Kong [5] identifies key aspects of AI literacy as recognizing and understanding AI, using and applying AI, evaluating and creating AI, and understanding AI ethics. In essence, AI literacy involves both technical proficiency with AI and a critical awareness of AI's ethical and social implications.

2.2. Relationship with Related Literacies

It is important to clarify how AI literacy relates to adjacent concepts such as digital literacy, data literacy, and computational thinking. AI literacy builds upon these foundational literacies but adds unique dimensions. Like digital literacy, AI literacy requires a basic facility with computers and technology, but it further includes understanding algorithmic decision-making and intelligent systems.

Data literacy – the ability to interpret and use data – is an essential subset of AI literacy, since modern AI (especially machine learning) is driven by data [6]. UNESCO's digital competency frameworks position data literacy as a core component of AI-related education [6].

Likewise, AI literacy is closely connected to computational thinking. Concepts from computational thinking (like problem decomposition or abstraction) underpin how students learn AI, and some experts suggest that AI curricula should align with computational thinking models [2]. Earlier studies in computing education often focused on how block-based or text-based programming tools (e.g., Code.org, CodeCombat) shaped students' computational thinking and motivation [7–15]. In contrast, recent research has shifted toward examining AI literacy as a broader and more interdisciplinary competency. However, AI literacy extends beyond general computing skills by introducing students to specific AI concepts (e.g., training a model, recognizing bias in algorithms) and fostering an understanding of AI's impact on society.

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2.3. Proposed Working Definition

Given the varied emphases in the literature, we adopt a working definition of AI literacy that synthesizes common elements from established frameworks (UNESCO, OECD) and educational initiatives (AI4K12, Alan Turing Institute). In this article, AI literacy is defined as the combination of knowledge, skills, and attitudes that enable an individual to understand core AI concepts, use AI tools and techniques, interpret AI outputs, and evaluate the ethical implications of AI technologies. This definition is grounded in prior work: it encompasses the cognitive dimension (knowledge of AI concepts and how AI works), the practical dimension (ability to apply AI or use AI-powered applications), and the socio-ethical dimension (awareness of issues like fairness, transparency, and privacy in relation to AI) [2,3].

2.4. AI4K12 "Five Big Ideas"

For example, the AI4K12 initiative in the United States – a project endorsed by major computing education organizations – articulates "Five Big Ideas" [1] of AI that K–12 students are expected to learn: (1) computers perceive the world via sensors, (2) machines maintain representations of the world for reasoning, (3) computers can learn from data, (4) intelligent agents require diverse knowledge to interact naturally with humans, and (5) AI can impact society in both positive and negative ways. These big ideas illustrate the blend of conceptual knowledge and societal context inherent in AI literacy. Across frameworks from UNESCO's guidance to the Alan Turing Institute's educational efforts, there is a broad consensus that AI literacy entails technical understanding of AI systems and the capacity to think critically about AI's role in the world and one's interaction.

3. Core Competencies of AI Literacy

AI literacy can be further described in terms of core competencies that learners are expected to develop. These competencies can be grouped into three broad categories: knowledge-based competencies, skill-based competencies, and ethical/attitudinal competencies. Together, they cover what a person should know about AI, what they should be able to do with AI, and how they should think about AI responsibly.

3.1. AI Literacy Frameworks and Assessment Tools

In addition to broad definitions, recent research has proposed specific frameworks to conceptualize AI literacy and instruments to assess it. Table 1 summarizes several notable AI literacy frameworks and assessment tools from the literature, highlighting their focus and key competency domains.

Table 1. Overview of Selected AI Literacy Frameworks and Assessment Tools.

Source	Framework / Tool Focus and Key Components
Long & Magerko (2020) [4]	**Core Competencies of AI Literacy**: Synthesized the interdisciplinary sources to identify 16 key competencies defining AI literacy. These competencies span: recognizing AI and understanding what counts as AI, grasping AI's strengths, limitations, and future implications, understanding how AI systems represent knowledge and make decisions (e.g. basics of machine learning, data and algorithms), awareness of the human role in building and training AI, familiarity with sensors/robots and how AI interacts with the world, and understanding key ethical issues surrounding AI (privacy, bias, etc.).
Kong & Zhang (2021) [16]	**Three-Dimensional Conceptual Framework**: Proposed a conceptual AI literacy framework with three dimensions.

