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AUTHORS

Srijita Chakraburty, Teresa M. Ober, and Lei Liu

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Preparing K–12 Students With AI Literacy: Proposed Framework, Progression, and Task Design Principles

Srijita Chakraburty[1], Teresa Ober[2], and Lei Liu[2]

[1] Indiana University, School of Education

[2] ETS Research Institute, ETS, Princeton, New Jersey, United States

Abstract

This paper presents a conceptual framework for AI literacy, a hypothesized learning progression, and assessment design principles for advancing AI literacy among K–12 learners. Recognizing the importance of technical competencies alongside ethical awareness, the framework integrates foundational knowledge, societal implications, and practical applications of AI. Key competencies include ethical decision-making, AI-powered collaboration, and critical evaluation of AI outputs. Developed through an evidence-centered design (ECD) process involving a review of existing literature and frameworks, the proposed AI literacy framework and progression maps a hypothesized trajectory of students' skill development, providing a structured pathway for improvement with behavior indicators connected to core AI literacy subskills. In this way, the framework and progression may offer educators a roadmap to apply scaffolded and differentiated teaching strategies that actively foster learners' skill acquisition. To further support connections between assessment and instruction, we introduce three design principles for task design: ensuring relevance to learners, minimizing barriers to resource access, and providing opportunities for skill advancement. These design principles may guide the creation of activities that evaluate and enhance students' AI literacy. By aligning scaffolded assessments and learning activities with the progression, this framework bridges instruction, assessment, and students' skill development. It ultimately may be used to support students in developing skills to critically and ethically engage with AI technologies, preparing them to navigate the digital landscape by fostering inclusive instruction that deepens students' understanding of AI concepts.

Keywords: AI literacy, K–12 education, skills assessment, skills progression, task design

Corresponding author: Lei Liu, email: lliu001@ets.org

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We used ChatGPT, an AI language model developed by OpenAI, to evaluate the consistency of the language used to describe the advancement across progress levels in the progression framework.

Introduction

Rapid advancements in artificial intelligence (AI) are transforming various aspects of our daily lives and will continue to shape the future. Learning to use AI potentially empowers students and prepares them for success in the global job market (Shiohira, 2021). However, as AI becomes more integrated into everyday life, K–12 educators and students need to develop competencies to recognize and mitigate potential inappropriate uses or unintended harm. Recent reports from the Organisation for Economic Co-operation and Development (OECD) highlight the increasing demand for AI and digital skills to meet global workforce needs and foster digital inclusion. For instance, the *OECD Digital Economy Outlook 2024* emphasizes the importance of developing AI-related skills to prepare students for an evolving job market shaped by technological advancements (OECD, 2024a). We refer to this broader skill set as AI literacy, which encompasses a general understanding of how AI systems operate and how to use them, alongside related skills such as critical thinking, ethical collaboration, responsible digital citizenship, and adaptability. These competencies are essential for students to thrive in an AI-driven world and demonstrate creativity, problem-solving, and computational thinking while navigating responsibly (Casal-Otero et al., 2023; Kafai & Proctor, 2022; Kewalramani et al., 2021; Ng et al., 2023; Vartiainen et al., 2020).

Although conceptualizations of AI literacy are still emerging, particularly in the K–12 context, there remains a gap in understanding how K–12 students develop and progress in these skills (Ottenbreit-Leftwich et al., 2023). Various OECD reports stress that clear pathways for AI skills can bridge educational disparities, align learning with labor market demands, and address societal challenges posed by AI (OECD, 2024a, 2024b). Structured AI literacy progressions provide a potential solution, offering pathways to guide students from foundational to advanced

AI literacy skills, and are rooted in research on learning progressions (Duncan & Hmelo-Silver, 2009). Such progressions can support educators in designing curricula and tasks that foster continuous, progressive skill growth while addressing inequities in access to AI education.

This paper addresses several key objectives. First, we develop a new AI literacy definition and framework grounded in current literature and explicitly situated within a broader digital literacy framework (Liu et al., 2025). While recognizing AI as a powerful and increasingly prevalent digital tool, we emphasize the importance of ethical and appropriate use, critical evaluation of AI-generated outputs, and responsible interaction with AI systems. In synthesizing findings from existing AI and digital literacy frameworks, we identify key themes, such as evaluating AI-generated information, understanding AI capabilities and limitations, and applying ethical reasoning in AI use. Building on this framework, we propose a hypothesized AI literacy progression that offers a structured roadmap for skill development, from foundational understanding to advanced, independent applications. Behavior indicators across core subskills demonstrate how learners progress from basic awareness to more sophisticated and context-sensitive practices. Finally, we introduce design principles for the development of assessment tasks aligned with the progression. These principles focus on relevance, accessibility, and scaffolded learning pathways, supporting the development of effective AI literacy activities. Together, the framework and progressions offer a coherent approach to defining, supporting, and assessing AI literacy, ultimately preparing K–12 students to navigate the challenges and opportunities of an AI-enabled future. This work contributes to the future development of context-specific AI curricula and assessment tasks that promote not only technical proficiency but also ethical reasoning and societal responsibility, a critical need identified in a review by Zhang et al. (2025).

Our framework represents a contribution by offering a theoretically grounded definition of AI literacy alongside a hypothesized, developmentally appropriate learning progression tailored to K–12 education. This progression is intended to be used to systematically identify and build students' AI literacy skills, beginning with foundational competencies such as recognizing and using AI tools and advancing to more complex abilities like ethical decision-making and promoting transparency in the use of AI. Although grounded in theory and supported by literature, the progression has not yet been empirically validated. Through an emphasis on developing students' technical proficiency and awareness of societal impacts, the framework integrates practical and ethical dimensions of AI literacy, equipping students to engage responsibly with AI technologies.

The proposed framework has the potential to serve as a resource that informs instructional design by providing a roadmap for aligning curricula and tasks with progressive skill-building in AI literacy. This approach ensures that students are prepared to navigate and meaningfully contribute to an AI-driven world, fostering both their technical capabilities and their understanding of AI's broader societal implications.

Synthesis of the Literature

To understand the various existing conceptualizations of AI literacy, we reviewed existing research literature and competency frameworks, which reflected efforts to define AI literacy. The insights gathered through this review highlighted common themes and essential competencies, providing a foundation for proposing a comprehensive AI literacy framework that aligns with the evolving technological landscape and societal demands.

Keywords such as "AI literacy," "AI education frameworks," and "AI competencies" were used to search major academic databases like Google Scholar and ERIC, with a focus on recent literature to capture the latest advancements and include global perspectives. Selection criteria included relevance to K–12 education and a focus on peer-reviewed sources to ensure academic rigor and reliability. Table S1 in Supplemental Materials provides a list of the main frameworks and literature reviewed.

During the process of reviewing relevant literature and frameworks, we used a design pattern document (Liu & Haertel, 2011) to provide structure for defining complex constructs according to an evidence-centered design (ECD) approach (Mislevy et al., 2009). The design pattern template used to guide our work included sections that prompted for a literature-based summary of the construct of AI literacy, a rationale for its measurement, expectations of the focal population (i.e., K–12 learners in the U.S.), important dimensions (i.e., subskills), and observable indicators (i.e., subskill indicators) reflecting the construct. The design pattern document also informed the structure of our coding process, helping us determine what elements to extract from each source and how to compare them. To analyze the literature, we conducted an iterative coding process in which we extracted competencies and indicators from each framework. Using an open coding approach, we identified recurring patterns across frameworks and grouped them into broader categories, such as foundational concepts, technical skills, cognitive and metacognitive skills, and ethical considerations and societal implications. This structured analysis enabled us to surface commonalities and gaps across frameworks and refine them into a set of actionable competencies aligned with K–12 learners' needs and developmental readiness. Additionally, the template incorporated prompts for related yet distinct constructs, contextual factors likely to influence how the skill would be expressed, and potential connections to K–12 disciplinary standards.

