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Review Article

Dimensions of Artificial Intelligence Literacy: A Qualitative Synthesis of Contemporary Research Literature

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Abstract

Artificial Intelligence (AI) is transforming education, workforce development, and daily life, necessitating a comprehensive understanding of AI literacy. This study explores the dimensions of AI literacy, its integration into educational and professional settings, and the challenges associated with its implementation. Using a systematic review and qualitative synthesis, this study examines research published between 2019 and 2024, identifying six key dimensions of AI literacy: technical literacy, ethical and societal awareness, critical AI literacy, AI in everyday life, human-AI collaboration, and AI pedagogical literacy. Findings indicate that AI literacy is increasingly embedded in K-12 education, higher education, and workforce training, though disparities in accessibility, ethical concerns, and inconsistent policies persist. Key challenges include the digital divide, lack of teacher training, and lack of standardized AI literacy assessment tools. Opportunities lie in interdisciplinary learning, project-based education, and AI-driven adaptive learning environments. This study makes several unique contributions, including a comprehensive framework for AI literacy, integration of AI literacy across education and workforce domains, identification of policy gaps, and a call for standardized AI literacy assessment tools. It also emphasizes the need for ethical AI engagement and responsible AI education. Policymakers and educators should prioritize integrating AI literacy into curricula, professional development for teachers, and establishing regulatory frameworks to ensure equitable AI education. Future research should focus on longitudinal studies, cross-cultural AI literacy comparisons, and developing adaptive AI learning models to enhance AI education globally.

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Introduction

Background and Significance

Artificial Intelligence (AI) has emerged as a transformative force across various sectors, fundamentally reshaping the education landscape, workforce dynamics, and societal interactions. The rapid advancements in AI technologies have led to their integration in

diverse fields, from healthcare to finance, and even in educational settings, where AI tools are increasingly utilized to enhance learning experiences and administrative efficiency (Ng et al., 2021; Ok et al., 2025; Preiksaitis & Rose, 2023). As AI continues to evolve, its implications for educational practices and workforce readiness become more pronounced, necessitating a comprehensive understanding of AI's capabilities and limitations among educators, students, and professionals alike (Allen & Kendeou, 2024; Biagini, 2024).

The significance of AI literacy cannot be overstated in this context. AI literacy is increasingly recognized as a crucial component of digital literacy, encompassing the skills required to navigate and utilize digital technologies effectively (De Silva et al., 2024). In the 21st century, where digital technologies permeate every aspect of life, the ability to understand, evaluate, and engage with AI systems is essential for fostering informed citizens who critically assess the ethical and societal implications of these technologies (Asrifan et al., 2025; Shen & Cui, 2024). The need for AI literacy is underscored by the growing reliance on AI in decision-making processes, which raises concerns about transparency, accountability, and the potential for bias in AI algorithms (Uygun Ilikhan et al., 2024).

Moreover, as AI technologies become more prevalent in educational curricula, there is an urgent need to equip both educators and students with the necessary skills to engage with these tools responsibly and effectively (Choi et al., 2024; Park et al., 2023). This includes not only technical skills but also an understanding of the ethical dimensions of AI, such as privacy concerns, data security, and the societal impacts of AI deployment (Laupichler et al., 2024; Thararattanasuwan & Prachagool, 2024). Integrating AI literacy into educational frameworks is thus imperative for preparing learners to thrive in an increasingly AI-driven world.

Definition and Conceptual Foundations

AI literacy is a multifaceted concept that encompasses various definitions and interpretations within the academic literature. Broadly, it refers to the ability to understand, engage with, and critically evaluate artificial intelligence technologies and their implications in various contexts (Ng et al., 2021). Ng et al. (2021) articulate that AI literacy includes knowledge of AI principles, applying AI tools, and understanding the ethical considerations surrounding AI deployment. This definition is echoed by other scholars who emphasize the importance of technical proficiency, ethical awareness, and critical thinking in navigating AI technologies (Chetty, 2023).