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	1. The cognitive dimension includes knowledge of basic AI concepts and the ability to use AI concepts for reasoning about the world. 2. The affective dimension emphasizes empowerment and confidence to engage with AI in daily life and work. 3. The sociocultural dimension highlights ethical and societal aspects, encouraging the ethical use of AI for sustainable development. This framework underpins later AI literacy curricula by ensuring a balance of technical knowledge, personal agency, and ethical understanding.
Laupichler et al. (2023) [17]	**SNAIL Assessment Scale**: Developed the "Scale for the Assessment of Non-Experts' AI Literacy (SNAIL)" through expert Delphi study and factor analysis. SNAIL is a validated questionnaire that assesses general AI literacy across three factors: (1) Technical knowledge of AI (understanding fundamental concepts and technologies), (2) Critical analysis skills (ability to evaluate and question AI systems' outcomes and impacts), and (3) Practical application of AI (knowing how to use AI tools in practice appropriately). This tool provides a way to measure AI literacy levels in the general population beyond formal education settings.
Kong, Cheung & Zhang (2023) [18]	**University AI Literacy Program Evaluation**: Implemented an AI literacy programme for undergraduates from diverse backgrounds, and identified key learning dimensions aligned with an AI literacy framework. The framework covered conceptual understanding of AI (knowledge of AI concepts and using AI to evaluate and understand real-world contexts), empowerment in using AI (e.g. improved self-efficacy, sense of meaningfulness, and creativity with AI), and ethical awareness (students' awareness of AI ethics principles like autonomy, beneficence, and fairness). Assessment surveys in the study correspondingly measured gains in AI concepts, AI empowerment, and ethical considerations, reflecting a holistic literacy framework.
Kassorla, Georgieva & Papini (2024) [19]	**Higher Ed AI Literacy Framework**: A comprehensive AI Literacy in Teaching and Learning framework for higher education that defines four core domains. These include technical understanding of how AI works, evaluative skills for critically analyzing AI applications and outputs, practical ability to integrate and use AI tools in educational contexts, and an ethical commitment to responsible AI use (addressing bias, transparency, etc.).
Kong, Cheung & Tsang (2024) [20]	**Secondary Student AI Literacy Framework**: Developed and evaluated a project-based AI literacy course for high school students to inform a framework for "educated citizens". The course emphasized problem-solving competencies (applying AI concepts to real-world problems) and ethical understanding of AI's use. Outcomes showed students improved in using AI tools to solve real-life problems and became more aware of ethical boundaries and principles in AI applications. This highlights a framework where practical AI skills and ethical awareness are learned together through hands-on projects.
Jin et al. (2024) [21]	**GLAT: Generative AI Literacy Assessment Test**: Developed a 20-item multiple-choice instrument to assess learners' generative AI literacy objectively. The test was constructed using established educational and psychological measurement procedures and validated with data from higher education students. GLAT measures knowledge of generative AI concepts, ability to use and evaluate GenAI tools, and decision-making in GenAI-supported tasks. It demonstrated strong reliability and predictive validity, outperforming self-reported measures such as perceived ChatGPT proficiency. These results suggest that

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	GLAT offers a robust and scalable tool for evaluating GenAI literacy and can support educational practice and policy development.

3.2. Knowledge-based Competencies

Knowledge-based competencies refer to understanding the fundamental concepts and mechanisms of AI. Learners need to understand core AI topics such as machine learning, algorithms, data, and models. This includes knowing that AI systems often learn from data (rather than being explicitly programmed), recognizing how algorithms like neural networks or decision trees function at a basic level, and understanding concepts like training vs. inference or human–AI interaction.

For example, an AI-literate student should understand that computers can perceive the world through sensors and make decisions based on data-driven models (one of AI4K12's big ideas) [1]. They should know key terminology (such as model, algorithm, neural network, dataset, training, and automation) and be aware of the capabilities and limitations of AI.

Research on emerging K–12 AI curricula shows a strong focus on conceptual understanding – students are expected to learn how to identify AI systems around them and explain in general terms how those systems work [2]. For instance, a middle school student might learn that a recommendation system (like a movie recommendation app) is an AI that makes predictions based on patterns learned from user data.

By high school, students might delve deeper into how specific algorithms function or compare different AI approaches. This conceptual knowledge provides the foundation upon which practical skills are built.