The synthesis of AI literacy frameworks and state-level initiatives, such as those which may be referred to as *Portrait of a Graduate* and *Portrait of a Learner* (Atwell & Tucker, 2024), highlighted the potential relevance of foundational skills like understanding AI concepts and applications, technical skills related to using and creating AI systems, and cognitive skills such as critical thinking and adaptability. However, our analysis found that while these state-level initiatives often emphasize broad competencies like digital literacy and problem-solving, they did not explicitly define or integrate AI-specific competencies at the time of this review. This underscores a gap in competency frameworks in taking AI use into consideration at the time this review was conducted and therefore highlights the need for a dedicated focus on AI literacy to support curriculum and assessment design.

Our review of existing AI literacy frameworks revealed several core themes, discussed in the next section, including foundational knowledge of AI concepts, evaluating AI outputs for credibility and bias, promoting ethical use of AI, effectively applying AI tools, adapting to new technologies, and enhancing collaboration and communication through AI. These themes reflect the breadth of competencies emphasized in existing frameworks, ranging from technical knowledge to ethical and cognitive skills. While societal implications, such as those highlighted in the UNESCO (2022) and Touretzky et al. (2019) frameworks, are often included, our analysis identified opportunities to further emphasize their integration into practical, real-world applications. For example, connecting discussions of societal impacts, like equity or systemic biases, to actionable tasks can deepen students' ability to navigate these issues meaningfully.

Building on these themes, our AI literacy framework also introduces a hypothesized progression that is structured and that explicitly connects foundational knowledge, critical analysis, and practical problem-solving. This progression provides educators with a roadmap to guide students from initial understanding to advanced applications of AI, equipping them to critically evaluate AI's broader implications and apply their knowledge across diverse contexts.

By aligning technical, ethical, and societal dimensions with actionable instructional design, the framework offers a unique and comprehensive approach to preparing students for an AI-driven world.

Themes from Current Perspectives on AI Literacy and Digital Literacy

Our synthesis of existing AI literacy frameworks revealed a set of recurring themes that reflect how the field currently defined and operationalized AI literacy. These themes emerged across a range of frameworks and literature, highlighting the diverse contexts and applications of AI technologies in education. Across the reviewed definitions and frameworks, some commonly emphasized elements were observed. For example, several frameworks underscore *foundational skills*, such as recognizing AI tools and understanding intelligence (OECD, 2019; UNESCO, 2022). The OECD (2019) framework, for instance, focuses on basic AI concepts and terminology, aiming to build students' foundational understanding of what AI is and how it operates in everyday applications. Similarly, UNESCO's (2022) AI literacy competency framework within *K–12 Curricula: A Mapping of Government-Endorsed AI Curricula* includes competencies related to understanding different types of AI and their functions, which are critical for helping students grasp the fundamentals of AI. To ensure a more holistic perspective, we also draw on the *AI Competency Framework for Students* (UNESCO, 2024a) and *AI Competency Framework for Teachers* (UNESCO, 2024b), which outline complementary sets of knowledge, skills, and attitudes relevant for learners and educators. Additionally, the *AILit* framework (OECD, 2025; TeachAI, n.d.-a) offers structured guidance on integrating AI education across K–12 settings, making it a valuable resource for informing curriculum design and instructional planning.

In addition, we intentionally grounded our AI literacy framework in a broader digital literacy framework (Liu et al., 2025), which provides a well-established foundation for understanding how learners engage with digital tools in purposeful, critical, and responsible ways. The digital literacy framework directly informed the conceptual structure of the AI literacy subskills. For example, digital literacy subskills related to digital tool use, information interpretation, and evaluation were foundational in shaping our AI subskills focused on understanding how AI works and how to critically interpret its outputs. Similarly, subskills related to digital communication and collaboration directly informed our framing of AI-supported communication and co-construction of knowledge. Moreover, subskills related to ethical responsibility, social inclusion, and digital well-being provided a clear basis for the ethical and societal dimensions of AI literacy.

To complement foundational skills, *technical skills* serve as an applied extension, bridging theoretical understanding with hands-on engagement. Foundational skills provide the basis for recognizing AI tools and understanding key concepts, but technical skills build on this knowledge by enabling students to use, apply, and create AI systems. For example, Ng et al. (2021) illustrated this progression through project-based learning, where students translate their understanding of AI into practical problem-solving tasks. Similarly, Kandlhofer et al. (2016) focused on experiential learning, allowing students to interact with basic AI algorithms to reinforce and expand their foundational knowledge. This extension from foundational to technical skills demonstrates a natural progression in AI literacy, equipping students with both conceptual and practical tools to engage meaningfully with AI technologies.

Beyond the integration of foundational and technical skills, many frameworks emphasize *cognitive* and *metacognitive skills* that focus on critical thinking, self-monitoring, and adaptability when working with AI. Kong et al. (2024) emphasized these skills through tasks that require students to monitor their learning progress and adapt strategies as they work with AI tools, which fosters independent learning and self-efficacy. Similarly, Cetindamar et al. (2022) include problem-scoping activities that challenge students to critically assess the scope and feasibility of AI projects, building essential cognitive skills. Although not extensively discussed, Long and Magerko (2020) address the critical evaluation of AI outputs, underscoring the importance of assessing credibility, efficacy, and potential biases within AI systems. For instance, their framework includes activities where students analyze AI-generated outputs to detect potential biases or errors. This in turn promotes critical thinking about AI's reliability and accuracy. This focus on critical evaluation, however, appears less frequently across other frameworks, which indicates a need for deeper integration of assessment skills in AI literacy.

Ethical considerations and *societal implications* are also addressed across frameworks, which highlights their importance. In the present discussion, we refer to ethical considerations primarily with a focus on individual decision-making, such as ensuring fairness, mitigating bias, and promoting responsible AI use. In contrast, we consider societal implications as examining the broader impact of AI on communities, economies, and cultures, such as addressing equity in AI deployment or understanding how automation influences labor markets. Frameworks such as those from UNESCO (2022) and Digital Promise (2024) explicitly address these dimensions. For example, the AI competency frameworks for students (UNESCO, 2024a) and teachers (UNESCO, 2024b) highlight the need for ethical awareness, understanding AI systems, and responsible use in educational settings. Similarly, Digital Promise's (2024) AI literacy framework includes components like "Ethics & Impact" and "Data Privacy & Security," encouraging students to critically evaluate AI's effects on society and understand the importance of responsible practices. Similarly, frameworks by Almatrafi et al. (2024) incorporate discussions on equitable AI use and its implications for marginalized communities. Although some frameworks address societal implications, they often fail to provide concrete, practical activities or examples that help students connect these discussions to real-world contexts, leaving students underprepared to critically analyze and navigate AI's broader social impacts. This gap highlights the need for frameworks that bridge technical competencies with critical reflection on AI's broader impacts by holistically integrating ethics and societal implications throughout the learning process.