There is a significant relationship between AI literacy and other forms of literacy, such as digital literacy, computational thinking, and data literacy. Digital literacy is a foundational skill set for AI literacy, as it encompasses the ability to effectively use digital technologies, which are integral to understanding AI applications (Yang et al., 2024). Computational thinking, which involves problem-solving and logical reasoning skills, is also closely related to AI literacy, as it enables individuals to comprehend how AI systems operate and make decisions (Huang & Ball, 2024). Data literacy, the ability to read, interpret, and analyze data, is crucial for understanding the data-driven nature of AI systems and their outputs (Xiao et al., 2024). Thus, AI literacy extends these literacies, integrating each element to equip individuals with the skills necessary to thrive in an AI-enhanced world.

Furthermore, the conceptualization of AI literacy is evolving as researchers explore its various dimensions. Biagini (2024) proposes a multidimensional approach to AI literacy that includes cognitive, behavioral, and ethical components, emphasizing the need for a holistic understanding of how individuals interact with AI technologies. This multidimensional framework aligns with the growing recognition that AI literacy is not merely about technical skills but also involves emotional and psychological competencies that influence how individuals approach AI (Ahmad & Aziz, 2019). As such, fostering AI literacy requires a comprehensive educational strategy that addresses these diverse dimensions.

Historical Evolution of AI Literacy

The historical evolution of AI literacy is traced through key milestones in AI research and education. AI literacy began to gain traction in the early 21st century as AI technologies became more prevalent in everyday life and various sectors, including education, healthcare, and business (Lérias et al., 2024). The rapid advancements in AI, particularly with the advent of machine learning and deep learning, have significantly influenced the literacy needs of individuals and organizations (Voulgari et al., 2021). For instance, introducing AI-driven tools in educational settings has prompted educators to rethink curricula and pedagogical approaches to incorporate AI literacy as a core competency (Du et al., 2024).

Significant advancements in AI, such as the development of natural language processing and computer vision, have further underscored the importance of AI literacy. These technologies have transformed how individuals interact with information and make decisions, necessitating a deeper understanding of AI's capabilities and limitations

(Subaveerapandiyan et al., 2023). As AI systems become more integrated into decision-making processes, the need for individuals to critically assess the ethical implications of AI technologies has become increasingly important (Laupichler et al., 2024). This shift has led to various educational initiatives promoting AI literacy across different age groups and professional sectors (Blancia et al., 2024).

In recent years, the COVID-19 pandemic has accelerated the integration of AI in education, highlighting the urgent need for AI literacy among educators and students alike (Dubey et al., 2024). As remote learning became the norm, the reliance on AI-powered educational tools increased, revealing gaps in AI literacy that needed to be addressed (Shen & Cui, 2024). Consequently, educational institutions have begun implementing AI literacy programs and curricula to equip learners with the necessary skills to navigate an AI-driven landscape (Zhou & Schofield, 2024). This historical context illustrates the dynamic nature of AI literacy and its ongoing evolution in response to technological advancements and societal needs.

Objectives and Research Questions

This literature review synthesizes existing research on the dimensions of AI literacy, providing a comprehensive overview of its various components and their implications for education and professional practice. By examining the current state of AI literacy research, this review aims to identify key themes, gaps, and future directions in the field, thereby contributing to the ongoing discourse on the importance of AI literacy in contemporary society (Dai et al., 2020).

The research questions guiding this review are as follows:

- What are the essential dimensions of AI literacy?
- How do these dimensions manifest in educational settings?
- What challenges and opportunities exist in integrating AI literacy into curricula?
- How do educators and policymakers effectively promote AI literacy among diverse populations?

Addressing these questions will provide valuable insights into the multifaceted nature of AI literacy and its critical role in fostering a technologically adept and ethically aware society (Atkinson-Toal & Guo, 2024).

Theoretical Framework

Theoretical Models Informing AI Literacy

The exploration of AI literacy is significantly informed by various theoretical models that provide a structured approach to understanding how individuals effectively engage with AI technologies. One prominent model is Computational Thinking, as articulated by Wing in 2006. This model emphasizes problem-solving skills that involve formulating problems in a way that enables a computer to help solve them, which is essential for understanding AI systems (Ng et al., 2024). Computational thinking encompasses concepts such as abstraction, algorithmic thinking, and decomposition, which are critical for learners to grasp the underlying principles of AI technologies and their applications in real-world scenarios (Ng et al., 2021).