3.3. Skill-based Competencies

Skill-based competencies involve the ability to use and even create AI practically. This means interacting with AI tools and interpreting their outputs at the most basic level. For example, students should learn how to use an AI-powered application (such as a chatbot, translation tool, or image recognition app) and understand the results it produces (and potential errors).

More advanced skills include experimenting with simple AI models – for instance, training a basic machine learning model using a user-friendly tool or programming environment. AI literacy frameworks often emphasize "learning by doing" so that students gain hands-on experience with AI systems [3]. This could mean coding a simple AI in a block-based programming language or adjusting parameters in a machine learning simulator to see how it affects outcomes.

In some high school programs, students build small AI projects, such as a system that classifies images or a mobile app with an AI feature [2]. Such activities aim not to turn every student into a professional AI developer, but to cultivate a practical fluency with AI concepts, similar to how basic programming classes cultivate computational thinking without requiring expert-level coding.

An AI-literate individual should be able to apply AI tools appropriately, interpret the reliability of an AI's output (for example, knowing that a prediction has uncertainty), and perhaps modify or design simple algorithms. As AI technologies become embedded in many software applications and workplace tools, these user-level and creator-level skills will be increasingly important.

Students also learn problem-solving skills in the context of AI – for example, how to frame a problem such that an AI could assist, or how to improve an AI model's performance. Studies have found that AI literacy education often aims to develop students' problem-solving and analytical thinking skills while teaching technical content [2].

3.4. Ethical and Attitudinal Competencies

Ethical and attitudinal competencies are a critical pillar of AI literacy, ensuring that learners know how to use AI and understand when and why (or why not) to use AI. As AI systems permeate society, issues of fairness, bias, transparency, accountability, and privacy have become central.

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An AI-literate person should know that AI algorithms can exhibit bias (for example, facial recognition systems performing poorly on specific demographic groups). That blind trust in AI can lead to unfair or unsafe outcomes. They should appreciate the importance of data privacy, knowing what it means to share personal data with an AI service and the potential risks involved.

Ethical competency also includes understanding the social impact of AI, such as how automation might affect jobs or how AI is used in surveillance [4]. These topics are now frequently included in AI curricula. Many definitions of AI literacy explicitly include an ethics component. Learners are encouraged to approach AI with a critical mindset, asking questions like "Is this AI making a fair decision?" or "How does this AI affect people's rights?".

Research by Ng et al. [22] introduced ethical considerations as one of four key dimensions of AI literacy, alongside awareness, usage, and creation. This might involve students discussing real-world case studies of AI misuse or debating the rules AI should follow. The desired attitude is healthy skepticism and responsibility: students should neither fear AI irrationally nor accept it uncritically, but rather understand its pros and cons.

As one study put it, students need to learn not just "basic AI skills and knowledge" but also "how to use AI technology wisely and understand ethical practices" [23]. This aligns with global calls for "responsible AI" – ensuring the next generation is prepared to develop and deploy AI fairly, transparently, and beneficially.

3.5. Competency Differences Across Educational Stages

The specific competency outcomes for AI literacy will significantly vary with learners' age and educational level [3]. Competency expectations are typically scaled to be age-appropriate across K–12, higher education, and adult learning.

In elementary grades, AI literacy might focus on simple conceptual models and curiosity, for example, recognizing AI in everyday devices or playing with educational robots, to build awareness and positive attitudes. By secondary school, students can handle more complex ideas like how machine learning works in principle, or engage in guided projects (such as training a simple classifier).

Studies have shown that even young students can grasp certain AI concepts when taught appropriately, though simplifying and metaphors are often needed. High school programs have demonstrated that teenagers can successfully learn advanced concepts like neural networks or data ethics, primarily through project-based learning that ties abstract ideas to concrete applications.

At the university level, AI literacy might be integrated into general education courses to ensure all graduates (not just computer science majors) understand AI fundamentals. Here the bar is higher: college students might experiment with real datasets, use programming libraries to implement AI algorithms, or study ethical frameworks in depth.

In vocational training and adult learning contexts, AI literacy often takes the form of upskilling – teaching workers how AI will impact their industry and how to work alongside AI tools. For example, healthcare professionals might learn about AI diagnostic systems, or marketing professionals might learn to use AI analytics in their job. The competencies for adults may emphasize practical tool use and critical interpretation of AI outputs relevant to their field.

