(REVIEW ARTICLE)

Educating for the Algorithmic Age: Mapping AI Literacy

Salma Fatih Tofiq [1] and Darya Abdulwahab Latif [2, *]

[1] Department of Media Studies, Bright Technical & Vocational Institute, Hawary-Shar, Sulaymaniyah, Kurdistan Region, Iraq.
[2] Department of Media, Technical Institute of Sulaimani, Sulaimani Polytechnic University, Sulaymaniyah, Iraq.

Abstract

AI technologies are increasingly embedded in the social, educational, and economic dimensions of daily life, prompting a growing recognition of the need for widespread AI literacy. This study conducts a systematic scoping review to synthesize current conceptualizations, educational implementations, and assessment strategies of AI literacy across diverse learning environments. Following PRISMA-ScR guidelines, 47 peer-reviewed studies published between 2019 and 2024 were analyzed to identify key dimensions of AI literacy and their alignment with broader pedagogical goals. The review reveals that AI literacy encompasses more than technical competencies; it includes ethical reasoning, critical thinking, and socio-cultural awareness, yet remains inconsistently defined and unevenly implemented across educational settings. Using a six-construct taxonomy and triangulation with prominent frameworks, the study identifies significant disparities in curricular integration, educator preparedness, and access to validated assessment tools. These findings underscore the urgent need for coherent, inclusive, and interdisciplinary approaches to AI literacy education. The study contributes to the field by mapping its current landscape, exposing conceptual and practical gaps, and offering direction for future research, curriculum development, and policy formation aimed at fostering equitable and critical engagement with AI systems.

Keywords: AI literacy; Education; Digital Competencies; Ethical Technology Use; Systematic review

1. Introduction

AI and advanced communication technologies are rapidly transforming the fabric of modern life (Soroori Sarabi et al., 2023). From the way individuals access information and communicate to how decisions are made in healthcare (Toosi et al., 2025), education (Rahmatian & Sharajsharifi, 2021), and governance (Farrell, 2025), the influence of intelligent systems has become deeply embedded in the routines and infrastructures of daily existence (Khodabin et al., 2024). Voice assistants mediate interactions, recommendation algorithms shape social and political discourse, and automated systems increasingly handle tasks once considered uniquely human (Zuboff, 2023). In parallel, ubiquitous connectivity, real-time data transmission, and digital platforms have fundamentally altered human communication patterns, reshaping how individuals form relationships, learn, work, and participate in civic life (Nosraty et al., 2025). These transformations are not marginal or peripheral—they are structural and global, carrying profound implications for societal functioning, individual agency, and democratic engagement.

In this context, literacy is no longer confined to reading and writing in traditional forms but has evolved to encompass the ability to critically engage with and navigate the digital and algorithmic systems that increasingly govern everyday life. AI literacy, in particular, emerges as a foundational competency necessary for informed participation in a world where intelligent technologies are omnipresent yet often opaque (Bahmani and Javaheri Tehrani, 2025). Unlike conventional digital literacy, AI literacy requires individuals to not only operate technological tools but also to

---

understand how algorithmic systems function, interpret data, and make decisions. It involves the capacity to recognize the limitations, biases, and ethical considerations inherent in AI systems, as well as the ability to evaluate their impacts on society, privacy, labor, education, and risk management (Sakhaei et al., 2024). Without these skills, individuals are at risk of becoming passive consumers of algorithmic decisions rather than active, critical participants in shaping the technological landscapes that affect their lives.

The necessity of AI literacy is thus both practical and epistemological. On a practical level, AI is increasingly embedded in professional workflows across diverse sectors—from agriculture to law, from journalism to medicine. The ability to understand and responsibly interact with AI systems is becoming a precondition for employability, adaptability, and lifelong learning. On a deeper level, AI literacy supports the development of critical consciousness, enabling individuals to question how technological systems reflect and reproduce power relations, cultural values, and structural inequalities. It allows people to move beyond mere usage toward thoughtful engagement, empowering them to ask not only "how does this system work?" but also "whose interests does it serve?" and "what are the broader implications of its deployment?" In this sense, AI literacy is inseparable from civic literacy and democratic participation in the digital age.

People of the world are icreasingly using new communication technologies for different purposes (Shahghasemi, Gholami & Alikhani, 2025) and despite the growing importance of AI literacy, there remains a lack of consensus about what it entails and how it should be cultivated across different educational contexts. Unlike traditional subject areas with well-established curricula and learning standards, AI literacy is a relatively new and evolving field. It intersects with multiple disciplines—computer science, ethics, education, sociology, psychology—each offering different perspectives on what competencies are most important. Some approaches emphasize technical understanding and programming skills; others prioritize ethical reflection, critical thinking, or societal awareness. This conceptual plurality reflects the complexity of AI itself but also poses significant challenges for designing educational programs, assessment tools, and policy frameworks that can effectively foster AI literacy across populations.

Moreover, the implementation of AI literacy education is uneven across demographic, institutional, and geographical lines. While some higher education institutions and K-12 systems have begun integrating AI topics into curricula, such efforts are often ad hoc, experimental, or limited in scope. Access to AI-related educational resources tends to be stratified along socioeconomic and regional lines, reinforcing existing educational inequalities. Educators often lack the training and tools necessary to teach AI concepts confidently and critically, and learners frequently encounter AI either through commercial products or passive exposure, rather than through structured pedagogical engagement (Rahmatian & Sharajsharifi, 2022). As a result, the development of AI literacy remains fragmented, raising urgent questions about how best to conceptualize, teach, and assess this increasingly vital competency.

