



REVIEW

## Conceptualizing Digital Literacy for the AI Era: A Framework for Preparing Students in an AI-Driven World

### Conceptualizando la Alfabetización Digital para la Era de la IA: Un Marco para Preparar a los Estudiantes en un Mundo Impulsado por la Inteligencia Artificial

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#### ABSTRACT

**Introduction:** as artificial intelligence (AI) has become increasingly integrated into daily life, traditional digital literacy frameworks must be revised to address the modern challenges. This study aimed to develop a comprehensive framework that redefines digital literacy in the AI era by focusing on the essential competencies and pedagogical approaches needed in AI-driven education.

**Method:** this study employed a constructivist and connectivist theoretical approach combined with Jabareen's methodology for a conceptual framework analysis. A systematic literature review from 2010-2024 was conducted across education, computer science, psychology, and ethics domains, using major databases including ERIC, IEEE Xplore, and Google Scholar. The analysis incorporated a modified Delphi technique to validate the framework's components.

**Results:** the developed framework comprises four key components: technical understanding of AI systems, practical implementation skills, critical evaluation abilities, and ethical considerations. These components are integrated with traditional digital literacy standards through a meta-learning layer that emphasises adaptability and continuous learning. This framework provides specific guidance for curriculum design, pedagogical approaches, assessment strategies, and teacher development.

**Conclusions:** this framework offers a structured approach for reconceptualising digital literacy in the AI era, providing educational institutions with practical guidelines for implementation. Integrating technical and humanistic aspects creates a comprehensive foundation for preparing students for an AI-driven world, while identifying areas for future empirical validation.

**Keywords:** Artificial Intelligence; Conceptual Framework; Digital Literacy; Education Theory; Ethical Considerations.

#### RESUMEN

**Introducción:** a medida que la inteligencia artificial (IA) se integra cada vez más en la vida cotidiana, los marcos tradicionales de alfabetización digital resultan inadecuados para abordar los desafíos modernos. Este estudio tuvo como objetivo desarrollar un marco integral que redefine la alfabetización digital para la era de la IA, centrándose en las competencias esenciales y los enfoques pedagógicos necesarios en la educación impulsada por la IA.

**Método:** el estudio empleó un enfoque teórico constructivista y conectivista, combinado con la metodología de Jabareen para el análisis de marcos conceptuales. Se realizó una revisión sistemática de la literatura desde 2010 hasta 2024 en los dominios de educación, informática, psicología y ética, utilizando las principales bases de datos, incluyendo ERIC, IEEE Xplore y Google Scholar. El análisis incorporó una técnica Delphi modificada

para validar los componentes del marco.

**Resultados:** el marco desarrollado comprende cuatro componentes clave: comprensión técnica de los sistemas de IA, habilidades de implementación práctica, capacidades de evaluación crítica y consideraciones éticas. Estos componentes se integran con los estándares tradicionales de alfabetización digital a través de una capa de meta-aprendizaje que enfatiza la adaptabilidad y el aprendizaje continuo. El marco proporciona orientación específica para el diseño curricular, enfoques pedagógicos, estrategias de evaluación y desarrollo docente.

**Conclusiones:** este marco ofrece un enfoque estructurado para reconceptualizar la alfabetización digital en la era de la IA, proporcionando a las instituciones educativas directrices prácticas para su implementación. La integración de aspectos técnicos y humanísticos crea una base integral para preparar a los estudiantes para un mundo impulsado por la IA, al tiempo que identifica áreas para la validación empírica futura.

**Palabras clave:** Inteligencia Artificial; Marco Conceptual; Alfabetización Digital; Teoría de la Educación; Consideraciones Éticas.

## INTRODUCTION

AI is rapidly transforming society and the workforce.<sup>(1,2,3,4)</sup> Its applications range from automated customer service to sophisticated decision making in healthcare, driving substantial societal changes.<sup>(5)</sup> The World Economic Forum predicts that by 2025, humans and machines will equally share task times, emphasising the need for readiness for an AI-driven future.<sup>(6)</sup> This disruption required a workforce with new skills and capabilities.<sup>(7)</sup> Educators face the challenge of preparing students for future jobs and technologies that do not yet exist.<sup>(8)</sup> AI's impact extends beyond work, affecting civic engagement, personal decisions, and social interactions, thus necessitating a comprehensive educational approach.