Across all levels, the trajectory is one of progressively deepening understanding: from basic awareness to hands-on experimentation to advanced analysis. Education researchers have called for explicit learning progression frameworks to develop AI literacy coherently over a student's educational career [2]. While such frameworks are still being refined, the overarching goal is clear – to prepare every learner, at an appropriate depth, to navigate an AI-rich world.

4. Opportunities in AI Literacy Integration

Integrating AI literacy into education offers many opportunities to enrich learning and prepare students for the future. Done thoughtfully, AI literacy can enhance students' technical knowledge

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and interdisciplinary learning, critical thinking, and creativity. It can help align education with the evolving demands of the workforce, where AI is becoming ubiquitous.

We conducted a comprehensive review of existing literature [24–31] and concluded the findings. This section explores key opportunities from embracing AI literacy in curricula.

4.1. Interdisciplinary Learning Through AI

One significant opportunity is to use AI literacy as a vehicle for interdisciplinary learning. By its nature, AI touches on concepts from computer science, mathematics, science, social studies, and ethics. Designing AI literacy lessons that bridge these domains can give students a richer learning experience and help them connect across subjects.

For example, a biology class could integrate AI literacy by analyzing how machine learning models epidemics, blending data science with biology content. A history or civics class could discuss how AI algorithms might influence societal decision-making or justice, thereby incorporating ethical reasoning and social science perspectives.

By working with AI tools and case studies, students practice critical thinking across disciplines – they must interpret results (a scientific skill), understand algorithms (a mathematical and computational skill), and consider impacts (a social and ethical analysis). Educators have noted that AI literacy can be leveraged to enhance the learning of core disciplinary subjects when integrated appropriately into those subjects' teaching [2].

Rather than being an isolated topic, AI can serve as a context in which students apply skills from different areas: for instance, using statistical knowledge in training an AI model or practicing communication skills when explaining an AI system's behavior. This interdisciplinary approach not only reinforces content knowledge but also cultivates higher-order thinking. Students learn to think critically about complex problems that do not fall neatly into one school subject, a skill that is invaluable in the real world, where AI problems often involve technical, societal, and ethical dimensions simultaneously.

4.2. Preparing Students for an AI-Augmented Workforce

Incorporating AI literacy also prepares students for the AI-augmented workforce of the future. Automation and AI increasingly affect every profession – from medicine and engineering to finance, agriculture, and the arts. By learning about AI early, students gain a head start in developing the adaptability and skills that employers will value.

Even for jobs that do not require coding AI, many will require workers to interact with AI tools or make decisions informed by AI. For example, journalists now use AI to help research and draft articles; factory technicians work with AI-driven robots; marketing professionals use AI analytics to target campaigns. An AI-literate high school graduate will be more comfortable learning new AI-based software or understanding the outputs of an AI recommendation system on the job.

Indeed, some educational strategists argue that learning AI is becoming as important as learning to read and write, because "future generations can become informed citizens who understand the technologies they interact with in their daily lives" and careers. By demystifying AI in school, we reduce the risk of a future workforce split between a small elite who understand AI and a majority who are merely subject to AI-driven decisions.

Instead, broad AI literacy can empower more equitable participation in an AI-driven economy. This aligns with the goals of national AI education policies in countries like South Korea and Finland, which view AI competence as key to economic competitiveness and innovation. Moreover, engaging with AI projects can inspire students to pursue STEM and computing pathways, helping cultivate the next generation of AI developers and researchers. Early exposure can encourage participation from underrepresented groups in tech by building confidence and interest before college.

4.3. Enhancing Learning With AI Tools

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AI literacy integration also opens new ways to enhance teaching and learning through AI tools. Paradoxically, while we teach about AI, we can also leverage AI as an educational tool to support learners. The field of "AI in Education" has long explored using AI-driven software to personalize learning, provide tutoring, or automate assessment. These AI-driven educational technologies are becoming more mature and accessible.

For example, intelligent tutoring systems can adapt to a student's learning pace and style, offering individualized practice problems or feedback [32,33]. AI-based language learning apps can converse with students in foreign languages or correct their writing with high accuracy. When students are taught about AI, they can simultaneously use AI tutors in their learning process, creating a meta-learning opportunity (learning with and about AI).