Many of these frameworks emphasize specific skill sets but lack a comprehensive progression that aligns with students' developmental readiness. This gap is particularly crucial for high school students (grades 9–12), who are on the cusp of postsecondary education and workforce entry, where foundational AI skills may offer certain advantages (Touretzky et al., 2019; UNESCO, 2022). Historically, AI education has targeted major technical skills for those specializing in computer science, leaving general users underprepared for interacting with AI in everyday contexts (Ng et al., 2021). With advancements in large language models and generative AI transforming industries, high school students need adaptable skills that enable them to engage critically, responsibly, and effectively with AI technologies. The AILit framework developed through a joint initiative with the European Commission and the OECD along with support from Code.org and leading international experts (OECD, 2025; TeachAI, n.d.-a) also underscores the need for students to develop broad, transferable AI competencies that extend beyond coding and technical mastery to include ethical reasoning, transparency, and real-world uses. To build on these efforts, we propose an AI literacy framework that integrates technical and ethical competencies alongside practical applications. This framework is designed to help students understand and use AI responsibly and effectively by combining skills like evaluating AI outputs with considerations of transparency and ethical decision-making, thus offering a more wellrounded approach to AI literacy for K–12 learners and equipping high school students with essential competencies for an AI-driven future.

A Definition and Framework of AI Literacy

With several common themes identified in existing frameworks, we propose a definition of AI literacy that integrates foundational knowledge, ethical considerations, and real-world applications. Additionally, drawing upon the concept of digital literacy (Sparks et al., 2024), we establish a basis that emphasizes responsible and productive engagement with digital tools, an essential principle for understanding and interacting with AI. Specifically, we build on a prior definition of digital literacy grounded in a review of literature which recognizes the skill as "a set of knowledge, skills, and attitudes necessary to use digital technologies and tools in a productive and responsible way across social, academic, and professional settings" (Liu et al., 2025, p. 6). This foundation enables us to adapt digital literacy principles to the context of AI, where we define AI literacy as

> The ability to understand, interact with, and responsibly use AI systems to access, manage, and create information, while effectively collaborating, both by engaging AI in the process and by working with other humans through AI, to make ethical, informed decisions.

In this context, AI systems are machine-based technologies that use input to generate outputs like predictions, content, recommendations, or decisions based on human-defined objectives. These outputs can impact both physical and virtual environments, with systems differing in the degree of autonomy and adaptability they provide users (OECD, 2024c). AI methods, such as machine learning and rule-based approaches, help achieve these objectives. Understanding these systems enables students to engage with AI responsibly and ethically. Along with defining AI, we identified key competencies and indicators to capture essential aspects of AI literacy.

Core competencies represent the overarching abilities students need to develop in order to interact with AI effectively. These competencies form the foundation for AI literacy by encompassing broad, essential skills such as ethical awareness, technical understanding, and the ability to apply AI knowledge in real-world scenarios. To make these competencies more distinct and readily observable, we broke them down into more granular components. *Subskills* emerge from these core competencies as a key element of AI literacy. These subskills reflect specific, measurable aspects of the broader competencies and focus on practical tasks such as analyzing AI outputs or understanding how AI systems make decisions. *Subskill indicators* further clarify each subskill by defining observable behaviors that provide evidence of students' proficiency at different stages. These indicators serve as a guide for assessing student progress and ensuring that AI literacy develops in a structured and measurable way. The resulting framework outlines four key subskills (see Table 1, columns 1 and 2).

The first subskill (AI.1) focuses on using AI to access, manage, evaluate, and select tools for information-related tasks, advancing from recognizing basic AI systems to applying multiple tools strategically. For example, students might tackle a task such as investigating an environmental issue and its impact on local ecosystems by leveraging AI tools to collect information from various platforms, such as news outlets, research articles, and popular science magazines. They could organize this information using reference management software that identifies and categorizes relevant sources. In doing so, students begin to recognize different types of AI (e.g., search engines, summarizers, chatbots) and explore their unique functionalities**.** As they progress, they might select and combine multiple tools, such as AI-powered search, translation, and synthesis apps, to compare sources, detect potential bias, and generate a comprehensive report or presentation tailored to a specific audience.

The second subskill (AI.2) focuses on using AI tools to communicate effectively, collaborate with others, and act responsibly in AI-assisted group settings. It progresses from individually engaging with AI systems using simple queries, to managing teamwork using collaborative AI tools, and eventually to leading projects while upholding ethical standards. For example, students might begin by practicing how to craft effective queries when interacting one-on-one with AI chatbots to gather ideas for a group project. As they advance, they could use AI-enabled task management tools to divide responsibilities, set deadlines, and monitor progress in group projects. At more advanced levels, students might refine their use of AI tools to optimize team communication, such as by generating summaries or translating peer input, and demonstrate responsible use by crediting AI contributions and advocating for fairness or transparency in group decisions.

The third subskill (AI.3) involves AI-driven content creation: evolving basic content creation to advanced customization and adaptation. Students might initially use AI tools, such as simple image generation or text-to-speech applications, to generate basic digital content. As they develop this skill, students could lead a project where they customize content for different audiences by using AI tools to adapt the tone, style, or format of the content, such as by transforming written reports into interactive multimedia presentations.

The fourth subskill (AI.4) emphasizes ethical considerations, transparency, and informed decision-making, advancing from basic ethical understanding to critically evaluating and proposing actionable solutions for responsible AI use. For example, students might begin by identifying ethical concerns in AI-generated outputs, such as biases in datasets or lack of transparency in algorithms used for decision-making. As they progress, they could engage in classroom debates about the societal impact of AI and develop detailed proposals or frameworks for implementing responsible AI practices within their school or community. Together, these subskills and their indicators provide a structured pathway for developing AI literacy in a comprehensive and measurable way.

Identifying Evidence of a Proposed AI Literacy Progression

While the subskills and their indicators provide a foundation for assessing AI literacy, they do not fully capture how students' progress from basic understanding to advanced competencies. To address this, we propose an AI literacy progression grounded in social constructivist theory, which emphasizes collaborative learning, scaffolded support, and contextual engagement (Levinson et al., 2000). This perspective is particularly relevant to AI literacy: a domain that is evolving rapidly, is socially situated, and requires students to engage with unfamiliar technologies in ways that benefit from shared dialogue, support, and reflection (Kim et al., 2025; Tan & Tang, 2025). By offering structured opportunities and expert guidance, this approach helps students systematically build on their current knowledge and apply AI concepts in increasingly sophisticated ways over time (Campione et al., 1984; Scrimsher & Tudge, 2003).

Our decision to use this theory stems from its alignment with the challenges and opportunities of teaching AI in K–12 settings. Young learners often encounter AI as a "black box," an unfamiliar and abstract system (Ma et al., 2025). Social constructivist principles support the design of scaffolded, inquiry-based learning experiences where students can make sense of AI systems through dialogue with peers, facilitation by teachers, and engagement with authentic tasks. These conditions are essential for developing not only technical proficiency but also ethical reasoning and collaborative problem-solving: key dimensions of our AI literacy framework (Yim & Su, 2025).

Moreover, drawing on ecological perspectives of learning, we recognize that students develop in constant interaction with the media-rich environments that surround them, including AI tools and platforms. These sociotechnical tools are not neutral, but rather they shape and are shaped by learners' experiences, making it imperative that AI literacy is taught through engagement, reflection, and contextually grounded dialogue. This theoretical framing also guided the structure of our proposed progression. Consistent with Vygotsky's Zone of Proximal Development (ZPD; Scrimsher & Tudge, 2003), we assume that students will move from needing help to performing AI literacy tasks independently. Each level of the progression reflects a shift in the kind and amount of support students require, making the framework not just descriptive but also instructionally actionable.