Recent educational models of digital literacy must catch up with AI updates.<sup>(9,10)</sup> Traditional frameworks emphasise information retrieval, essential software, and online safety,<sup>(11,12)</sup> but only partially address AI complexities, such as algorithmic bias, deepfakes, and automated decision-making.<sup>(13)</sup> Ethical considerations in AI use and creation should be integrated into digital literacy curricula.<sup>(14)</sup> The emerging "AI divide" may exacerbate inequities due to unequal access to AI education and resources.<sup>(15)</sup> Rapid AI advancements have also created discrepancies between academic instruction and real-world applications, challenging educators.<sup>(16)</sup>

These challenges highlight the urgency of a new framework for digital literacy in the AI age.<sup>(17)</sup> However, for broader societal goals, the framework should not be limited solely to new digital skills; it must also include a deep understanding of AI systems and how they may impact society<sup>(18)</sup>. It should empower students with the capacity to analyse information generated by AI, appreciate the ethical aspects of using AI, and possess skillsets that can adjust as the technological landscape rapidly transforms.<sup>(19)</sup> Further, this framework must have the ability to grow with technology while remaining grounded in the principles of critical thinking and ethical reasoning.<sup>(20)</sup>

To address these challenges and develop a comprehensive framework for AI era digital literacy, this study seeks to answer the following research questions: Figure 1 provides a visual representation of our research questions and how they relate to the development of an AI-Era Digital literacy framework.

1. How can we reconceptualise digital literacy to address the unique challenges and opportunities presented by AI technologies?
2. What core competencies should include in a comprehensive AI literacy framework to prepare students for an AI-driven world?
3. How can AI literacy be integrated with traditional digital literacy concepts to create a holistic educational approach?
4. What pedagogical strategies and educational policies are required to effectively implement AI literacy in diverse educational contexts?

This study proposes a comprehensive conceptual framework for AI literacy to guide curriculum, pedagogy, and education policy in the AI era. It offers an interdisciplinary approach that integrates perspectives from education, computer science, psychology, and ethics to aid in understanding AI. This framework aims to help educators, researchers, and policymakers prepare students to address misinformation in an AI-driven world. This work is crucial for linking current educational practices with the new skills required in an AI-driven society and promoting an equitable and ethical technological future.