Study [34] has found that AI techniques applied in education, such as machine-learning algorithms for student models or AI feedback systems, can improve learning outcomes by providing support tailored to each learner. In classrooms, teachers can offload some routine tasks to AI (for instance, automated grading or summarizing student questions), freeing time to focus on higher-value interactions.

The recent rise of generative AI (like large language models that can generate text or code) presents both challenges and opportunities for education [18–20]. On one hand, generative AI tools can act as creative partners for students [38], for example, helping brainstorm ideas, simulate scientific data, or visualize concepts, thus enriching project-based learning. On the other hand, they require students to have the literacy to use them properly (e.g., prompting effectively, checking the AI's output for correctness).

This again underscores why AI literacy is important: students who understand the strengths and weaknesses of tools like ChatGPT can use them to augment their learning (for instance, by asking the AI to explain a concept and then critically evaluating that explanation), while avoiding pitfalls like over-reliance or plagiarism. Educators are beginning to explore these possibilities [39,40]. Early surveys [34,40] indicate that today's youth are often more open to adopting generative AI in learning than their teachers, highlighting a need to bridge this gap through AI literacy for both students and educators.

Overall, integrating AI literacy can make classrooms more innovative – students and teachers can experiment with educational AI software as part of the curriculum, turning the classroom into a microcosm of how AI is used in society.

4.4. Policy and Curriculum Innovation

There are also strong policy and curriculum development opportunities tied to AI literacy. Globally, forward-thinking education systems are using the momentum around AI to modernize curricula and invest in new educational resources.

For example, China's Ministry of Education incorporated AI as a compulsory topic in high school as early as 2018, catalyzing the development of textbooks and teacher training for AI courses [1]. The province of Ontario in Canada revised its K–8 science and technology curriculum to include AI and emerging technology, explicitly aiming to teach students about the development and application of AI in daily life [1].

These moves introduce students to AI and encourage an update of pedagogical approaches – curricula are becoming more project-focused and inquiry-based to accommodate AI topics. International collaboration is another opportunity: countries and organizations are sharing resources (such as open curricula from initiatives like AI4K12 or elements of Google's and Microsoft's AI for youth programs) to accelerate AI education development.

By integrating AI literacy, educational policymakers have the chance to make schooling more relevant to the digital era. It also presents an opportunity to address equity and inclusion by intentionally spreading AI knowledge beyond the tech hubs to all classrooms. Some national policies (e.g., Singapore's AI education roadmap, or Korea's AI curriculum reforms) explicitly mention preparing all citizens, not just specialists, to be conversant with AI. This democratization of AI

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knowledge can empower students everywhere and potentially spur interest in STEM among those who might not have seen its relevance before.

In summary, embracing AI literacy can make education more interdisciplinary, future-oriented, and reflective of the tools and questions that define contemporary society. It can produce more technically adept students and critical, creative, and informed thinkers.

5. Challenges and Risks

While the push for AI literacy in education is promising, significant challenges and risks must be acknowledged and addressed. Implementing AI literacy at scale is not straightforward – schools and systems face practical barriers, and the integration of AI raises societal and ethical concerns.

We conducted a comprehensive review of existing literature [22,24–26,34,37,41–43] and concluded the findings. This section discusses some of the most salient challenges: educator readiness, resource and infrastructure gaps, curriculum constraints, and broader ethical/societal risks.

5.1. Educator Readiness and Training Gaps

A fundamental challenge is the lack of teacher training and preparedness in AI. Most current K–12 teachers have had little to no AI exposure during their education or teacher training programs. Expecting them to teach AI literacy without substantial professional development is unrealistic.

Studies [3,37] consistently show that teachers feel unprepared to teach about AI and are uncertain about the content and pedagogy to use. Unlike traditional subjects, AI is a fast-evolving field, which can be intimidating for educators who are not specialists. Additionally, misconceptions about AI (e.g., "you need advanced math to understand it" or "AI is science fiction") may deter teachers from engaging with it. The result is a shortage of confident instructors, which directly limits AI curriculum implementation.

For instance, Singapore's pilot program for school AI lessons encountered implementation difficulties mainly due to a shortage of teachers with adequate AI training [44]. Even when curriculum guidelines or materials exist, they cannot be effectively delivered without teacher buy-in and competence. This challenge is compounded by the need for teachers to not only learn AI concepts but also appropriate teaching methods for those concepts (which can be abstract and complex).