Another influential framework is the Technological Pedagogical Content Knowledge (TPACK) model developed by Mishra and Koehler in 2006. This model integrates technology into teaching by highlighting the interplay between content, pedagogy, and technological knowledge (Biagini, 2024). In the context of AI literacy, TPACK encourages educators to develop a nuanced understanding of how AI tools enhance teaching and learning processes. It underscores the importance of knowing how to use AI technologies and how they are effectively integrated into pedagogical practices to foster more profound learning experiences (Deshen & Noa, 2024).

Additionally, socio-constructivist perspectives, particularly those influenced by Vygotsky (1978), play a crucial role in AI learning. This theoretical framework posits that knowledge is constructed through social interactions and cultural contexts (Xiao et al., 2024). In AI literacy, this perspective emphasizes collaborative learning environments where students engage with peers and educators to co-construct knowledge about AI technologies. Such interactions facilitate a deeper understanding of AI's ethical implications and societal impacts, as learners are encouraged to critically reflect on their experiences and the consequences of AI applications in their lives (Çelebi et al., 2023).

AI Literacy Competency Frameworks

Several competency frameworks have been developed to guide the implementation of AI literacy in educational contexts, each addressing different aspects of AI knowledge and skills. One notable framework is UNESCO's AI Competency Model, which outlines essential competencies for individuals to engage with AI technologies effectively. This model

emphasizes the need for a comprehensive understanding of AI concepts, ethical considerations, and the ability to apply AI in various contexts (Choi et al., 2024). UNESCO's framework guides educators and policymakers in designing curricula that foster AI literacy across different educational levels.

In the K-12 education sector, the AI4K12 and AI4All frameworks have emerged as significant initiatives to promote AI literacy among younger learners. The AI4K12 framework provides a structured approach to integrating AI concepts into K-12 curricula, emphasizing the importance of foundational knowledge in AI principles, ethics, and applications (Ding et al., 2024). Similarly, the AI4All initiative broadens participation in AI education, particularly among underrepresented groups, by providing resources and support for educators to teach AI concepts inclusively (Moser, 2021). Both frameworks highlight the necessity of fostering a diverse and equitable learning environment where all students develop essential AI competencies.

The OECD's AI Skills Framework is another critical resource that outlines the skills required for workforce readiness in an AI-driven economy. This framework identifies key competencies such as data literacy, critical thinking, and ethical reasoning, which are essential for individuals to navigate the complexities of AI technologies in professional settings (Subaveerapandiyan et al., 2023). By aligning educational practices with the skills outlined in this framework, educators better prepare students for the demands of the modern workforce, ensuring they possess the necessary skills to thrive in an AI-enhanced job market.

The theoretical models and competency frameworks discussed provide a comprehensive foundation for understanding and promoting AI literacy. By integrating computational thinking, TPACK, and socio-constructivist perspectives alongside established competency frameworks, educators develop effective strategies for teaching AI literacy that are responsive to the needs of diverse learners and the evolving technological landscape.

Methodology

This study employs a systematic review and qualitative synthesis approach to examine AI literacy dimensions, challenges, and best practices across educational and professional contexts. The methodology is structured to thoroughly analyze existing literature while identifying key themes and research gaps.

Research Design

A systematic review was conducted to synthesize contemporary research literature on AI literacy. This approach ensures a comprehensive and structured examination of existing studies, allowing for an in-depth understanding of AI literacy frameworks, educational implementations, and emerging challenges. The review follows established guidelines for systematic literature reviews in educational technology and digital literacy research (Ng et al., 2021).

A qualitative synthesis was also employed to interpret and categorize findings within broader themes, ensuring that both theoretical perspectives and practical implementations of AI literacy are adequately addressed.

Data Collection

The study follows a multi-stage data collection process to ensure a comprehensive review of AI literacy research:

Database Selection: Literature was sourced from peer-reviewed academic databases, including Google Scholar, Scopus, Web of Science, IEEE Xplore, and ERIC. These databases were selected for their extensive coverage of AI education, digital literacy, and technological pedagogy.