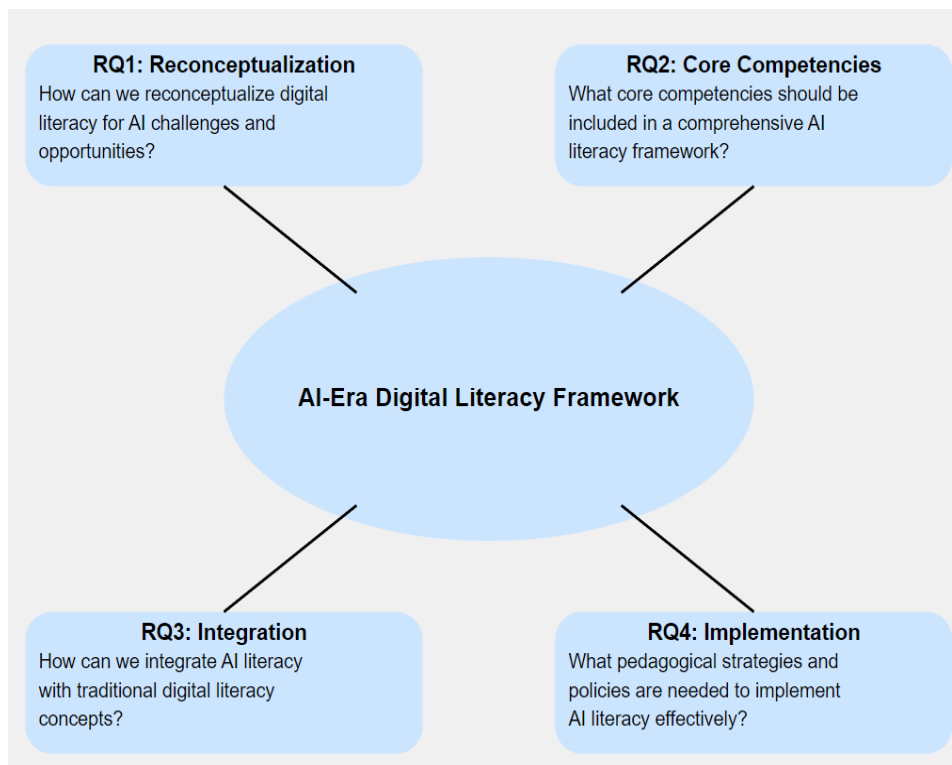


Figure 1. Research Questions for AI-Era Digital Literacy

## METHOD

We theorise from a constructivist standpoint<sup>(21)</sup> and connectivist basis,<sup>(22)</sup> recognising that knowledge is created through experience and peer collaboration in networked contexts. Specifically, we leverage Mishra and Koehler's<sup>(23)</sup> model, which highlights the interaction of technological, pedagogical, and content knowledge, while adding unique considerations for AI. Simultaneously, we draw upon notions of critical digital literacy<sup>(13)</sup> and the new media literacy framework of Lin et al.<sup>(24)</sup> to focus on the sociocultural dimensions of AI literacies.

In addition, given the velocity of change in AI, we drew on a future-thinking approach<sup>(25)</sup> to consider plausible scenarios emerging from different trajectories of development and their implications for education. This is supported by the ethical framework proposed by Florida and Cows<sup>(26)</sup> regarding guiding principles for beneficial AI. Combining such theoretical perspectives allows for a broad yet flexible approach to an AI literacy framework that seeks to enmesh technical knowledge with critical thoughts and ethical understanding.

We applied Jabareen's<sup>(27)</sup> methodology to analyse a conceptual framework, which is very efficient and effective in the case of multidisciplinary phenomena. A comprehensive literature review of education, computer science, psychology, and ethics was undertaken, with a specific focus on publications between 2010-2024 to reflect the most contemporary thinking around AI literacy in a digitally literate space. A search of major databases such as ERIC, IEEE Xplore, and Google Scholar was conducted using terms like "artificial intelligence education," "digital literacy," "AI ethics," and "future skills." We also analysed policy papers from international bodies, such as UNESCO and the OECD, to obtain a global perspective on AI in education.

Themes and concepts emerge through an iterative process of coding categories. These were then mapped and combined by considering how the different elements of AI literacy were connected. Using this method, we identified gaps in the current frameworks and developed a cross-disciplinary conceptual model. Finally, we used a modified Delphi technique<sup>(28)</sup> to reach a consensus on the core components of the framework. This iterative process helped ensure that our framework was theoretically grounded and practically relevant, thus addressing the complex challenges of AI literacy within educational contexts.

## RESULTS

Based on our review and synthesis of the existing literature, we formulated a new digital literacy framework for the AI age. This framework addresses specific challenges and opportunities for AI technologies in educational contexts.

### Core components of AI literacy

The first pillar of our framework is the basic technical understanding of the AI systems. To understand this, students should be able to define and comprehend the important AI terminologies.<sup>(19,29,30)</sup> This includes machine-learning algorithms, neural networks, and natural language processing. A similar understanding should cover the

material needs of AI systems, including how big data is utilised and the importance of data quality and diversity.

In addition, students must understand the differences between narrow AI, built for specific tasks, and broad-based general AI,<sup>(31)</sup> as well as the current state and potential future developments of AI technologies. These technical underpinnings are essential for demystifying AI and empowering students to engage critically with such systems. This foundation also serves as a basis for developing more advanced AI applications and implementation skills.

Building on technical understanding, the second component focuses on gaining hands-on practical skills in designing and deploying AI technologies.<sup>(32,33,34)</sup> Students need experience with AI tools and platforms to recognise which solutions make the most sense for various problems.<sup>(18)</sup> They should develop competencies in using AI-powered software, programming simple AI models, and understanding the process of training and refining these models.<sup>(35)</sup>

Moreover, this component focuses on data-handling capabilities, which are fundamental to successful AI execution. Students should learn to collect, preprocess, and structure data for AI systems.<sup>(36)</sup> The translation of AI outputs into interpretable and actionable insights is crucial. These skills are suitable for future careers in AI development and are designed to inform students and effective users of a wide range of professional AI technologies.