Researchers stress that supporting teachers through extensive professional development and upskilling is critical for AI literacy initiatives to succeed [2]. Some proposed solutions include short courses or certification programs in AI for teachers, communities of practice where teachers can share AI teaching experiences, and the inclusion of AI modules in pre-service teacher education. However, scaling these solutions is non-trivial and requires policy support and resources. Until a broad base of educators is comfortable with AI, the expansion of AI literacy will likely be uneven.

5.2. Infrastructure, Resources, and the Digital Divide

Another major challenge is the issue of unequal access to AI learning resources, which ties into the broader digital divide. Not all schools have the necessary infrastructure to support AI learning activities, such as up-to-date computers, reliable internet access, and modern software.

Many AI tools or hands-on experiments (e.g., training a simple machine learning model) require computing resources that may be scarce in under-resourced schools. There is a risk that AI literacy education, if not implemented with equity in mind, could widen existing educational gaps. Well-funded schools in tech-forward regions might implement cutting-edge AI labs and robotics programs, while schools in poorer or rural areas struggle to provide basic computer science classes.

A recent study on AI literacy [3] determinants found that the digital divide significantly affects students' AI literacy: factors like access to technology and prior exposure to computing were strong predictors of AI literacy levels. This indicates that introducing AI in curricula without interventions could benefit those with tech access more than those without, exacerbating inequity.

 doi:10.20944/preprints202508.0497.v1

Addressing this challenge requires investment in infrastructure (e.g., devices for students, high-speed internet for schools) and creative approaches like using low-cost or unplugged AI learning activities that do not depend on advanced hardware. Partnerships with industry and government funding will be important to ensure that all schools can participate in AI literacy, not just a privileged few.

Additionally, teacher distribution plays a role – even if materials are available, underserved schools often lack teachers with a computer science background. Without explicit strategies to bridge these divides, AI literacy could inadvertently become a niche offering rather than a universal literacy.

5.3. Curriculum Integration and Standards Uncertainty

Curriculum integration poses its own set of challenges. School curricula are already crowded with subjects and learning objectives, so finding space for AI literacy is difficult. Educators and curriculum designers face the question of whether AI should be taught as a standalone course, integrated into existing subjects, or as extracurricular enrichment.

Each approach has drawbacks. A standalone AI course might only reach a subset of students (and may not fit into the timetable). However, integrating bits of AI content into various subjects can dilute focus or rely on teachers who may not be prepared across disciplines. Moreover, education systems have mandated standards and high-stakes assessments primarily focused on traditional literacies and STEM subjects, which can make the addition of AI topics feel like an extra burden.

There is also a lack of unified standards or guidelines on a proper K–12 AI curriculum. Unlike mathematics or language arts, where decades of research have led to relatively straightforward standards, AI literacy is still in its formative stage. Different states or countries have developed their learning objectives for AI, which can vary widely in scope and depth. The absence of consensus can confuse implementation.

Schools might ask: What exactly should a 5th grader versus a 10th grader know about AI? How do we assess whether a student is "AI-literate"? These questions are under active discussion, but not fully resolved. A systematic review [2] noted that very few educational interventions thus far have assessed student learning gains in AI, highlighting that even assessment methods are lagging.

Without assessment and standards, it's challenging for administrators to justify and evaluate AI literacy programs. This represents a risk that AI literacy could remain peripheral or inconsistent across different education systems. To mitigate this, efforts are underway by organizations like UNESCO and IEEE to draft competency frameworks, and researchers have called for the development of a "competency framework to guide didactic proposals and define a curriculum sequence" for AI literacy. Until such frameworks gain traction, however, curriculum integration will likely proceed in a patchwork manner, potentially leaving gaps or redundancies in what is taught.

5.4. Ethical, Cultural, and Societal Risks

Beyond implementation hurdles, educators must navigate important societal and ethical concerns about teaching AI. One concern is the content of what is being taught: discussions of AI inevitably raise issues such as algorithmic bias, surveillance, autonomous decision-making, and the impact of AI on jobs. These topics can be sensitive and may meet with resistance from various stakeholders.

For example, parents or community members might worry that teaching about AI bias and ethics could be controversial or political. Conversely, some might worry that schools teaching AI could inadvertently promote technology without sufficiently critiquing it. There is a delicate balance between encouraging enthusiasm for AI's possibilities and instilling a critical awareness of its pitfalls.