Inclusion Criteria: Studies were included based on the following criteria:

- Published between 2019 and 2024 to reflect the latest research developments.
- Peer-reviewed journal articles, conference proceedings, and book chapters.
- Studies focusing on AI literacy dimensions, educational contexts, ethical concerns, workforce training, and policy recommendations.
- Empirical studies, theoretical frameworks, and systematic reviews related to AI literacy.

Exclusion Criteria: Studies unrelated to AI literacy (e.g., general digital literacy without AI-specific content) and articles without full-text access were excluded.

The initial search yielded over 500 studies, which were then filtered based on relevance and methodological rigor. After applying exclusion criteria and manual screening, 64 studies were selected for final analysis.

Data Analysis

The selected studies were analyzed using thematic coding and content analysis, which involved:

- Identifying key AI literacy dimensions by categorizing studies into technical literacy, ethical awareness, and human-AI collaboration themes.
- Examining educational contexts (K-12, higher education, workforce development) to understand how AI literacy is implemented across different learning environments.
- Mapping challenges and research gaps related to accessibility, pedagogy, and regulatory frameworks.
- Extracting best practices and policy recommendations for integrating AI literacy into curricula and workforce training.

A thematic framework was developed based on the most frequently cited concepts and challenges, ensuring consistency in categorizing findings.

Research Validity and Reliability

To ensure the reliability and validity of the study:

- A cross-validation process was conducted, where two independent researchers reviewed and categorized the selected studies to minimize bias.
- Inter-coder reliability was measured using Cohen's Kappa coefficient, ensuring consistency in thematic coding.
- The review followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, ensuring a structured and transparent approach.

Ethical Considerations

Since this study is a secondary analysis of existing literature, there were no direct ethical concerns related to human participants. However, ethical considerations included:

- Ensuring proper attribution of sources through accurate citations.
- Avoiding misrepresentation of findings by critically evaluating sources.
- Maintaining objectivity and neutrality in thematic synthesis.

This methodology ensures a structured and rigorous examination of AI literacy research. By systematically reviewing existing literature and categorizing key themes, this study provides a comprehensive overview of AI literacy dimensions, challenges, and future directions, contributing to ongoing discourse on AI education and policy development. Future research should complement this review with empirical studies to validate the effectiveness of AI literacy interventions.

Findings

Table 1 and Figure 1 both categorize AI literacy research into four main themes, each with sub-themes reflecting diverse aspects of the field. The total number of resources analyzed is 64, with varying distributions across themes and sub-themes.

Table 1. Summary table showing the thematic distribution of AI literacy research across key dimensions, educational contexts, challenges, and emerging practices

Main Theme	Sub Theme	Citations	n	%
Dimensions of AI Literacy	Technical Literacy	Bulashevska et al. (2024); Haleem et al. (2023); Hattenhauer (2024); Lukkien et al. (2023)	4	6.25%
	Ethical and Societal Awareness	Huang et al. (2023); Ryan et al. (2021); Zhao et al. (2022)	3	4.69%
	Critical AI Literacy	Kurmis (2023)	1	1.55%
	AI in Everyday Life	Hannink et al. (2023); Panța and Popescu (2023); Teikari et al. (2019)	3	4.69%
	Human-AI Collaboration	Gallardo Paredes et al. (2023); Lameras et al. (2022); Poquet and de Laat (2021)	3	4.69%
	AI Pedagogical Literacy	Musigmann et al. (2023); Temitayo Temitayo Sanusi (2021); Woo et al. (2022)	3	4.69%
Dimensions of AI Literacy Total			17	26.56%
AI Literacy in Different Educational Contexts	AI Literacy in K-12 Education	Dai et al. (2024); Jeon et al. (2024); Pagliara et al. (2024); Scott and White (2024)	4	6.25%
	AI Literacy in Higher Education	Alm et al. (2021); Kavitha and Joshith (2024); Lim et al. (2024); Marengo et al. (2024); Noy et al. (2017); Rony et al. (2024); Schleiss et al. (2023); Semeniuk et al. (2024); Zhou et al. (2024)	9	14.06%
	AI Literacy for Workforce Development	Humble et al. (2023). Joseph and Uzondu, (2024), Lu et al. (2024); Oh and Sanfilippo (2024); Salhab (2024); Wei (2024); Valerio (2024)	7	10.94%
AI Literacy in Different Educational Contexts Total			20	31.25%
Challenges and Gaps in AI Literacy Research	Accessibility and Equity Issues	Biagini (2024); Folmeg et al. (2024); Xiao et al. (2024); Yang et al. (2024)	4	6.25%
	Ethical and Regulatory Challenges	Ciampa et al. (2023); Huang and Ball (2024); Ng et al. (2024); Su and Yang (2024)	4	6.25%
	Gaps in Pedagogical Approaches	Blancia et al. (2024); Boscardin et al. (2024); Ng et al. (2021); Yetişensoy and Rapoport (2023); Zhai et al. (2024)	5	7.81%
Challenges and Gaps in AI Literacy Research Total			13	20.31%
AI Literacy Research and Practice	Developing Comprehensive AI Literacy Curricula	Basnawi and Koshak (2024); Barrera Castro et al. (2024); Pliushch and Sorokun (2024); Wei (2023); Yuan et al. (2018)	5	7.81%
	Enhancing AI Literacy for Different Stakeholders	Masrek et al. (2024); Pan (2024); Trang and Thi Thu (2024);	3	4.69%
	Emerging Technologies and AI Literacy	Abbas et al. (2023); Adeleye et al. (2024); Bezzina et al. (2021); Bing et al. (2024); Familoni and Onyebuchi (2024); Kucirkova and Leaton Gray (2023);	6	9.38%
AI Literacy Research and Practice Total			14	21.88%
Grand Total			64	100.00%