We propose that our framework can serve as a model of a structured, developmental progression for AI literacy in K–12 students, with a particular focus on high school learners (Grades 9–12). This progression not only reflects the theoretical principles of social constructivism but also provides actionable guidance for instructional design, enabling educators to scaffold learning and tailor teaching strategies to individual student needs. The AI literacy learning progression maps the trajectory of learning in a specific domain over time, guiding students through increasingly complex concepts and applications (Corcoran et al., 2009). In education research, learning progressions are recognized as tools that describe how students' understanding and abilities develop along a continuum, moving from basic to more sophisticated levels (Duschl et al., 2007). While most existing progressions focus on disciplinary concepts, such as science or mathematics concepts, this progression addresses cross-cutting skills like critical thinking, collaboration, and ethical decision-making, which are vital for navigating AI technologies. Frameworks in science education have extensively explored progressions in domains like carbon cycling (Mohan et al., 2009) or force and motion (Duschl et al., 2007). In contrast, progressions targeting skills that transcend specific disciplines, such as critical thinking or digital literacy, remain underdeveloped—and there is generally a lack of understanding of how skills, including AI literacy, develop over time. By applying the concept of learning progression to AI literacy, we propose an AI literacy progression as a hypothesized pathway that ensures students systematically acquire key competencies as their understanding advances. While not yet empirically validated, this structured progression is grounded in theory and literature. Through it, students build foundational knowledge and advance toward a sophisticated understanding and application of AI tools in real-world contexts.

Behavioral indicators at each level of the progression provide practical insights for instructional planning, helping educators design scaffolded activities and monitor student progress. These indicators highlight specific milestones and illustrate the pathway from initial understanding to advanced and innovative applications. Furthermore, such progressions may provide insights to educators who can then help to track students' progress in developing key components of the overarching skill by tailoring instructional strategies or otherwise providing targeted support. By aligning these developmental pathways with instructional design principles, the framework ensures that students can meaningfully engage with AI in both theoretical and practical contexts. Thus, the framework offers clear developmental pathways from emerging to advanced proficiency, guided by specific skill and behavioral indicators, while also integrating social constructivism. As a result, the framework emphasizes collaborative learning and contextual tasks, as well as the design of community projects where students build their AI competence through social interactions and shared experiences. These design choices reflect our central theoretical commitment: AI literacy is not simply a set of skills to be acquired in isolation, but a set of practices that must be developed through interaction, reflection, and support in social learning environments. This alignment with both theory and practice underscores the progression's potential to support educators in creating meaningful, scaffolded learning experiences. Behavior indicators in the framework's proficiency levels (Levels 1 to 4) illustrate how learners develop their ability to apply AI literacy skills in increasingly complex and exemplary ways (see Table 1).

The proposed AI literacy progression is structured across four levels, reflecting the gradual development of AI literacy. At Level 1 (Emerging), learners show initial awareness and willingness to engage in tasks, often supported through modeling, explanations, and collaborative efforts. At Level 2 (Developing), learners begin to approach tasks with greater initiative, building foundational skills and applying them in familiar contexts. By Level 3 (Proficient), learners demonstrate a deeper understanding and consistently perform AI-related tasks with confidence and accuracy. At Level 4 (Exemplary), learners demonstrate advanced application of their knowledge by showcasing precision, adaptability, and the ability to effectively apply AI literacy in novel and complex situations. This progression provides a developmental framework for skill acquisition while offering educators a practical tool for instructional design, ensuring students can apply their learning across diverse contexts.

Table S2 in the Supplemental Materials offers an example task titled “DALL-E Image Generation – Ethical Decision-Making.” This task is designed to engage students in analyzing a real-world case of AI-generated images exhibiting patterns or biases in their content based on specific prompts. The task exemplifies how the progression supports scaffolded learning and instructional design, thereby providing educators with an approach to guide student development. The task encourages students to explore ethical concerns related to representation, societal impacts, and inclusivity in AI-generated visuals, emphasizing how these issues influence perceptions and creative outputs. At Level 1 (Emerging), students may begin noticing patterns in AI-generated content, such as recurring themes or objects, and might recognize concerns like stereotypical depictions. They could also express an awareness of fairness in image generation but may find it difficult to articulate how bias or inclusivity could be addressed. At Level 2 (Developing), students tend to analyze specific patterns in AI-generated images, identifying trends such as underrepresentation or overgeneralization. They might explore basic ways to mitigate these concerns, such as diversifying prompts or experimenting with alternative content-generation strategies. By Level 3 (Proficient), students are likely to engage more critically with the societal impacts of biases in AI-generated imagery and apply ethical reasoning to suggest potential solutions. For example, they may recommend refining prompts, considering the diversity of training data, or exploring methods to reduce bias in outputs. At Level 4 (Exemplary), students demonstrate a deeper engagement with ethical considerations by proposing ways to improve transparency in image-generation processes or integrating feedback mechanisms to address bias over time. They might also contribute by sharing insights, facilitating discussions, mentoring peers or near-peers, or potentially developing resources that promote more ethical and inclusive AI-generated content.

This progression and its accompanying instructional design principles may provide a roadmap for educators to align teaching strategies with students’ developmental stages and, as a result, better enable meaningful engagement with the ethical and societal implications of AI while fostering practical problem-solving skills that will help learners thrive as adults.

Table 1. Behavior Indicators and Levels of the Proposed AI Literacy Progression for the Subskills

Subskill	Subskill Indicators	Level 1: Emerging	Level 2: Developing	Level 3: Proficient	Level 4: Exemplary
AI.1: Use AI tools to access, manage, and evaluate information	**AI.1.1:** *Awareness of Different AI Types and Tools:* Understand foundational concepts of various AI types and their everyday applications.	Know there are different types of AI, like chatbots or tools for recognizing images.	Identify common AI tools, such as voice assistants, and describe their basic purpose.	Explain features of specific AI types, like how machine learning helps predict outcomes.	Explain how different AI tools work, list their strengths and weaknesses, and suggest ways to improve or use them to solve real-world problems more effectively and fairly.
	AI.1.2: *Identify and Utilize AI Tools for Specific Tasks:* Select appropriate AI tools and understand their functionalities.	Recognize some AI tools that are suitable for specific tasks.	Identify and begin using different AI tools for specific tasks.	Apply knowledge of different AI tools for specific tasks in various contexts.	Use multiple AI tools together to complete detailed and multi-step projects.
	AI.1.3: *Access and Organize Information:* Use AI tools to gather and structure information from various sources.	Recognize that AI tools can organize information, like search engines or document organizers.	Use AI tools to gather and organize simple information, such as sorting data into categories.	Use AI tools to collect and organize more complex information from multiple sources.	Find ways to make AI tools handle large amounts of information, like combining texts, images, and charts.
	AI.1.4: *Evaluate Information:* Interpret and assess AI-generated outputs to ensure relevance, detect bias, and understand implications.	Understand the importance of checking if AI outputs are useful and starts to notice things like bias or errors.	Use AI tools to choose relevant information and summarize content in simple tasks.	Check AI-generated content for accuracy and fairness when working on tasks like finding credible sources.	Explain and evaluate AI content in different situations, like comparing results across platforms or formats.