The ability to critically assess content produced by AI remains crucial in an age when such systems generate and curate more information than ever before.<sup>(37)</sup> Another part of our framework suggests developing skills to recognise potential biases, inaccuracies, or limitations in AI-generated information.<sup>(13)</sup> Students should cultivate a sophisticated appreciation of the motivations behind AI algorithms as curators and personalisers as well as the risks of echo-chamber effects.

Critical reasoning regarding the provenance and context of AI-synthesised information is essential. To develop this capacity, Tiernan et al.<sup>(38)</sup> Argue that students need rudimentary AI literacy to evaluate the credibility of their sources, discern between human and machine-generated content, and recognise manipulations mediated by deepfakes or other AI-enabled techniques. This component aims to promote healthy scepticism around AI-generated information while recognising its potential benefits, ultimately fostering informed decision-making in an AI-rich information landscape.

The last core part of our framework deals with moral questions and the broader social impacts related to AI. This includes appreciating fundamental ethical principles in AI development and deployment, such as fairness, accountability, transparency, and privacy.<sup>(26)</sup> Students should be able to recognise the possible ethical challenges arising from the application of AI and consider diverse stakeholder perspectives.

In addition, it comprises awareness of AI's societal consequences of AI in terms of employment, social interactions, and democratic processes.<sup>(39)</sup> Students should be able to reason about algorithmic bias and how artificial intelligence can worsen or improve social inequalities. It is designed to inculcate responsible AI citizenship so that students are prepared to participate in informed debates about AI governance and make ethical decisions as developers, users, and policymakers of AI technology.

Figure 2, titled 'Interconnected Components of the AI Literacy Framework', visually depicts the dynamic and interconnected nature of our proposed AI literacy framework. This shows that Technical Understanding, Application & Implementation, Critical Evaluation, and Ethical Considerations are interrelated aspects of AI literacy, not isolated elements. The bidirectional connections, labelled with verbs like 'Informs', 'Guides', 'Shapes', and 'Enhances', highlight their reciprocal relationships. At the centre, 'AI Literacy' signifies the holistic understanding derived from integrating these components. This visual emphasises our framework's comprehensive and interconnected approach to AI literacy, rather than a collection of separate competencies.

### Integration with traditional digital literacy concepts

The framework is not standalone, but overlaps and incorporates traditional digital literacy concepts. Specifically, we reference existing digital literacy frameworks, such as the European Digital Competence Framework for Citizens (DigComp 2.1)<sup>(17)</sup> and the International Society for Technology in Education (ISTE) Standards for Students,<sup>(40)</sup> while expanding upon them with considerations specific to AI use. We retain the essential features of these frameworks—information literacy, media literacy, and digital communication skills—but reinterpret them in light of AI technologies. For example, information literacy extends to navigating AI-curated content and understanding where algorithms act in information retrieval, potentially fuelling fake news. This also includes understanding of AI-generated or AI-manipulated media. It is crucial to learn efficient digital communication skills to interact with AI chatbots and virtual assistants.

We incorporated computational thinking concepts<sup>(20)</sup> as a bridge between traditional digital literacy and AI literacy, emphasising pattern recognition, decomposition, and algorithmic thinking as essential for understanding AI systems. Our model also integrates digital citizenship concepts,<sup>(41)</sup> expanding them to include AI-specific considerations such as the implications of AI on digital rights, responsibilities, and the impact on digital participation and access. This framework merges traditional concepts with AI-specific elements, adapting to the evolving technological landscape, while maintaining established educational foundations. Figure 3 outlines our methodological approach, theoretical foundations, key search terms, and research process.