The distribution of citations in Table 1 reveals that research on AI literacy in educational settings, notably higher education and workforce training, dominates the discourse. However, specific sub-themes, such as Critical AI Literacy and AI Literacy in K-12 Education, are underrepresented, indicating potential areas for further investigation. Additionally, challenges related to accessibility, ethics, and pedagogical strategies remain central concerns, while the rapid development of AI technologies continues to shape the evolving landscape of AI literacy education.

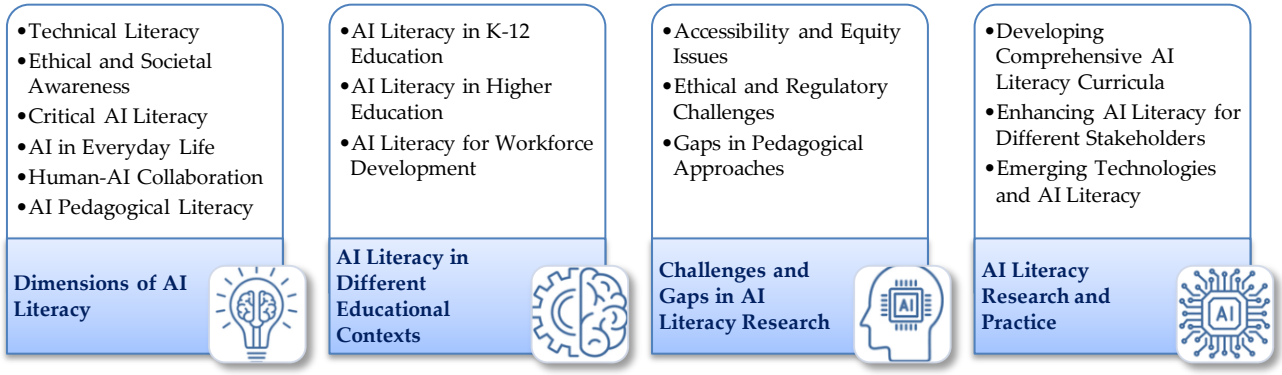

Figure 1. The main themes and sub-themes emerging from the qualitative synthesis of the research literature

Results

Theme 1 - Dimensions of AI Literacy

Artificial Intelligence (AI) literacy encompasses multiple dimensions, each essential for understanding and engaging with AI technologies in an informed manner. From technical proficiency and ethical awareness to critical evaluation and human-AI collaboration, these dimensions shape how individuals interact with AI in various aspects of life. This discussion explores the key components of AI literacy, emphasizing its relevance in education, industry, and everyday applications.