Subskill	Subskill Indicators	Level 1: Emerging	Level 2: Developing	Level 3: Proficient	Level 4: Exemplary
AI.2: Use AI tools to communicate, enhance teamwork, and ensure responsible collaboration	**AI.2.1:** Converse with AI Systems: Communicate effectively with AI chatbots and virtual assistants.	Use simple queries when individually interacting with AI chatbots or virtual assistants.	Construct detailed queries independently to get more accurate and helpful responses from AI.	Develop and refine specific and relevant queries during one-on-one AI interactions to get more useful responses.	Use advanced strategies independently to get clear, accurate, and human-like responses from AI systems.
	AI.2.2: *Use AI for Collaboration:* Leverage AI tools to enhance teamwork and collaborative tasks.	Use AI tools to help with simple group tasks, like assigning roles, making a shared to-do list, or brainstorming ideas with AI tools.	Use AI tools to organize and divide group tasks, such as assigning responsibilities, setting deadlines, or tracking progress using task management tools.	Use AI tools to manage group projects with multiple steps, like organizing tasks, sharing resources, and improving team communication with tools like chatbots or automated reminders.	Lead group projects by showing how to use AI tools to organize tasks, communicate with teammates, and keep a project on track.
	AI.2.3: *Responsible AI Collaboration:* Use AI responsibly in teamwork, ensuring fair practices, acknowledging AI contributions, and sharing content appropriately.	Recognize the importance of acting responsibly while working AI in group projects, such as by citing AI-generated content.	Acknowledge AI's role in group work and gives proper credit.	Consistently use AI responsibly in team projects and ensure AI contributions are acknowledged.	Apply ethical practices in teamwork, such as advocating for transparency in AI-generated decisions.
AI.3: Use AI to create, personalize, and adapt content	**AI.3.1:** *AI-Facilitated Content Creation and Personalization*: Use AI tools to create and personalize content.	Create basic content using AI, with some customization for specific audiences.	Adjust content using AI features, like tone or style, to better suit different audiences.	Create and customize content for different audiences or purposes using AI tools.	Use advanced AI techniques to create and tailor multimedia or complex content for various audiences.
	AI.3.2: *Adapting Content:* Utilize AI tools to modify and tailor existing content.	Make simple edits to existing content using AI tools.	Adjust content for specific audiences or purposes with AI tools.	Adapt content for different formats or audiences, ensuring relevance and clarity.	Use AI tools creatively to adapt content for new situations, explaining how and why adjustments were made.

Subskill	Subskill Indicators	Level 1: Emerging	Level 2: Developing	Level 3: Proficient	Level 4: Exemplary
AI.4: Use AI with an understanding of ethical impacts and responsible decision-making	**AI.4.1**: *Ethical Use of AI and Awareness of its Societal Impact:* Recognize and practice ethical AI use, including identifying consequences of AI use.	Identify issues like bias or privacy concerns in AI tools and recognize the importance of ethical use.	Explain basic ethical practices, like fairness and transparency, with real-world examples (e.g., privacy in facial recognition).	Evaluate real-world scenarios to spot ethical concerns, such as biases in AI-generated recommendations (e.g., in social media apps).	Propose solutions to address ethical concerns, like reducing misinformation or improving fairness in AI tools.
	AI.4.2: *Transparency in AI:* Recognize the importance of transparency and explainability in AI systems.	Identify AI systems that lack clear and understandable processes.	Recognize ways to make AI systems more transparent, like showing how decisions are made.	Use strategy to improve AI transparency, such as choosing systems with interpretable results.	Explain and applies methods to promote AI transparency in various contexts, ensuring AI decisions are clear and fair.
	AI.4.3: *Decision-Making Based on Risk Assessment:* Assess risks and consequences of AI-influenced decisions using ethical frameworks.	Identify potential risks of AI in specific situations, like unfair decisions or privacy concerns.	Recognize risks and suggest simple ways to address them, like improving fairness or protecting data.	Evaluate risks in more complex scenarios and apply ethical principles to propose responsible solutions.	Describe detailed methods to evaluate and minimize risks, considering the long-term societal impacts of AI.

Design Principles for an AI Literacy Task

While the proposed AI literacy progression provides a structured approach to identify AI literacy skill development, educators may need to consider how to adapt the proposed progression to their specific teaching contexts to yield actionable insights about their students' progress. Tasks provide opportunities for students to apply AI literacy skills meaningfully while enabling teachers to monitor progress and offer feedback. To support this, in this section, we propose a set of design principles aimed at guiding the creation of tasks that align with the proposed AI literacy progression. These principles focus on ensuring student relevance, accessibility, and scaffolded learning to help educators create engaging and inclusive learning experiences where all students can thrive as they develop their AI literacy.

Design Principle 1: Relevance to Learners

Relevance ensures tasks include authentic, contextually meaningful examples that activate students' prior knowledge and interests. Research emphasizes the importance of connecting AI concepts to real-world applications to foster meaningful learning (Brown et al., 1989; Lave & Wenger, 1991). Additionally, multiple pedagogical theories highlight how learning is most likely to be effective when it reflects students' varied backgrounds and real-world experiences and therefore enables them to better engage with and understand complex and socially embedded concepts like AI (Ladson-Billings, 1995). This approach not only enhances students' AI literacy but also increases their interest and participation in the subject (Chiu et al., 2023, 2024).

One possible strategy for applying the principle of relevance is to leverage scenarios or contexts familiar to learners. For example, by using AI topics that reflect familiar issues or contexts, learners can be encouraged to investigate the origins, collection methods, and limitations of the issues or AI tools they work with. Furthermore, by starting with explainable AI approaches that use local examples familiar to students, educators can gradually build toward a global understanding of AI's societal and personal impacts. This method ensures that students not only grasp the technical aspects of AI but also appreciate its broader implications, thereby making the learning experience more meaningful (Lundberg et al., 2020).

Other features of a task can also facilitate relevance to learners and subsequently hold their interest as they engage in the task. For example, leveraging students' interests, such as those related to favorite pastimes like games, sports, or music, can further enhance the relevance and impact of tasks designed to promote AI literacy by triggering initial situational interest (Renninger & Hidi, 2022). Integrating interactive features, such as social robots, games, and online simulators, into AI literacy tasks can make learning more engaging and enjoyable for younger students. These tools offer hands-on experiences that help students connect complex concepts to real-world applications. For instance, social robots can help students explore ethical AI decision-making and transparency (see Table 1, AI.4.1 and AI.4.2 respectively) by demonstrating real-time decision-making processes. These activities allow students to observe how AI operates and reflect on ethical implications like bias or transparency. For example, students might use robots to make decisions about resource allocation, sparking discussions on ethical frameworks. Interactive features such as programming exercises, robot construction, and role-playing games further make abstract AI concepts relatable and enjoyable (Burgsteiner et al., 2016; Sabuncuoğlu, 2020; Williams et al., 2019). By connecting AI concepts to engaging tasks, educators can equip students with the skills to navigate and contribute to an AI-driven world.

Design Principle 2: Minimal Barriers to Access Resources

Ensuring minimal barriers to accessing resources is crucial for fostering AI literacy, especially in educational settings where technology availability varies widely. Inequities in access to emerging technologies, resources to use them, or the opportunities needed to develop and apply relevant technology skills can significantly impact students' success (Meng et al., 2024; Warschauer & Matuchniak, 2010). To address this, instructional materials should be inclusive and accessible to all learners. Universal Design for Learning (UDL) principles advocate for multiple ways to access and engage with content so that diverse learners can participate effectively (Meyer et al., 2014; Tomlinson, 2014).