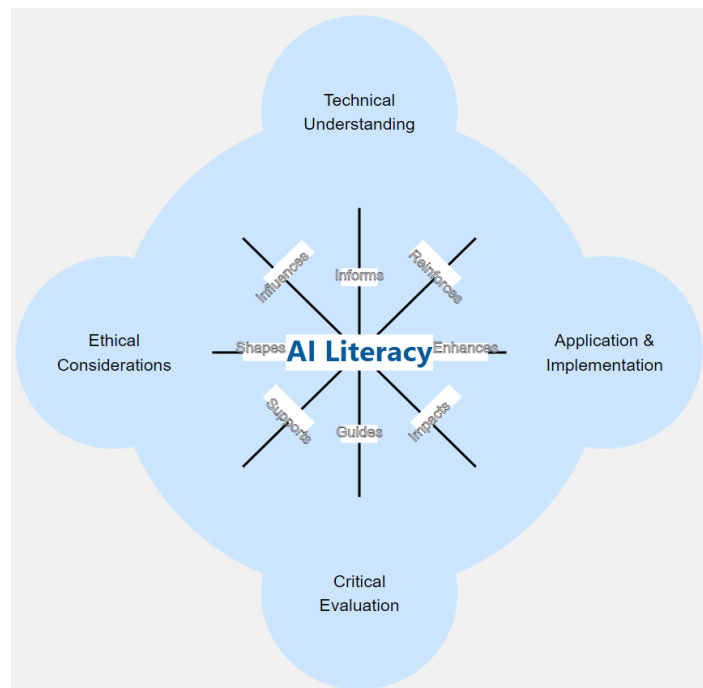


Figure 2. Interconnected Components of AI Literacy Framework

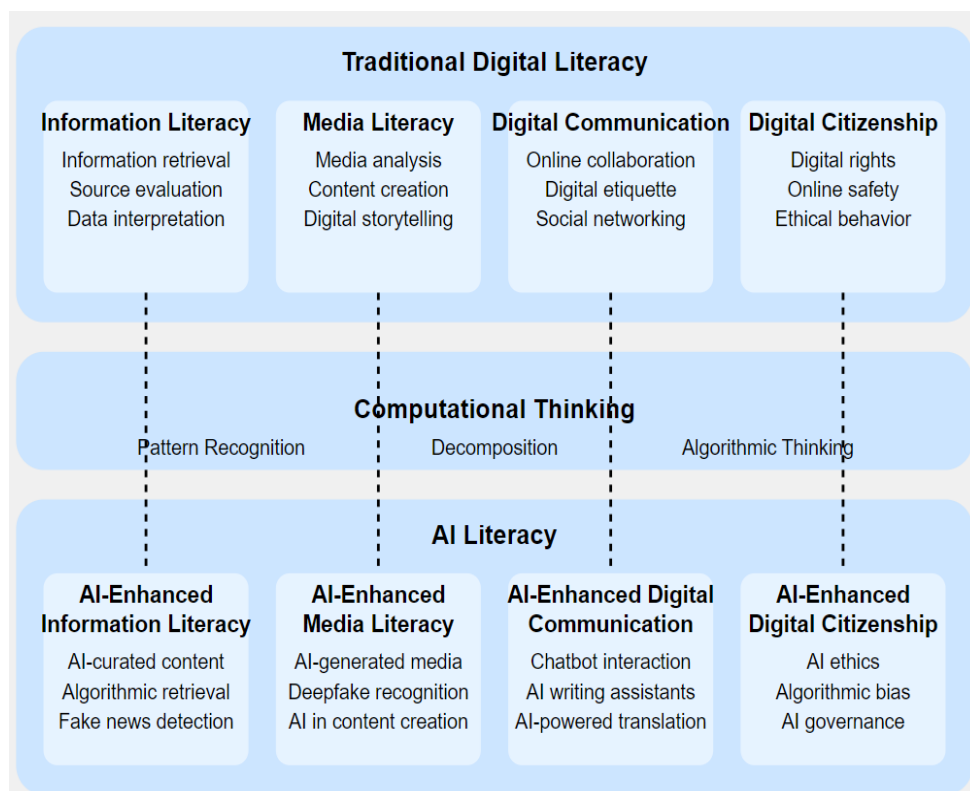


Figure 3. Integration of Digital Literacy with AI Literacy

**Framework for developing adaptability and lifelong learning skills**

Our framework focuses on preparing graduates for the constantly changing landscape of AI development through their adaptability and commitment to lifelong learning. This follows the idea of “learning to learn”<sup>(42)</sup> and cues from self-regulated learning theory.<sup>(43)</sup>

It is a meta-learning layer built on top of the core components. This new generation of “ability-building” layer is meant to foster the mindsets and capacities within us as humans to continue adapting to AI advancements. Key elements include:

1. Students will develop an understanding of skills needed with AI and self-directed learning<sup>(44)</sup> Aspect



in pursuing them.