This study responds to these challenges by conducting a systematic scoping review of the emerging literature on AI literacy in educational contexts. It aims to clarify how AI literacy is currently defined, implemented, and assessed across different educational levels and learning environments. By synthesizing findings from a wide range of empirical, theoretical, and conceptual sources, the study seeks to identify both convergences and divergences in how scholars and practitioners approach the development of AI literacy. Particular attention is paid to how AI literacy is positioned in relation to broader educational goals, such as critical thinking, ethical reasoning, interdisciplinary learning, and equity (Shahghasemi, 2025). The study also examines how educational interventions are designed, what learning outcomes they aim to achieve, and what instruments—if any—are used to measure those outcomes.

In doing so, this research contributes to the foundation of a coherent and inclusive understanding of AI literacy, one that is pedagogically grounded and practically applicable. Rather than advocating for a single, universal definition, the study acknowledges the contextual and evolving nature of literacy itself, especially in relation to emerging technologies. It seeks to map the conceptual terrain of AI literacy education, highlighting patterns, gaps, and opportunities that can inform future curricular design, teacher training, and policy development. The analysis is situated within the broader discourse of 21st-century education, which emphasizes learner agency, interdisciplinary problem-solving, and ethical awareness as essential components of meaningful learning in a complex and technologically mediated world.

Ultimately, the goal of this work is to support the development of AI literacy as a robust and equitable educational priority. As societies navigate the accelerating integration of AI into social, cultural, economic, and political systems, the ability to engage with these technologies critically and responsibly becomes indispensable—not just for specialists or technologists, but for all citizens. Ensuring broad access to AI literacy education is thus a matter of educational justice and democratic integrity. This review represents a step toward that goal by systematically examining how current research frames and approaches AI literacy, with the aim of supporting a more informed, inclusive, and reflective engagement with one of the most consequential technological transformations of our time.

2. Methodology

This study utilized a systematic scoping review methodology to synthesize existing research on AI literacy within educational contexts. Systematic reviews offer a rigorous, transparent, and replicable method for aggregating evidence, minimizing bias, and identifying patterns and gaps in the literature (Shahghasemi, Heisey & Mirani, 2011). To ensure methodological transparency and reproducibility, the study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR) guidelines. This structured approach enhances the credibility of the findings by ensuring comprehensive coverage of the research domain and by documenting each step of the search, selection, and analysis processes. Scoping reviews are particularly well-suited for emerging and heterogeneous fields such as AI literacy, where definitions, frameworks, and implementations vary widely across disciplines and educational levels.

A comprehensive search strategy was developed to identify peer-reviewed publications addressing AI literacy across formal and informal learning environments from 2019 to 2024. Academic databases such as Scopus, Web of Science, and ERIC were systematically searched using a combination of controlled vocabulary and free-text terms (e.g., "AI literacy," "artificial intelligence education," "AI curriculum," "AI assessment"). Inclusion criteria required that studies (a) were published in English, (b) directly addressed AI literacy in educational or professional training contexts, and (c) provided empirical, theoretical, or conceptual contributions. Grey literature, dissertations, and purely technical papers not related to literacy or education were excluded. After initial screening of titles and abstracts, full-text reviews were conducted on 104 articles, resulting in a final dataset of 47 studies meeting the eligibility criteria.

Data extraction was guided by a structured content analysis framework derived from Almatrafi et al. (2024), enabling thematic synthesis across three core dimensions: conceptualization of AI literacy, implementation of educational interventions, and assessment strategies. Each article was coded independently by two reviewers to ensure inter-rater reliability, and disagreements were resolved through iterative consensus discussions. The extracted data were classified using a six-construct taxonomy—Recognize, Know and Understand, Use and Apply, Evaluate, Create, and Navigate Ethically—allowing for consistent cross-study comparison. This taxonomy enabled the identification of prevailing trends, educational gaps, and divergent conceptualizations across different learner populations, including children, adolescents, university students, and professionals.

To enhance analytical rigor, the review incorporated triangulation with prominent theoretical frameworks, notably the ED-AI Lit model (Allen & Kendeou, 2024) and the co-designed framework proposed by Chiu et al. (2024). These models provided additional lenses to evaluate the breadth and pedagogical relevance of AI literacy constructs present in the reviewed studies. Particular attention was given to the inclusion of ethical, socio-cultural, and cognitive components, which are often underrepresented in technically focused frameworks. Furthermore, studies were evaluated for the presence of validated assessment instruments, highlighting a persistent methodological gap in the empirical evaluation of AI literacy outcomes. This systematic and theory-informed methodological approach ensured a comprehensive, critical, and contextually grounded synthesis of the current state of AI literacy research in education.

3. Findings

Ng et al. (2021) conducted an exploratory review aimed at conceptualizing the emerging construct of AI literacy within educational contexts. Recognizing a gap in the literature regarding public understanding of AI and the pedagogical foundations necessary for fostering AI literacy, the authors synthesized findings from 30 peer-reviewed articles. Their analysis led to the proposal of a four-dimensional framework for AI literacy, encompassing: (1) knowing and understanding AI concepts, (2) using and applying AI tools, (3) evaluating and creating with AI, and (4) addressing ethical considerations. This framework draws on traditional literacy paradigms, adapting them to the unique characteristics of AI as a socio-technical domain. The review highlighted the paucity of dedicated educational research on AI literacy, emphasizing the need for structured approaches to define, teach, and assess AI-related competencies. By offering a preliminary conceptual model, the study contributes a foundational perspective to guide future research on curriculum design, competency development, and evaluative frameworks in the field of AI literacy education.