Practical tools like Google's Teachable Machine and Code.org offer free, user-friendly resources to simplify AI concepts. Teachable Machine allows beginners to train models with images, sounds, and poses while maintaining data privacy (Carney et al., 2020). Code.org provides interactive AI and coding lessons, emphasizing playful, hands-on experiences for learners of all ages (Barradas et al., 2020). TeachAI, in collaboration with organizations like Code.org, supports equitable AI literacy through resources such as the AI Guidance for Schools Toolkit, which helps education leaders thoughtfully integrate AI into schools (TeachAI, n.d.-b).

The availability of open educational resources (OER) further supports more equal access to high-quality educational materials, which ensures greater inclusion of all learners in opportunities to develop AI literacy (Wiley et al., 2012). By lowering barriers to accessing high quality resources through the availability of free and accessible AI tools and platforms, educators can create a more equitable learning environment that fosters students' success in developing AI literacy. When paired with effective pedagogical support, such types of resources may be used in preparing a diverse and well-informed generation capable of critically engaging with AI technologies.

Design Principle 3: Opportunities for Skill Advancement

Creating opportunities for learners to advance—ideally gradually, or otherwise at their own pace—is likely to be critical for supporting students as they navigate potentially complex AI concepts. As noted previously, the social constructivist approach emphasizes that learning occurs effectively when students are guided through tasks that are slightly beyond their current abilities but achievable with appropriate support, a principle supported in digitally mediated environments as well (Reynolds & Goodwin, 2016). Scaffolding provides this essential guidance through teacher facilitation, peer collaboration, and the use of instructional tools, enabling students to build on prior knowledge while progressively engaging with more advanced AI topics (Hmelo-Silver, 2004). Empirical research in science, technology, engineering, and mathematics (STEM) education supports this approach, demonstrating that scaffolding can improve cognitive outcomes by helping learners break down difficult tasks into manageable parts, thereby fostering deeper understanding and long-term retention (van de Pol et al., 2010). Studies in differentiated instruction further reinforce the importance of tailoring scaffolds to individual students' proficiency levels. Kim et al. (2007) examined the use of technology-enhanced inquiry tools in middle school science classes and found that customizing learning pathways significantly engaged students by offering appropriate levels of challenge. The sixth-grade students in the study worked on interdisciplinary projects with digital tools designed to scaffold metacognitive skills, allowing them to engage in scientific inquiry. These supports ensured that tasks were challenging yet accessible, which fostered deeper engagement without oversimplification. As learners gain confidence and their skills advance, scaffolds may be gradually withdrawn, promoting self-directed skill development (Collins et al., 1989). Providing students opportunities to reflect on their progress, another key feature of scaffolded learning, further helps them consolidate knowledge by encouraging students to connect new AI concepts with their existing cognitive frameworks and apply their understanding to novel problems (Hmelo-Silver & Barrows, 2006).

In developing AI literacy skills, students may encounter unfamiliar concepts of varying degrees of abstraction (Ottenbreit-Leftwich et al., 2023). By providing structured support that is gradually removed as students' skills develop, educators can help learners build confidence as they learn how to apply tools to tackle increasingly complex challenges on their own. Ultimately, scaffolded learning opportunities may foster a deeper, more sustained engagement with AI, where students are not just passive recipients of information but active participants in their own learning journeys.

An Illustrative Example of a Task

In this section, we explore how the "DALL-E Image Generation – Ethical Decision-Making" task is designed with the intent to align with key design principles (see Table S2 in Supplemental Materials). This task may also serve as a formative assessment aligned with subskill AI.4 (use AI with an understanding of ethical impacts and responsible decision-making), specifically subskill indicator AI.4.1 (ethical use of AI and awareness of its societal impact). This task engages students in analyzing AI-generated images to identify patterns in the outputs and biases related to prompts while understanding the role of prompts in shaping AI-generated results. It leverages three key design principles: *relevance to the student, minimal barriers to resource access,* and *opportunities for skill advancement*.

The task introduces students to the concepts of AI-driven creativity and biases in the content of image generation through a *relatable activity*. This task gives students the opportunity to explore DALL-E, an AI-powered image-generation tool, by creating images based on various prompts. Through this hands-on experience, students can investigate how AI generates visual outputs and can further examine how training data and algorithms may influence recurring themes or stereotypes in content. By allowing students to engage with real-world AI applications, the task encourages critical thinking about societal and ethical considerations, such as fairness and representation in AI-generated visuals, which fosters deeper reflection on AI's impact on art and culture.

To address *potential barriers to resource access,* the task is designed such that it can be solved using widely available tools, such as free DALL-E accounts or similar image-generation platforms, along with open-access resources like videos explaining how AI generates images. Students can document their observations using accessible tools like Google Docs or Google Slides. This approach aims to ensure inclusivity by accommodating diverse technological access levels and supporting engagement for a broader range of students. The task is designed to offer *opportunities for skill advancement* through scaffolded activities. Students can begin by exploring how prompts influence the content of AI-generated images and identifying simple recurring themes, such as objects, styles, or characters. As they progress, they may analyze more complex patterns that may reveal biases and consider ways to make AI-generated visuals more inclusive. The task is structured across four proficiency levels (see Table S2), which correspond to the proposed AI literacy progression. Each level includes observable behaviors that teachers can use to assess students' conceptual understanding and ethical reasoning. At Level 1 (Emerging), students are expected to identify simple patterns (e.g., repeated themes or visual styles) and may begin to notice fairness issues, such as stereotypical depictions. At Level 2 (Developing), students might analyze image content more critically and offer basic suggestions to increase diversity in outputs (e.g., prompt variation). At Level 3 (Proficient), students are likely to evaluate the role of training data and propose strategies for mitigating bias. At Level 4 (Exemplary), students are expected to demonstrate deeper ethical reasoning, such as proposing long-term or systemic improvements (e.g., refining datasets or incorporating transparency mechanisms), and may also take the lead in peer discussions or suggest enhancements to the task itself. Teachers can gather student responses through written reflections, screenshots of generated images, and class discussions. These artifacts can serve as evidence of student thinking and be used to provide feedback, adapt instruction, and support student growth—key features of formative assessment. This design ensures that students not only understand how AI generates content but also critically evaluate its outputs and propose solutions to improve fairness and representation in AI-generated imagery.

As noted, this task could also be used for the purpose of formative assessment as it allows teachers to monitor students' progression along the AI literacy levels and offer timely scaffolds or extensions based on student performance. Aligning the task example with a subskill and a specific indicator helps to draw out its focus, so that students can engage in meaningful, structured learning activities that address ethical concerns related to AI. This approach encourages students to analyze patterns, reflect on ethical considerations, and propose strategies for improving inclusivity and representation in AI-generated visuals, thereby fostering their understanding of AI's creative and societal implications. Incorporating the key design principles of relevance, accessibility, and scaffolded skill development further ensures that the task is engaging and effective among students with varying levels of proficiency.

Discussion

This paper introduces an AI literacy framework that focuses on the technical and societal dimensions of AI, along with a structured progression for K–12 students with a particular focus on learners in Grades 9–12. By grounding this framework in social constructivist principles and drawing upon learning progressions, we emphasize the importance of guiding students as they advance from basic AI knowledge to more sophisticated, independent applications of AI tools.

The AI literacy progression maps students' learning journeys through four levels of proficiency, from emerging to exemplary, so that students can build foundational skills before advancing to more complex tasks. To support both task and instructional design, we propose three key design principles: *relevance to learners, minimal barriers to access,* and *opportunities for skill development*. We also provide actionable recommendations for educators by offering strategies to create tasks and learning experiences that connect AI concepts to students' lives, promote equal access, and foster gradual skill progression.