2. This is referred to as critical reflection, where pre-existing knowledge of AI is used to identify gaps and misconceptions.<sup>(45)</sup>
3. Focusing on technological adaptability, students will become tech-savvy and able to quickly adapt their knowledge and skill sets to new AI contexts.<sup>(46)</sup>
4. Given the interdisciplinary nature of AI, students draw insights from different areas to understand and address the problems raised by this technology.<sup>(47)</sup>
5. Future-oriented thinking involves anticipating future AI developments and outcomes and encouraging a proactive rather than reactive learning approach.<sup>(48)</sup>

These meta-learning skills are threaded by the core components of AI literacy instruction. For example, in a course on AI systems, questions can prompt students to reflect on what they have learned, identify more to learn, and predict the future of certain AI technologies. By embedding these notions of adaptability and lifelong learning into our framework, we aim to prepare students for the current state of AI and the ever-changing technological landscape over their lifetimes.

Figure 4 illustrates our framework for developing adaptability and lifelong learning skills in the AI literacy context. The central circle represents the core components of AI literacy, whereas the outer circle represents the meta-learning layer of adaptability and lifelong learning skills. This ‘ability-building’ layer comprises five key elements: self-directed learning, critical reflection, technological adaptability, interdisciplinary insights, and future-oriented thinking. These meta-learning skills were designed to foster the mindsets and capacities necessary for continuous adaptation to AI advancements. The figure also provides an example of how these skills can be integrated into an AI system course, thereby demonstrating the practical application of this framework. By embedding these adaptability and lifelong learning concepts throughout our AI literacy framework, we aimed to prepare students for the current state of AI and the ever-evolving technological landscape they will encounter.

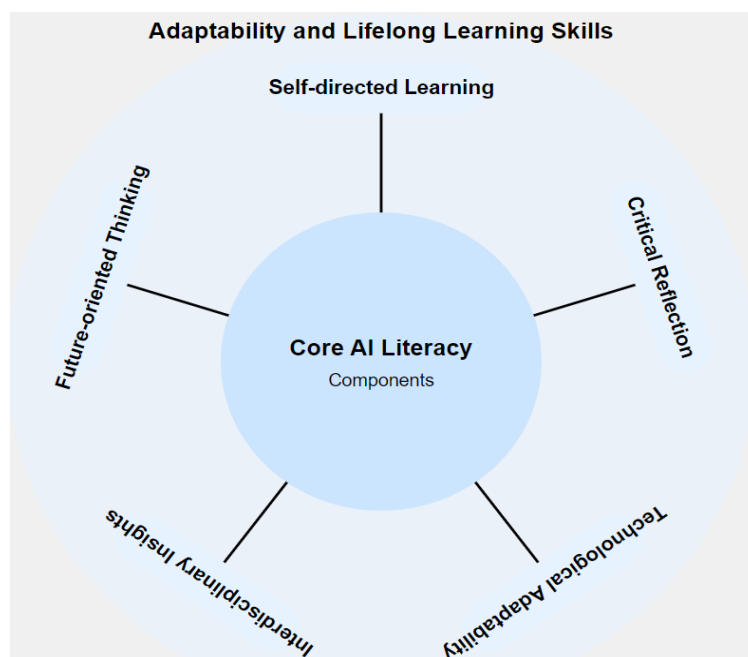


Figure 4. Framework for Adaptability and Lifelong Learning in AI Literacy

## DISCUSSION

The proposed conceptual framework for AI-Era Digital Literacy has essential implications across educational practice, ethical considerations, and broader research design needs within educational technology.