Cultural contexts also matter – in some societies, there may be more skepticism or fear about AI (e.g., fears of robots replacing teachers or concerns about privacy and Big Tech), which can manifest as resistance to adopting AI in classrooms. Ensuring cultural acceptance may require awareness campaigns or community involvement so that AI literacy is seen as beneficial and necessary, not as an imposition of tech ideology.

 doi:10.20944/preprints202508.0497.v1

Another ethical issue is data privacy and child protection. Using AI tools in classrooms could involve collecting student data or having students interact with online AI systems, raising questions about consent and security. Schools will need clear guidelines to protect students' data when using AI applications.

Moreover, some AI educational tools could inadvertently introduce bias (for instance, AI tutors might work better for some dialects than others, or might reflect gender/racial biases present in training data). Educators must be vigilant about these risks – a kind of meta-literacy is needed for the teachers to evaluate AI tools for classroom use.

The broader concern is to avoid harm: we must ensure that introducing AI in education does not reinforce inequalities or biases. This is why "responsible AI literacy" is often emphasized – meaning the teaching of AI should follow principles of fairness and inclusivity.

Finally, there is the risk of over-reliance on AI or losing traditional skills. If, for instance, students get used to always using an AI writing assistant, one must ask whether their writing skills or critical thinking might suffer. Striking the right balance in using AI as a supportive tool without undermining fundamental skill development is an ongoing challenge.

In summary, while pushing forward with AI literacy, educators and policymakers must tread carefully to address these ethical and social issues, maintain public trust, and prioritize student welfare.

5.5. Moving Forward: Addressing the Challenges

In conclusion, the road to integrating AI literacy widely into education is fraught with challenges that span human, infrastructural, curricular, and ethical domains. Overcoming the teacher preparedness gap will likely require significant investment in training and a shift in teacher education.

Bridging the resource and access gap demands policy-level commitments to equitable technology infrastructure. Resolving curricular and standards uncertainties will benefit from ongoing research and international dialogue to converge on best practices.

Also, managing ethical concerns calls for a proactive and transparent approach, embedding ethics into AI literacy. By recognizing these challenges early, stakeholders can develop strategies to mitigate risks – for example, by piloting programs, learning from those pilots, involving ethicists in curriculum design, and providing ample support to educators.

Pursuing AI literacy for all students is a worthy goal, but it must be pursued carefully to ensure it is done right and yields positive outcomes for learners and society.

6. Conclusion

AI literacy has emerged as an essential educational goal globally, reflecting the increasing influence of artificial intelligence across diverse fields and everyday life. This comprehensive review has clarified AI literacy's conceptual foundations, identifying it as encompassing knowledge of AI principles, practical skills in using and creating AI, and an ethical awareness of its societal impacts. Key competencies have been categorized into knowledge-based, skill-based, and ethical-attitudinal dimensions, demonstrating the multi-faceted nature of AI literacy.

The integration of AI literacy into education presents significant opportunities. Interdisciplinary learning can be enhanced by connecting AI concepts across subjects like mathematics, science, ethics, and social studies, thus preparing students to think critically and creatively about complex problems. Equipping students with AI literacy skills also positions them for success in a workforce increasingly influenced by AI. Moreover, incorporating AI-based educational tools can personalize learning, improve teaching efficiency, and inspire classroom innovation.

However, meaningful implementation of AI literacy faces substantial challenges. Educator readiness remains a critical barrier, as teachers often lack adequate training and resources to teach AI concepts confidently. Infrastructure disparities exacerbate educational inequities, potentially leaving disadvantaged students further behind. Furthermore, curricular constraints and the absence of clear

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educational standards complicate the structured integration of AI literacy. Ethical, cultural, and societal risks also require careful attention, ensuring responsible, inclusive, and unbiased use of AI in educational settings.

Looking forward, several key areas warrant further exploration and action. Future research should focus on developing universally accepted competency frameworks and reliable assessment tools to evaluate AI literacy effectively across different educational contexts. Investments in comprehensive teacher training programs and equitable infrastructure expansion will be critical to democratizing access to AI education. Policymakers must engage in ongoing international collaboration and dialogue to proactively refine curricula, address ethical concerns, and facilitate the responsible integration of AI literacy into education. By systematically addressing these areas, educators, researchers, and policymakers can ensure that AI literacy empowers learners equitably and sustainably, preparing them to thrive in an increasingly AI-driven world.

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