We also illustrate how the AI literacy progression and associated design principles can inform the development of a classroom task focused on ethical decision-making in AI-generated imagery. This example shows how the framework can guide the creation of tasks that not only align with specific subskills but also serve as a formative assessment task. This supports critical thinking, ethical reasoning, and technical proficiency. Another key implication is the role of behavioral indicators in tracking student progress. For instance, a task that asks students to interact with AI chatbots to gather information for a research project can serve as an authentic learning opportunity while offering insights into how effectively students communicate with AI systems. Through contextually relevant and accessible learning opportunities, students can build foundational knowledge, apply it to complex problems, and reflect on the societal and ethical dimensions of AI.

Implications for Future Practice, Policy, and Research

There are several potential implications of the proposed AI literacy framework and progressions. For educators, this framework offers a structured approach to supporting students in developing AI literacy skills. By leveraging the outlined subskills and behavior indicators, educators can align instruction with students' developmental stages and tailor learning experiences to individual needs.

Some practical implications are curriculum integration, where AI literacy tasks are embedded into core subjects. For instance, in a science class, students could use AI tools to analyze climate change data, helping them develop skills in accessing and organizing information. Similarly, in a social studies class, students might examine how AI influences political campaigns, fostering critical thinking about its societal impact. Other implications, such as scaffolding strategies, the use of accessible AI tools, and ethical discussions, are further detailed in Table S3 in the supplemental materials.

While we offer some general recommendations, at the same time it is important to recognize that significant variability exists in how students apply these skills across different contexts. Factors such as access to resources, prior technological exposure, and individual differences influence how students develop and demonstrate AI skills, necessitating localized adaptations of the framework to address diverse educational settings (Selwyn, 2019). It is also important to recognize that learning is rarely a straightforward process. Students may advance in some subskills faster than others, and their progression may follow non-linear pathways. Research on learning progressions highlights the need for instructional flexibility to accommodate diverse learning trajectories (Duncan & Rivet, 2013; Kali et al., 2008). Differentiated instruction and scaffolded tasks can address these challenges and support students in advancing their skills at their own pace. Additionally, the integration of AI literacy into traditional subjects like language arts, mathematics, science, and social studies requires further exploration. Effective integration must ensure that AI skills support, rather than compete with, broader disciplinary goals. Studies on interdisciplinary learning demonstrate the potential for such integration to enhance student engagement and outcomes (Schweingruber et al., 2007; Yadav et al., 2017). AI skills can enhance mathematics by supporting data analysis and enrich social studies through discussions on AI's societal impact. These intersections ensure AI literacy complements traditional learning and prepares students for an AI-driven future.

At a policy level, our framework has implications for the integration of AI literacy into K–12 education, aligning with global priorities to prepare students for an increasingly AI-driven world. Organizations like the OECD and United Nations Educational, Scientific, and Cultural Organization (UNESCO) emphasize the need for policies that promote equitable, ethical, and sustainable AI education (OECD, 2024a; UNESCO, 2022). Such policies are essential for meeting the growing demand for AI-related skills while mitigating potential risks, such as bias and educational inequality. Additionally, initiatives like Digital Promise's Artificial Intelligence in Education program advocates for a human-centered approach to AI integration in education. This program focuses on fostering students' and teachers' AI literacy; promoting digital equity through expanded access to technology, as well as the knowledge and skills needed to use AI; and ensuring the responsible use of AI tools in learning environments. By offering resources and guidance, it supports educators in implementing AI literacy programs that prioritize inclusivity and accessibility, enabling all learners to engage meaningfully with AI technologies (Digital Promise, 2024).

In terms of future research, understanding how the proposed AI literacy framework can be applied and adapted across diverse educational settings appears to be a critical next step. Further research is needed to validate the proposed AI literacy progression and provide empirical evidence of its effectiveness (as previously noted in the Implications for Future Practice, Policy, and Research section). While theoretically grounded, studies are needed to verify if the framework accurately reflects AI skill development. Pilot studies, longitudinal research, and classroom implementations will help refine its applicability.

Pilot studies will be essential to validate the framework, refine its structure, and assess its effectiveness in guiding AI literacy development. Research emphasizing the role of scaffolding and differentiated learning (Puntambekar & Hubscher, 2005) could also help refine strategies for supporting students as they progress through different AI literacy proficiency levels. Future research could also explore how integrating AI skills into core subjects, such as language arts, mathematics, science, and social studies, impacts learning outcomes and interdisciplinary engagement. Embedding computational and AI skills into subject-specific curricula has been shown to enhance student engagement and learning outcomes (Grover & Pea, 2013; Yadav et al., 2017). Further research should also explore how AI literacy intersects with related competencies such as digital literacy, computational thinking, critical reasoning, and adaptability, as well as the extent to which certain types of domain knowledge and skills are necessary and complementary to the use of AI literacy. In particular, while this framework is meant to be used to identify AI literacy in general and non-discipline specific contexts, knowledge of the task's relevant domain (O'Reilly et al., 2019), general literacy skills (Kalantzis & Cope, 2025), and other essential skills are likely to remain critical in contexts where AI literacy is used. We also emphasize caution in overreliance on AI, especially if it undermines opportunities to develop knowledge, or maintain and enhance cognitive functions such as processing speed and long-term memory retention and retrieval—all of which are essential for skills such as critical thinking, problem-solving, and decision-making (Oakley et al., 2025). Additional research that would inform instruction and assessment could explore the antecedents of AI literacy, as well as the near- and long-term consequences of applying the skill in various contexts.

The framework's flexibility may allow for its application beyond formal classrooms, providing opportunities to examine how AI skills develop in informal learning environments and across different student populations. Accessible tools like Scratch (Brennan & Resnick, 2012) or Teachable Machine (Carney et al., 2020) have demonstrated their effectiveness in supporting equitable engagement with computational concepts, which helps to ensure that students from diverse backgrounds can meaningfully participate in learning about computational thinking and AI technologies.

The rapid pace of technological advancements means that AI tools and systems are constantly evolving, and research on AI literacy in the service of informing teaching and learning should ideally keep pace. To remain relevant, the framework may require periodic updates to incorporate emerging technologies, methodologies, and ethical considerations (Luckin & Holmes, 2016). For example, competencies related to evaluating and responsibly using generative AI systems might become increasingly necessary as these tools proliferate.

Conclusion

The proposed AI literacy framework offers an approach to cultivating essential competencies related to the use and understanding of AI technology, focusing on ethical AI use, practical applications, and adaptability across diverse educational settings. By accommodating varying levels of resources and educational contexts, the framework is intended to ensure more equitable access to AI literacy and therefore enable students from all backgrounds to engage meaningfully with AI concepts. This approach encourages students to reflect on the societal and ethical implications of AI while prompting critical considerations of potential biases and the impact of AI on communities and the environment.

The framework prioritizes social interactions, collaborative learning, and contextual engagement as vital to AI literacy. Through guided interactions with peers and teachers, students build critical AI skills in a way that is applicable and relevant to real-world challenges while fostering critical thinking and problem-solving. This approach supports scaffolded learning, enabling students to advance from initial understanding toward independent and innovative applications of AI. The framework also provides a foundation for assessment, with structured skill levels and behavioral indicators that allow educators to evaluate students' progress accurately. By capturing students' current abilities and growth trajectories, these assessments help educators identify specific needs and offer targeted support. This may enable responsive assessment practices, where instruction is adjusted in real-time based on each student's evolving understanding so that they receive guidance tailored to their learning pace. Incorporating this framework into assessment design enables educators to track students' knowledge acquisition, ethical understanding, and practical application of AI skills, therefore supporting students' journeys from foundational learning to proficiency and beyond. Ultimately, this structured approach fosters the development of informed, ethical, and capable AI users who are well-prepared to navigate and shape the evolving digital landscape and contribute agentically and responsibly to a technology-driven society.