### Implications for educational practice

Incorporating AI literacy into the existing curricula offers promises and challenges. Our framework for AI literacy extends computational thinking, which Grover and Pea<sup>(49)</sup> proposed, and the state should be woven throughout K-12 education. The result should be a well-integrated sequence that balances standalone AI courses with the infusion of AI concepts across disciplines.<sup>(19)</sup>

One caution is that curriculum designers should consider the developmental appropriateness of AI concepts

at different educational levels. For elementary grades, curricula might centre on computing practices and ethical awareness. Older students can be introduced to more advanced technical ideas and critical evaluation skills. The curriculum should also remain flexible to allow rapid technological evolution, emphasising enduring principles over specific tools or applications.<sup>(16)</sup>

AI literacy education is intended to differ in how pedagogical methods are applied. Project-based learning is compatible with AI education's hands-on and exploratory nature,<sup>(50)</sup> and enquiry-based methods have proven successful in computer science. Students learn valuable tools and techniques that can be applied to real-world AI, leading to richer learning experience and critical thinking skills. Collaborative learning strategies are also essential, reflecting the interdisciplinary nature of AI development in professional settings.<sup>(51)</sup> Educators should create opportunities for students to work in teams on AI projects, encourage peer learning, and develop communication skills.

We can use AI-supported educational tools that adapt to students by providing personalised learning experiences tailored to individual needs and preferences.<sup>(52)</sup> Simultaneously, students need to see behind the curtain and learn how these tools work to engage with AI critically rather than passively in their studies.

Given the rapid evolution of AI technologies and various complex skills, literacy in this domain requires much work. Existing assessment methods must be better suited to capturing the multifaceted nature of AI literacy. A more thoughtful approach is needed that incorporates formative and summative evaluations in tandem.<sup>(53)</sup> Performance-based assessments, such as AI project portfolios or demonstrations of AI tool use, can effectively evaluate practical skills and understanding.<sup>(54)</sup> Scenario-based assessments or debates might be more appropriate for assessing critical thinking and ethical reasoning regarding AI.

Additionally, self-assessment and peer assessment can play essential roles in fostering metacognitive skills and supporting the development of lifelong learning capabilities.<sup>(55)</sup> These assessment strategies should be aligned with the core components of our AI literacy framework to ensure comprehensive evaluation of student competencies.

Successful implementation of AI literacy education depends heavily on well-prepared teachers. However, many educators require formal training in AI concepts and applications. This necessitates comprehensive professional development programs that cover the technical aspects of AI and pedagogical strategies for teaching AI concepts.

Teacher education programs should be updated to include AI literacy components and prepare future educators for AI integrated classrooms. For in-service teachers, ongoing professional development opportunities are crucial to keeping pace with AI advancements. This could include workshops, online courses, and collaborative learning communities that focus on AI in education. Moreover, partnerships between schools and AI industry professionals can provide valuable real-world insights and keep teachers updated on AI developments and applications.<sup>(56)</sup>

### **Ethical considerations and challenges**

As AI becomes integral to life and work, equitable access to AI education is essential to prevent the worsening of the digital divide. Significant challenges include resource disparities between schools and regions, leading to uneven AI learning opportunities.<sup>(57)</sup> Representation issues in AI development and perspectives impact student engagement in AI education.<sup>(58)</sup> It is essential to develop culturally responsive AI curricula for diverse students. Policymakers and educators must prioritise resource allocation for AI education in underserved communities, possibly through partnerships with tech companies for hardware and software resources, and initiatives to increase diversity in AI education and the broader field. Online learning platforms and open educational resources can help democratise access to AI education.<sup>(59)</sup>

AI systems can perpetuate and amplify existing biases, making it crucial for AI literacy education to address this issue explicitly.<sup>(60)</sup> Students need to understand how biases can be embedded in AI systems through biased training data or flawed algorithms, and the potential consequences of these biases in various domains.

In education, AI-powered learning systems may exhibit biases, potentially disadvantaging certain student groups.<sup>(52)</sup> Educators must be vigilant about these potential biases and teach students how to critically evaluate AI-driven educational tools.

Addressing this challenge requires a multifaceted approach. The curriculum content should include case studies on AI bias and its impact. Students should be taught methods for detecting and mitigating biases in AI systems. Moreover, developing AI educational tools should involve diverse teams and should undergo rigorous testing for bias. This emphasis on bias awareness and mitigation is crucial for developing responsible AI practitioners and informed AI citizens.