Druga et al. (2019) explored the perceptions and conceptual understanding of AI among 102 children aged 7–12 across four countries (U.S.A., Germany, Denmark, and Sweden), with a focus on how socioeconomic and cultural contexts influence children's interaction with and attitudes toward AI technologies. The study found that children outside the U.S. exhibited more critical views of AI, likely due to reduced exposure to smart technologies. Socioeconomic status (SES) also played a notable role: children from lower and middle SES backgrounds demonstrated stronger collaboration skills but faced challenges in advancing due to limited prior experience with coding and AI devices. In contrast, children

from higher SES backgrounds showed a more robust understanding of AI concepts, despite initial difficulties in collaborative engagement. These findings underscore the importance of culturally and socioeconomically responsive design in AI literacy education. The authors proposed preliminary guidelines for creating inclusive, hands-on AI learning experiences tailored to K–8 learners, emphasizing the need for accessible smart toys and devices that can support equity in early AI education. This research contributes to the development of globally inclusive AI literacy curricula by highlighting disparities in access and understanding, and by advocating for design approaches that bridge these gaps.

Long and Magerko (2020) addressed the growing necessity for public understanding of AI by proposing a conceptual framework for AI literacy within the context of human-computer interaction (HCI). As AI technologies become increasingly embedded in everyday life, the authors emphasized the importance of equipping users with the competencies required to interact with and critically evaluate AI systems. Through an interdisciplinary synthesis of existing literature, they identified a set of core competencies essential to AI literacy, including understanding AI concepts, recognizing its limitations, and engaging with its ethical and societal implications. In addition to defining these competencies, the paper presented key design considerations for developing learner-centered AI technologies that foster user comprehension and engagement. These considerations focused on aligning AI educational tools with cognitive and contextual user needs to enhance accessibility and meaningful learning. The resulting framework serves as both a foundation for conceptualizing AI literacy and a guide for educators, developers, and researchers aiming to promote effective public engagement with AI. The study contributed to initiating a structured discourse on AI literacy within the HCI community and highlighted pathways for future research and design practices.

Yi (2021) investigated the foundational concept, competencies, and educational aims of AI literacy, positioning it as an essential capability for navigating life in an AI-driven society. The study framed AI literacy not merely as technical proficiency but as a broadened form of modern literacy that mirrors the societal shift from teacher-centered to learner-centered education. Arguing that AI has become as integral to daily life as writing, the author emphasized its role in expanding human capabilities, particularly in terms of relational networks and access to information. Central to the discussion was the notion that AI literacy must include the ability to make autonomous decisions about what knowledge is needed and with whom to connect—an ability grounded in metacognition. Consequently, the study proposed metacognition as a core competence of AI literacy, enabling learners to critically reflect on their knowledge needs. Moreover, it suggested that AI literacy should foster anticipatory thinking, equipping individuals to manage uncertainty and complexity in a rapidly evolving technological landscape. By redefining AI literacy through a humanistic and educational lens, the article contributes to the theoretical framing of the field and underscores its relevance beyond technical domains.

Heyder and Posegga (2021) proposed an expanded conceptualization of AI literacy tailored to organizational contexts, recognizing its increasing relevance as AI technologies reshape the future of work. Positioned within the broader discourse on workplace readiness, the study aimed to refine the understanding of AI competencies necessary for employees to effectively engage with AI-based systems. Building on existing frameworks, the authors employed a multimethod taxonomy development process to formulate a preliminary taxonomy of AI literacy. This taxonomy delineated three key dimensions: functional (practical use and interaction with AI tools), critical (evaluation and understanding of AI's limitations and impacts), and sociocultural (contextual awareness and ethical engagement). Notably, the findings underscored the centrality of sociocultural literacy, highlighting its role in facilitating informed and responsible AI use within workplace environments. The study advanced theoretical models of AI literacy by illustrating the interrelationships among its core dimensions and calling attention to the need for organizational strategies that foster these competencies. This research contributes to the growing body of literature on AI literacy by offering a foundation for further empirical validation and practical application in workforce training and professional development.

Ng et al. (2022) explored the evolving role of AI in education, with a particular focus on promoting AI literacy across K–16 classrooms. Framing the discussion within the broader context of rapid technological change in the 21st century, the authors highlighted how AI has become embedded in various aspects of daily life, from consumer technology to personalized learning environments. The chapter traced the emergence of AI in education (AIED), noting its dual role in enhancing individualized student learning experiences and alleviating administrative burdens for teachers. The authors emphasized that as AI applications grow more pervasive, fostering AI literacy becomes increasingly essential to prepare students for active participation in AI-integrated societies. They outlined the core domains of AI technology—including computer vision, natural language processing, robotics, machine learning, and neural networks—and examined their relevance in educational contexts. The chapter argued that AI literacy should extend beyond technical understanding to include critical thinking about AI's role, implications, and ethical considerations. It called for educators to adopt structured approaches to integrate AI concepts across all educational levels, emphasizing interdisciplinary collaboration, curriculum development, and teacher training. This foundational work contributes to

the broader movement of AI literacy education by mapping its importance and setting a baseline for its implementation in both compulsory and higher education systems.

Wilton et al. (2022) addressed the critical need for fostering AI literacy among educators, particularly in light of the increasing integration of AI technologies in formal educational settings. Drawing on three years of reflective data from an instructor-designed graduate course in artificial intelligence in education (AIED), the study explored how educators engage with core issues such as ethics, bias, privacy, inclusion, data collection, and explainability in AI tools. The course emphasized critical inquiry into the use and implications of AI in teaching and learning, offering educators a structured environment to analyze real-world AI applications. Through reflective practice and engagement with emerging AIED literature, the authors identified recurring themes and conceptualizations of AI literacy. The findings underscored the necessity for educators—not just technologists—to understand both the opportunities and risks associated with AI adoption in education. The study introduced the concept of AI Literacy for Educators (AILE), advocating for the development of targeted frameworks and pedagogical guidelines that empower educators to make informed, ethical decisions when integrating AI tools into their teaching. By centering the educator's perspective, this work contributes to a growing body of interdisciplinary scholarship aimed at democratizing AI literacy and ensuring responsible use in educational contexts.