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Supplemental Materials

Table S1. Overview of Reviewed AI Literacy Frameworks and Core Dimensions

Framework	Definition	Components/focus
Digital Promise (2024)	AI literacy includes knowledge and skills to critically understand, use, and evaluate AI systems and tools for safe and ethical participation	Transparency, Safety, Ethics, Impact
Kong et al. (2024)	Elements that the workforce needs to harness AI and form a synergistic relationship with technology	Cognitive, Metacognitive, Affective, Social Dimensions
Almatrafi et al. (2024)	Focuses on recognizing AI tools, understanding basic AI concepts, applying AI tools, evaluating AI algorithms, and navigating ethical concerns	Recognize AI Tools, Understand AI Concepts, Apply AI Tools, Evaluate Algorithms, Navigate Ethical Risks
Long & Magerko (2020)	A set of competencies enabling individuals to critically evaluate AI technologies, communicate and collaborate with AI, and use AI as a tool	Competencies: Recognizing AI; Understanding Intelligence, Ethics, Data Literacy, Decision-Making
Ng et al. (2023)	Fundamental knowledge of AI and proper use of this technology	Four Dimensions: Affective, Behavioral, Cognitive, Ethical
Cetindamar et al. (2022)	Four capabilities related to AI literacy	Technology-, Work-, Human-Machine-, and Learning-Related Capabilities
Ng et al. (2021)	Encompasses knowing and understanding AI, using and applying AI, evaluating and creating AI, AI ethics	AI Concepts, AI Practices, AI Perspectives
OECD (2019)	Concepts related to AI literacy	Basic AI Concepts, Digital Literacy, Data Literacy, Online Safety, AI Ethics, Technical Skills
UNESCO (2022)	Focuses on AI foundations, understanding, using, and developing AI, and the ethics and social impact of AI technologies	AI Foundations, Ethics, Social Impact
Touretzky et al. (2019): AIK12	Structures AI literacy around five big ideas tailored for K–12 education	Perception, Representations and Reasoning, Learning, Natural Interaction, Social Impact
Lao (2020)	Defines AI literacy through knowledge, skills, and attitudes, emphasizing general AI knowledge, problem scoping, and project planning	Knowledge, Skills, Attitudes
Kandlhofer et al. (2016)	Describes AI literacy development stages from kindergarten to university	Awareness, Experimentation, Core AI Topics, Advanced Problem-Solving
TeachAI/AILit Framework (OECD, 2025)	Describes AI literacy as the combination of technical knowledge, durable skills, and future-ready attitudes that enable learners to engage with, create with, manage, and design AI systems, while critically evaluating their risks, benefits, and ethical implications	Four domains of competency, each built on Knowledge, Skills, and Attitudes: Engaging with AI, Creating with AI, Managing AI, Designing AI

Example Task

Task: DALL-E Image Generation – Ethical Decision-Making
Objective: Students will explore how AI generates images based on prompts, identify patterns in outputs, and propose strategies to improve inclusivity and representation in AI-generated content.
Context: A real-world case where AI-generated images show patterns or biases, raising questions about fairness and creativity in AI.
Tools: Free DALL-E accounts (or similar), online videos explaining AI-generated imagery, and tools like Google Docs or Slides to document findings.
Target Learners: Students enrolled in grades 9–12 (with potential for adaptation to other grade levels)

Table S2. Task Breakdown by Proficiency Levels

Levels	Task	Scaffolds	Expected outcome
Level 1: Emerging	Students explore DALL-E to generate images and observe basic patterns in the content, such as repeated objects or themes.	Teacher-provided prompts (e.g., “Generate images of scientists”) and guiding questions (e.g., “What patterns or repetitions do you notice?”); visual aids to identify patterns	Students list one or two simple patterns in the images, such as recurring objects or styles. *(AI.4.1: Identifies issues like bias or fairness in AI tools and recognizes the importance of ethical use.)*
Level 2: Developing	Students analyze the content of the images to identify trends or representation issues (e.g., stereotypical depictions in characters or settings).	Guided worksheet with specific questions (e.g., “Do you notice underrepresentation of certain groups? Why might this happen?”); videos on bias in AI-generated content	Students identify trends, such as underrepresentation or recurring stereotypes, and suggest basic solutions. *(AI.4.1: Explains basic ethical practices like fairness and transparency with examples.)*
Level 3: Proficient	Students evaluate how prompts shape the content of images and propose strategies to address patterns or biases.	Minimal guidance, access to optional articles/videos about societal impact and AI bias, and peer discussions to share observations	Students provide detailed analyses of content patterns, such as stereotypes or exclusions, and suggest ways to diversify outputs. *(AI.4.1: Evaluates real-world scenarios to identify ethical concerns and proposes solutions to improve fairness.)*
Level 4: Exemplary	Students discuss ethical challenges in the content of AI-generated images, suggest improvements, and collaborate with peers.	Collaboration opportunities with peers, access to advanced case studies about biases in AI systems, and minimal teacher input to encourage leadership.	Students propose innovative solutions, such as improving training data for image generation, and lead group discussions on the issue. *(AI.4.1: Proposes advanced strategies for ethical AI use, such as promoting fairness and representation in outputs.)*

Table S3. Recommendations for Using the Proposed AI Literacy Framework in Practice

Implication	Description	Example
Curriculum Integration	Embedding AI literacy tasks into subjects like science, mathematics, or social studies to connect AI literacy with broader learning goals and align with the AI literacy progression	• In a science class, students working on subskill indicator AI.1.1 (access and organize information) at Level 2 proficiency can use AI tools to gather data on climate change impacts, organizing information with minimal guidance. • In a social studies class, students at Level 3 proficiency can engage with subskill indicator AI.4.1 (ethical use of AI) by analyzing how AI influences political campaigns, which fosters critical thinking about societal impacts.
Formative assessments	Using behavior indicators as benchmarks for student assessment; designing assessments that match proficiency levels and specific subskills in the framework	• Teachers can assess students' progress in subskill indicator AI.2.1 (interact with AI systems) by evaluating how effectively they communicate with AI chatbots to gather historical facts for a project, using behavior indicators to tailor feedback according to each student's proficiency level.
Scaffolding and differentiation	Providing appropriate support based on student proficiency levels outlined in the AI literacy progression, gradually reducing assistance as students become more skilled in specific subskills	• For subskill AI.3.2 (adapting content), Level 1 students may receive guided worksheets to modify existing texts using AI tools, while Level 3 students can demonstrate advanced proficiency by independently adapting complex content for different audiences.
Use of accessible AI tools	Utilizing free or low-cost AI tools that align with the framework's subskills, so that all students can engage with AI literacy tasks regardless of resources	• Students can use free platforms like Scratch with AI extensions to explore subskill AI.1.3 (awareness of different AI types and tools) at Level 1 proficiency, experimenting with basic AI concepts without needing advanced technology.
Ethical discussions	Facilitating discussions on the societal impacts of AI that correspond with the ethical subskills in the framework, while encouraging students to apply ethical considerations appropriate to their proficiency level	• In an English class, students at Level 4 proficiency can engage with subskill AI.4.3 (decision-making based on risk assessment) by leading a debate on AI in surveillance, proposing innovative solutions to balance security and privacy, and mentoring peers on ethical implications.

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