While technical skills are crucial for AI literacy, it is equally important to cultivate humanistic values and critical thinking skills.<sup>(8)</sup> The challenge lies in striking the correct balance between these elements in AI education. Educators must emphasise that AI can augment human capabilities and not replace human judgement and creativity. This involves fostering an understanding of AI's limitations and the continued importance of human

skills, such as empathy, ethical reasoning, and creative problem-solving.<sup>(7)</sup> Integrating ethical discussions into technical AI courses and incorporating AI considerations into humanities courses can help achieve this balance, promoting a holistic understanding of AI's role in society.

### Limitations of the proposed framework

Although our proposed framework offers a comprehensive approach to AI literacy, several limitations warrant acknowledgement. First, the rapid pace of AI development means that the specific technical components of the framework may quickly become outdated. While we have attempted to focus on foundational concepts, regular reviews and updates are necessary to maintain relevance.<sup>(36)</sup> Second, the effectiveness of the framework may vary across educational contexts and cultures. What constitutes essential AI literacy may differ based on local needs and values, necessitating adaptations of the framework to different settings.<sup>(61)</sup>

Third, the framework primarily focuses on formal educational settings. Its applicability to informal learning environments or adult education may be limited and requires further development.<sup>(62)</sup> Finally, while our framework emphasises the importance of ethical considerations, the rapidly evolving nature of AI ethics means that new ethical challenges may emerge that still need to be fully addressed by the current framework.<sup>(63)</sup> These limitations highlight the need for ongoing research and refinement of this framework to ensure its continued relevance and effectiveness in promoting AI literacy.

### Future Directions

The proposed framework has numerous potential applications in the educational setting. It can guide the development of K-12 AI curricula, inform the design of undergraduate courses in AI literacy, and shape teacher-training programs. Beyond formal education, the framework could be adapted for workplace training programs, helping improve the current workforce in AI literacy.<sup>(64)</sup>

The framework can also inform policy decisions regarding AI in education, providing a structured approach for policymakers to consider when developing educational standards and resource allocation strategies. Additionally, it could serve as a basis for developing AI literacy assessment tools, allowing for standardised evaluation of AI competencies across different educational contexts.<sup>(65)</sup>

Although our framework provides a foundation for understanding AI literacy, several areas warrant further theoretical development. The intersection of AI literacy with other emerging fields, such as the Internet of Things (IoT) or blockchain literacy, requires exploration.<sup>(66)</sup> The framework can be extended to address AI's psychological and sociological impacts more explicitly by incorporating theories from these disciplines. Additionally, the development of stage-based models of AI literacy acquisition, similar to those in other areas of educational theory, could provide valuable insights into curriculum design and assessment.<sup>(67)</sup> Finally, theoretical work on the long-term impacts of AI literacy on cognitive development and learning processes could yield essential insights for educational practice.

Therefore, extensive empirical research is required to validate and refine the proposed framework. Longitudinal studies tracking the development of AI literacy in elementary schools through higher education students would provide valuable insights into the effectiveness of different educational approaches.<sup>(68)</sup> Comparative studies examining the implementation of the framework across different educational systems and cultural contexts are crucial for understanding its generalisability and necessary adaptations.<sup>(69)</sup>

Moreover, research on the relationship between AI literacy and other educational outcomes, such as general academic performance or career readiness, would help establish the broader impact of AI literacy education. This empirical study is essential for refining the framework and ensuring its practical effectiveness in diverse educational settings.

## CONCLUSION

This study successfully developed a comprehensive framework for AI-Era Digital literacy that addresses the growing need for AI education. The framework re-conceptualises digital literacy through four interconnected components: technical understanding, implementation skills, critical evaluation, and ethical considerations. These components are integrated with traditional digital literacy concepts through a meta-learning layer that emphasises adaptability. This framework provides concrete guidance for educational institutions by identifying essential AI competencies and suggesting pedagogical approaches for implementation. Further empirical research is needed to validate the framework's effectiveness across different educational contexts and refine its application in various learning environments.

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## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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