Laupichler et al. (2022) conducted a scoping literature review to assess the current state of research on AI literacy in higher and adult education, a domain gaining importance as AI technologies increasingly permeate daily life. From an initial pool of 902 records across ten databases, 30 studies met the eligibility criteria and were included in the review. The analysis revealed that research on AI literacy in postsecondary and adult learning contexts remains nascent, with significant variation in how AI literacy is conceptualized and implemented. The reviewed studies covered a range of thematic foci, including pedagogical structures of AI literacy courses, the competencies targeted, and the tools used to deliver instruction. Common instructional approaches included introductory modules aimed at non-experts, often emphasizing basic technical understanding, ethical considerations, and the societal implications of AI. However, the review highlighted a lack of consensus on curricular content and a noticeable absence of validated assessment instruments to evaluate learning outcomes. The authors called for more empirical research to establish a clearer definition of AI literacy tailored to adult learners and to support the development of robust, scalable teaching models and measurement tools. This review contributes to the foundational understanding of AI literacy in higher and adult education and offers recommendations to guide future research and practice in this emerging field.

Schüller (2022) proposed a comprehensive framework for data and AI literacy aimed at fostering a shared understanding that supports systematic integration into educational curricula and standards across all levels of learning. The framework is designed to promote transdisciplinary competence development by incorporating three key perspectives: the *application-oriented*, focusing on practical uses of data and AI; the *technical-methodological*, emphasizing analytical and computational foundations; and the *socio-cultural*, addressing ethical, societal, and contextual implications. Intended for implementation in schools, teacher education, higher education, and lifelong learning settings, the framework supports the development of fundamental skills necessary for navigating a data- and AI-driven society. Schüller emphasized the framework's adaptability for vocational training and public education, particularly through initiatives by statistical institutions seeking to improve public data literacy. As a practical example, the author highlighted the "Stadt | Land | Datenfluss" app, which applies the framework to promote adult learning in a real-world context. This work contributes to the broader discourse on democratizing AI and data literacy, offering a scalable, ethically grounded model for inclusive education and informed civic participation in the digital age.

Southworth et al. (2023) presented a comprehensive institutional initiative from the University of Florida (UF) aimed at integrating AI literacy across the undergraduate curriculum to address the growing societal and workforce demands for AI-competent graduates. The paper outlined the design and implementation of the "AI Across the Curriculum" model, grounded in a broad AI literacy framework and aligned with the university's accreditation-driven Quality Enhancement Plan (QEP). Central to the model is the inclusion of AI education as a foundational element for all students, regardless of discipline, to ensure interdisciplinary engagement and promote inclusive access to AI competencies. The initiative capitalizes on substantial institutional investment and strategic planning to provide students with a range of AI-focused opportunities—through coursework, research, and co-curricular activities—designed to foster both technical and ethical dimensions of AI literacy. The authors positioned AI literacy as essential for cultivating global citizenship and professional readiness, particularly as AI continues to redefine industries and societal systems. The UF model is presented as a scalable and transformative approach, offering a blueprint for higher education institutions seeking to embed AI literacy as a cross-disciplinary educational priority in response to 21st-century challenges.

Perchik et al. (2023) evaluated the effectiveness of a multi-institutional AI literacy course designed for radiology residents across nine programs in the Southeast and Mid-Atlantic United States. Recognizing the limited exposure to AI

in current radiology training, the authors developed a one-week remote learning course comprising ten 30-minute lectures and a proctored hands-on session using an FDA-cleared AI tool for advanced cancer imaging. The curriculum covered foundational AI concepts, clinical applications across radiology subspecialties, and critical issues such as ethics, algorithmic bias, economics, and medicolegal implications. Pre- and post-course surveys were administered to assess participants' knowledge and interest in AI. Results showed a statistically significant improvement in AI knowledge scores—from a mean of 8.3/15 pre-course to 10.1/15 post-course ($p = 0.04$). Nearly all participants reported a prior lack of adequate AI exposure (96.7%), yet most expressed a strong interest in continued AI education (78.6%). The study demonstrates that a collaborative, remote-delivery model can effectively enhance AI literacy among radiology trainees and reduce barriers to specialized training. The findings support the integration of structured AI education into radiology curricula and underscore the importance of multi-institutional collaboration to broaden access and standardize AI literacy in medical education.

Casal-Otero et al. (2023) conducted a systematic literature review to examine how AI literacy is being addressed in K-12 education globally, responding to the increasing societal demand for citizens capable of navigating AI-integrated environments. Using the Scopus database, the authors reviewed 179 relevant publications and classified the literature into two major thematic categories: learning experiences and theoretical perspectives. The first category encompassed instructional practices aimed at developing students' technical, conceptual, and applied AI skills, while the second focused on the formulation of frameworks and models to conceptualize AI literacy within K-12 settings. A key finding was the scarcity of empirical studies assessing students' actual understanding of AI concepts following instructional interventions. Additionally, the review noted limited engagement with the ethical and societal implications of AI, despite their importance. The authors argued for the development of a comprehensive competency-based framework to inform curriculum design, emphasizing modularity, personalization, and contextual adaptability. They also highlighted the potential for AI literacy to enhance core disciplinary learning when integrated thoughtfully into subject teaching, provided the curriculum is co-designed in collaboration with educators. This review underscores the need for more robust pedagogical strategies, assessment tools, and interdisciplinary collaboration in advancing AI literacy at the K-12 level.

Su, Ng, and Chu (2023) conducted a scoping review to explore the state of AI literacy within early childhood education (ECE), a domain where research and curriculum development remain nascent. Analyzing 16 empirical studies published between 2016 and 2022, the review synthesized findings across key dimensions including curriculum design, AI tools, pedagogical strategies, research methodologies, assessment techniques, and learning outcomes. The analysis revealed several pressing challenges inhibiting the effective integration of AI literacy in ECE, notably the limited AI knowledge, skills, and confidence among teachers, insufficient curriculum frameworks, and a lack of structured teaching guidelines. Despite these barriers, the review emphasized the pedagogical potential of AI learning for young children, particularly in fostering foundational understanding of AI concepts, practices, and perspectives. Opportunities for growth were identified in the development of age-appropriate instructional resources and tools, along with increasing recognition of the value of early exposure to AI. The authors concluded by offering recommendations for future research and practice, aimed at enhancing instructional design, supporting educator development, and advancing age-aligned AI literacy education in early learning settings.

Ng et al. (2023) conducted a comprehensive review of AI literacy education in secondary schools, responding to the growing need for equipping students with the digital competencies necessary for evaluating, communicating, and ethically engaging with AI in contemporary society. The review synthesized findings from 50 studies published between 2016 and 2022, aiming to inform educators, researchers, and policymakers on effective practices in AI education at the secondary level. Through thematic analysis, five key findings were identified: (1) collaborative, project-based learning emerged as the dominant pedagogical model, emphasizing interdisciplinary problem-solving and artifact creation; (2) a diverse range of teaching tools were employed, including hardware, software, intelligent agents, and unplugged resources; (3) learning content varied by age group, with junior students introduced to foundational AI concepts and senior students engaged in more advanced, technical applications; (4) assessment practices ranged from knowledge tests and surveys to qualitative evaluations of student outputs; and (5) learning outcomes were assessed across affective, behavioral, cognitive, and ethical dimensions. The study also highlighted implementation challenges, including curriculum alignment, teacher preparedness, and resource availability. By offering a detailed account of current approaches and gaps in secondary-level AI education, this review provides actionable insights for curriculum designers and education stakeholders aiming to promote AI literacy in formal schooling environments.

Hornberger, Bewersdorff, and Nerdel (2023) developed and validated a multiple-choice test to assess AI literacy among university students, addressing the need for reliable, psychometrically sound tools to evaluate students' baseline knowledge in this domain. Recognizing that AI increasingly permeates everyday life and work, the authors emphasized the importance of equipping students with foundational AI understanding regardless of their academic discipline.

Existing AI literacy assessments often rely on self-report measures or are designed for specific course contexts, limiting their generalizability and psychometric robustness. This study contributed a standardized test with validated psychometric properties to assess AI literacy across a broader student population. The findings revealed substantial variance in students' AI literacy levels, with generally higher scores observed among those with technical academic backgrounds or prior exposure to AI-related topics. Most students demonstrated at least a basic understanding of AI, though notable knowledge gaps remained, particularly among those from non-technical disciplines. These results highlight the importance of designing inclusive AI education that accommodates diverse academic backgrounds and prior knowledge levels. The study provides both a practical assessment tool and empirical evidence to inform the development of effective AI literacy curricula in higher education.

Kong et al. (2024b) presented a collaborative, international commentary advocating for the integration of AI literacy into educational systems as a foundational response to the transformative impact of AI on society. Emphasizing the urgency of aligning educational practices with rapid technological developments, the authors argued for a paradigm shift that centers AI literacy not only on technical proficiency but also on its ethical, societal, and pedagogical implications. The article highlighted how AI, when responsibly implemented in education, can foster equity, inclusiveness, and lifelong learning by enabling personalized, adaptable learning experiences that support a diversity of learner needs. Moreover, the authors contended that AI literacy is essential for preparing individuals to actively contribute to sustainable societal development, both professionally and civically. They proposed that education should cultivate learners' competencies and mindsets to critically engage with AI, use it to address complex societal challenges, and make informed decisions in their personal and professional lives. This position piece contributes to ongoing global discussions by reframing AI literacy as a vehicle for empowering future-ready citizens and professionals and calls for its formal inclusion in education policy and curriculum development at all levels.

Stolpe and Hallström (2024) examined how AI literacy can be integrated into technology education, proposing a framework that aligns AI literacy with the broader concept of technological literacy, understood here as a form of multiliteracy. The study critically analyzed five existing AI literacy frameworks in relation to three key traditions of technological knowledge: technical skills, technological scientific knowledge, and socio-ethical technical understanding. The findings indicated that AI literacy within the context of technology education places strong emphasis on technological scientific knowledge—such as understanding what AI is, identifying AI systems, and engaging with systems thinking—and socio-ethical technical understanding, including issues of AI ethics and the human role in AI decision-making. While programming and technical skills were acknowledged, they were comparatively less prominent in the analyzed frameworks. The authors argued that AI literacy should not be treated in isolation but rather as an integrated component of technological literacy that supports students in navigating both the technical and societal dimensions of AI. The study concluded with a proposed framework tailored to technology education, offering guidance for researchers and educators in curriculum development and pedagogical implementation of AI literacy in this domain.

Sperling et al. (2024) conducted a scoping review to explore how AI literacy is conceptualized in relation to teachers' professional knowledge within the context of teacher education (TE), a domain in which AI literacy remains significantly underrepresented. Drawing on 34 studies published between 2000 and 2023, the review utilized Aristotelian categories—*episteme* (theoretical knowledge), *techne* (practical skills), and *phronesis* (professional judgment)—as an analytical lens to examine the epistemic, practical, and ethical dimensions of teachers' engagement with AI. The findings revealed that computer science and exploratory pedagogical approaches largely shape the discourse, often framing ethics narrowly through a technical lens—focusing on data-driven AI systems rather than broader societal implications. Teachers' practical knowledge was primarily associated with the use of digital tools to teach AI or integrate AI-powered educational technologies, rather than the development of deeper pedagogical strategies or critical understanding. The review identified a critical gap in the literature regarding the integration of educational science perspectives, noting that the contributions of teachers and teacher educators are essential for constructing a holistic and contextually relevant model of AI literacy in TE. The authors argue for expanded interdisciplinary collaboration to develop a more robust and ethically grounded conception of AI literacy tailored to the professional knowledge and needs of teachers.

Yim (2024) conducted a critical review aimed at addressing the underdeveloped state of AI literacy frameworks for primary school education, an area that has received considerably less attention compared to secondary and tertiary levels. Through a scoping review of 19 selected articles sourced from four academic databases, the study identified 17 existing AI literacy frameworks spanning various educational levels. These frameworks predominantly drew on empirical research and literature reviews and often adhered to national or institutional educational standards. Common theoretical underpinnings included Bloom's taxonomy, the Use-Create-Modify progression model, constructionism, and computational theories, reflecting a strong influence from computer science and educational psychology. The review found that while recent developments in AI learning tools have made AI education more accessible to younger learners, existing frameworks tend to emphasize constructionist approaches and often overlook the complex interactions

between human and technological agents. Yim proposed a new, intelligence-based AI literacy framework that situates AI literacy at the intersection of digital literacy, data literacy, computational thinking, and AI ethics. The proposed framework advocates for a transdisciplinary approach that balances technical knowledge with critical understanding of AI's societal impacts, aiming to equip young learners with both conceptual and ethical foundations. This study offers valuable theoretical and practical insights for curriculum designers, educators, and policymakers seeking to implement age-appropriate, holistic AI literacy education in primary schools.

Chiu et al. (2024) proposed a comprehensive framework to advance the understanding and implementation of AI literacy and competency in K–12 education, addressing limitations in existing definitions that often stem from engineering-oriented perspectives unsuitable for non-technical audiences. Drawing on data from 30 experienced AI educators across 15 middle schools, the study employed an iterative co-design methodology across four cycles to collaboratively refine the framework. The authors distinguished between *literacy*—defined as knowledge and skills related to AI—and *competency*—defined as the confident and beneficial application of such knowledge, incorporating self-reflective mindsets. Their framework comprises five core components essential for AI education: technology, impact, ethics, collaboration, and self-reflection. Additionally, they identified five types of effective learning experiences aimed at nurturing both ability and confidence in students. The framework not only aligns with the realities of contemporary generative AI technologies (e.g., ChatGPT, Sora) but also integrates teacher perspectives to ensure educational relevance and pedagogical feasibility. Finally, the authors outlined five priority areas for future research: prompt engineering, data literacy, algorithmic literacy, self-reflective learning, and empirical validation. This study contributes significantly to the development of theoretically grounded and practically applicable models for AI education in school settings.

Almatrafi, Johri, and Lee (2024) conducted a systematic review to synthesize recent developments in AI literacy research, focusing on conceptualizations, implementation efforts, and assessment strategies between 2019 and 2023. Drawing from a corpus of 47 peer-reviewed articles, the review mapped the evolving landscape of AI literacy across diverse populations, including learners from pre-kindergarten through adulthood. The analysis revealed three overarching thematic contributions in the literature: (a) efforts to conceptualize AI literacy, (b) initiatives aimed at promoting AI literacy education, and (c) the development of assessment tools for evaluating AI literacy. Through content analysis, the authors derived a six-construct framework encompassing the core dimensions of AI literacy: *Recognize*, *Know and Understand*, *Use and Apply*, *Evaluate*, *Create*, and *Navigate Ethically*. This taxonomy enabled the classification of empirical studies according to which aspects of AI literacy they targeted, revealing varied emphases across educational levels and populations. The review also examined existing AI literacy assessment instruments, highlighting gaps in validation and coverage of ethical and creative dimensions. By offering a structured synthesis of both conceptual and practical developments, the study provides a comprehensive foundation to guide future research, curriculum design, and policy-making in AI education. It underscores the need for inclusive, adaptable, and holistic approaches to fostering AI literacy across formal education and workforce contexts.

Allen and Kendeou (2024) proposed the ED-AI Lit framework, a multidisciplinary and holistic model for AI literacy in education, addressing the growing need to prepare students, educators, and policymakers for the increasing integration of AI technologies in learning environments. Framing AI as a transformative force in education, the authors argued that AI literacy must extend beyond technical skills to include cognitive, social, and ethical dimensions. The ED-AI Lit framework comprises six interrelated components: *Knowledge* (understanding AI systems and their functions), *Evaluation* (critical appraisal of AI applications and impacts), *Collaboration* (interfacing effectively with AI systems and human actors), *Contextualization* (situating AI use within relevant educational, cultural, and societal contexts), *Autonomy* (maintaining human agency and decision-making), and *Ethics* (considering moral implications and promoting responsible AI use). This interdisciplinary model was developed to inform educational research, instructional practice, and policy development, emphasizing the importance of preparing individuals to engage meaningfully and critically with AI. By integrating perspectives from cognitive science, education, and human-computer interaction, the ED-AI Lit framework advances the conversation on what comprehensive AI literacy should entail and serves as a guide for future work in AI literacy development across educational contexts.

Kong et al. (2024a) evaluated the development of an AI literacy framework through the implementation of a 14-hour project-based learning (PBL) course designed for senior secondary students. Recognizing the growing need for AI literacy in preparing individuals for future workforce demands, the study aimed to assess students' competencies in AI-informed problem-solving and their understanding of ethical considerations. A total of 128 students participated in the course, which emphasized applying AI concepts to real-life scenarios through collaborative projects. Using a mixed-methods approach, the study found that students demonstrated significant improvements in their problem-solving abilities, metacognitive strategies, and ethical awareness. Post-course assessments and self-surveys indicated enhanced empowerment in using AI tools to address complex challenges, while focus group interviews and reflective writing

supported the conclusion that the PBL approach fostered critical thinking about the ethical implications of AI. The findings underscore the value of experiential, inquiry-driven pedagogy in cultivating both technical and ethical dimensions of AI literacy. The authors proposed that this evidence-informed course structure could serve as a foundation for a holistic AI literacy framework and recommended broader validation of the evaluation instruments in future studies to ensure generalizability.

4. Conclusion

As artificial intelligence continues to permeate the social, cultural, and economic infrastructures of contemporary life, the demand for a nuanced, comprehensive understanding of AI literacy becomes increasingly urgent. This study has illuminated the multifaceted nature of AI literacy, revealing it not as a singular technical skillset, but as a constellation of cognitive, ethical, sociocultural, and practical competencies required to navigate an AI-integrated world. AI literacy, in its fullest sense, encompasses the ability to interpret, critique, and ethically engage with systems that are simultaneously technical and political. Far from being the exclusive domain of technologists, AI literacy must be cultivated across the general population if democratic societies are to preserve agency, transparency, and justice in the face of algorithmic governance.

The scoping review highlights both progress and fragmentation within the emerging field of AI literacy education (Zamani, Hosseini, and Rahmatian, 2024). While various frameworks and pedagogical models have been proposed, there remains a significant lack of coherence in definitions, competencies, and assessment strategies across educational levels. The literature reveals efforts that are creative and contextually grounded, yet uneven in rigor and reach—often reflecting broader inequalities in access to resources, institutional readiness, and educator preparedness. Moreover, critical dimensions such as ethics, power, and inclusivity are frequently underemphasized in favor of narrow technical competencies. This imbalance underscores the need to reframe AI literacy not only as a curricular goal but as a broader educational imperative that connects epistemology, civic engagement, and human agency.

Looking forward, the task for educators, policymakers, and researchers is twofold: first, to consolidate a shared, inclusive understanding of what AI literacy entails in diverse learning contexts; and second, to design pedagogical approaches that are adaptable, critically engaged, and empirically validated. This includes developing interdisciplinary curricula, training educators in both content and pedagogy, and designing assessment tools that capture not just knowledge, but critical awareness and ethical reasoning. Ultimately, fostering AI literacy is not only a matter of preparing individuals for a changing labor market, but of equipping them to ask fundamental questions about the role of technology in society—and to shape its trajectory with insight, responsibility, and care.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

References

[1] Allen, L. K., & Kendeou, P. (2024). ED-AI Lit: An Interdisciplinary Framework for AI Literacy in Education. Policy Insights from the Behavioral and Brain Sciences, 11(1), 3–10. https://doi.org/10.1177/23727322231220339

[2] Almatrafi, O., Johri, A., & Lee, H. (2024). A systematic review of AI literacy conceptualization, constructs, and implementation and assessment efforts (2019–2023). Computers and Education Open, 6, 100173. https://doi.org/10.1016/j.caeo.2024.100173

[3] Bahmani, H. and Javaheri Tehrani, F. (2025). Cancer, Suffering, and the Role of Social Media: Insights from Iranian Nurses. Journal of Cyberspace Studies, 9(2), 487-503. doi: 10.22059/jcss.2025

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

[5] Chiu, T. K. F., Ahmad, Z., Ismailov, M., & Sanusi, I. T. (2024). What are artificial intelligence literacy and competency? A comprehensive framework to support them. Computers and Education Open, 6, 100171. https://doi.org/10.1016/j.caeo.2024.100171

[6] Druga, S., Vu, S. T., Likhith, E., & Qiu, T. (2019). Inclusive AI literacy for kids around the world. In Proceedings of FabLearn 2019 (pp. 104–111). https://doi.org/10.1145/3311890.3311904

[7] Farrell, H. (2025). AI as Governance. Annual Review of Political Science, 28(1), 375-392

[8] Heyder, T., & Posegga, O. (2021). Extending the foundations of AI literacy. In Proceedings of the International Conference on Information Systems (ICIS 2021): IS and the Future of Work. https://aisel.aisnet.org/icis2021/is_future_work/is_future_work/9

[9] Hornberger, M., Bewersdorff, A., & Nerdel, C. (2023). What do university students know about Artificial Intelligence? Development and validation of an AI literacy test. Computers and Education: Artificial Intelligence, 5, 100165. https://doi.org/10.1016/j.caeai.2023.100165

[10] Khodabin, M., Sharifi Poor Bgheshmi, M. S. and Movahedzadeh, F. (2024). Critical AI Literacy: Preparing Learners for Algorithmic Societies. Journal of Cyberspace Studies, 8(2), 371-397. https://doi.org/10.22059/jcss.2024.102582

[11] Kong, S.-C., Cheung, M.-Y. W., & Tsang, O. (2024a). Developing an artificial intelligence literacy framework: Evaluation of a literacy course for senior secondary students using a project-based learning approach. Computers and Education: Artificial Intelligence, 6, 100214. https://doi.org/10.1016/j.caeai.2024.100214

[12] Kong, S.-C., Korte, S.-M., Burton, S., Keskitalo, P., Turunen, T., Smith, D., et al. (2024b). Artificial Intelligence (AI) literacy – an argument for AI literacy in education. Innovations in Education and Teaching International, 62(2), 477–483. https://doi.org/10.1080/14703297.2024.2332744

[13] Laupichler, M. C., Aster, A., Schirch, J., & Raupach, T. (2022). Artificial intelligence literacy in higher and adult education: A scoping literature review. Computers and Education: Artificial Intelligence, 3, 100101. https://doi.org/10.1016/j.caeai.2022.100101

[14] Long, D., & Magerko, B. (2020). What is AI Literacy? Competencies and Design Considerations. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (pp. 1–16). https://doi.org/10.1145/3313831.3376727

[15] Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review. Computers and Education: Artificial Intelligence, 2, 100041. https://doi.org/10.1016/j.caeai.2021.100041

[16] Ng, D. T. K., Leung, J. K. L., Su, M. J., Yim, I. H. Y., Qiao, M. S., & Chu, S. K. W. (2022). AI Education and AI Literacy. In AI Literacy in K–16 Classrooms (pp. 9–19). Springer, Cham. https://doi.org/10.1007/978-3-031-18880-0_2

[17] Ng, D. T. K., Su, J., Leung, J. K. L., & Chu, S. K. W. (2023). Artificial intelligence (AI) literacy education in secondary schools: a review. Interactive Learning Environments, 32(10), 6204–6224. https://doi.org/10.1080/10494820.2023.2255228

[18] Nosraty, N., Soroori Sarabi, A., Arsalani, A., Toosi, R., & Sharajsharifi, M. (2025). Artificial intelligence for disaster risk management in the beauty industry. International Journal of Advanced Multidisciplinary Research and Studies, 5(3), 1076-1086. https://doi.org/10.62225/2583049X.2025.5.3.4422

[19] Perchik, J. D., Smith, A. D., Elkassem, A. A., Park, J. M., Rothenberg, S. A., Tanwar, M., Yi, P. H., Sturdivant, A., Tridandapani, S., & Sotoudeh, H. (2023). Artificial Intelligence Literacy: Developing a Multi-institutional Infrastructure for AI Education. Academic Radiology, 30(7), 1472–1480. https://doi.org/10.1016/j.acra.2022.10.002

[20] Rahmatian, F., & Sharajsharifi, M. (2021). Artificial intelligence in MBA education: Perceptions, ethics, and readiness among Iranian graduates. Socio-Spatial Studies, 5(1). https://doi.org/10.22034/soc.2021.223600

[21] Rahmatian, F., & Sharajsharifi, M. (2022). Reimagining MBA education in the age of artificial intelligence: A meta-synthesis. Socio-Spatial Studies, 6(1). https://doi.org/10.22034/soc.2022.223610.

[22] Sakhaei, S., Soroori Sarabi, A., Tomraee, S., Khodabin, M., & Sharajsharifi, M. (2024). Disaster risk management and AI: A grounded theory approach to epidemic response. International Journal of Advanced Multidisciplinary Research and Studies, 4(3), 1699-1708. https://doi.org/10.62225/2583049X.2024.4.3.4420.

[23] Schüller, K. (2022). Data and AI literacy for everyone. Statistical Journal of the IAOS, 38(2), 477–490. https://doi.org/10.3233/SJI-220941

[24] Shahghasemi, E. (2025). AI; A Human Future. Journal of Cyberspace Studies, 9(1), 145-173. doi: 10.22059/jcss.2025.389027.1123

[25] Shahghasemi, E., Gholami, F., & Alikhani, Z. (2025). Global patterns of social media use and political sentiment. Discover Global Society, 3(1), 36. https://doi.org/10.1007/s44282-025-00171-y

[26] Shahghasemi, E., Heisey, D. R., & Mirani, G. (2011). How do Iranians and U.S. Citizens Perceive Each Other: A systematic Review. Journal of Intercultural Communication, 11(3), 1–13. https://doi.org/10.36923/jicc.v11i3.539

[27] Soroori Sarabi, A., Zamani, M., Ranjbar, S. and Rahmatian, F. (2023). Innovation – But with Risk: The Strategic Role of IT in Business Risk Management. Journal of Cyberspace Studies, 7(2), 253-275. https://doi.org/10.22059/jcss.2023.101605.

[28] Southworth, J., Migliaccio, K., Glover, J., Glover, J., Reed, D., McCarty, C., Brendemuhl, J., & Thomas, A. (2023). Developing a model for AI Across the Curriculum: Transforming the higher education landscape via innovation in AI literacy. Computers and Education: Artificial Intelligence, 4, 100127. https://doi.org/10.1016/j.caeai.2023.100127

[29] Sperling, K., Stenberg, C.-J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. Computers and Education Open, 6, 100169. https://doi.org/10.1016/j.caeo.2024.100169

[30] Stolpe, K., & Hallström, J. (2024). Artificial intelligence literacy for technology education. Computers and Education Open, 6, 100159. https://doi.org/10.1016/j.caeo.2024.100159

[31] Su, J., Ng, D. T. K., & Chu, S. K. W. (2023). Artificial Intelligence (AI) Literacy in Early Childhood Education: The Challenges and Opportunities. Computers and Education: Artificial Intelligence, 4, 100124. https://doi.org/10.1016/j.caeai.2023.100124

[32] Toosi, R., Tomraee, S., Khodabin, M. and Sakhaei, S. (2025). Telemedicine: An AI solution, at last?. Code, Cognition & Society, 1(1), 59-87. https://doi.org/10.22034/ccsr.2025.526987.1002.

[33] Wilton, L., Ip, S., Sharma, M., & Fan, F. (2022). Where Is the AI? AI Literacy for Educators. In M. M. Rodrigo, N. Matsuda, A. I. Cristea, & V. Dimitrova (Eds.), Artificial Intelligence in Education. Posters and Late Breaking Results, Workshops and Tutorials, Industry and Innovation Tracks, Practitioners' and Doctoral Consortium. AIED 2022. Lecture Notes in Computer Science, vol 13356. Springer, Cham. https://doi.org/10.1007/978-3-031-

[34] Yi, Y. (2021). Establishing the concept of AI literacy. Jahr – European Journal of Bioethics, 12(2). https://doi.org/10.21860/j.12.2.8

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

[36] Zamani, M., Hosseini, S. H. and Rahmatian, F. (2024). The Role of Education in Successful Business Management. Journal of Cyberspace Studies, 8(2), 317-346. https://doi.org/10.22059/jcss.2024.101609.

[37] Zuboff, S. (2023). The age of surveillance capitalism. In Social theory re-wired (pp. 203-213). Routledge.