This theme represents 26.56% of the total citations (17 out of 64). Within this theme, Technical Literacy is the most frequently cited sub-theme, accounting for 6.25% (4 citations). Ethical and Societal Awareness, AI in Everyday Life, Human-AI Collaboration, and AI Pedagogical Literacy contribute equally with 4.69% (3 citations each). Meanwhile, Critical AI Literacy receives the least attention within this category, with only one citation (1.55%) suggesting a gap in research exploring how individuals critically engage with AI systems.

Technical Literacy

Technical literacy in the context of AI encompasses a foundational understanding of AI algorithms, models, and machine learning principles. This includes knowledge of how various algorithms function, the types of models used in AI applications, and the underlying

mathematical and statistical concepts that drive these technologies (Hattenhauer, 2024). For instance, understanding supervised and unsupervised learning, neural networks, and decision trees is crucial for individuals who wish to engage with AI technologies effectively (Bulashevska et al., 2024). Such knowledge enables users to utilize AI tools and critically assess their outputs and limitations.

Moreover, basic programming and data science knowledge are essential for applying AI in practical scenarios. Familiarity with programming languages such as Python or R, which are commonly used in AI development, allows individuals to manipulate data, implement algorithms, and create AI models (Haleem et al., 2023). Data science skills, including data cleaning, analysis, and visualization, are also integral to understanding how AI systems operate and how they are optimized for specific tasks (Lukkien et al., 2023). As AI continues to permeate various sectors, the demand for individuals with technical literacy in AI is expected to grow, making it a critical component of modern education and workforce development.

Ethical and Societal Awareness

Ethical and societal awareness is a crucial dimension of AI literacy that addresses AI technologies' ethical implications, including bias, fairness, accountability, and transparency. As AI systems increasingly influence hiring, law enforcement, and healthcare decision-making processes, understanding the potential for bias in AI algorithms becomes essential (Huang et al., 2023). For example, studies have shown that AI systems perpetuate societal biases if not designed and monitored carefully, leading to unfair outcomes for marginalized groups (Ryan et al., 2021). Therefore, fostering ethical awareness among users is vital for promoting responsible AI use.

Additionally, the impact of AI on privacy, surveillance, and digital rights is an area of growing concern. Integrating AI technologies into everyday life raises questions about data privacy and how individuals' personal information is collected, analyzed, and utilized (Zhao et al., 2022). Understanding these implications is critical for individuals to navigate the digital landscape responsibly and advocate for their rights in an increasingly surveilled society (Zhao et al., 2022). Ethical and societal awareness should be a fundamental aspect of AI literacy education, equipping individuals with the knowledge to engage critically with AI technologies and their societal impacts.

Critical AI Literacy

Critical AI literacy involves the ability to evaluate AI-generated content, recognize misinformation, and understand the nuances of algorithmic decision-making. In an era where AI-generated content, such as deepfakes and automated news articles, is becoming increasingly prevalent, the capacity to discern credible information from misleading or false content is essential; this dimension of AI literacy empowers individuals to assess the reliability of AI outputs critically and question the motivations behind their creation (Kurmis, 2023).

Furthermore, understanding algorithmic decision-making and its inherent biases is crucial for fostering critical AI literacy. Individuals must comprehend how algorithms make decisions, the data they rely on, and the potential biases that arise from these processes (Kurmis, 2023). This understanding enables users to engage with AI systems more thoughtfully, recognizing algorithmic decision-making's limitations and ethical considerations. Individuals become more informed consumers of AI technologies by cultivating critical AI literacy and advocating for transparency and accountability in AI applications.

AI in Everyday Life

AI's integration into everyday life is a significant dimension of AI literacy, encompassing practical applications across various domains such as communication, education, healthcare, and business. For instance, AI-powered tools like virtual assistants, recommendation systems, and chatbots have become commonplace in daily interactions, enhancing convenience and efficiency (Teikari et al., 2019). Understanding how these technologies work and their implications for personal and professional life is essential for navigating the modern landscape.

AI applications are revolutionizing patient care through predictive analytics, personalized treatment plans, and diagnostic support (Hannink et al., 2023). As AI continues to transform industries, individuals must be equipped with the knowledge to leverage these technologies effectively while understanding the ethical considerations they entail. The role of AI in automation and workforce transformation further underscores the importance of this dimension, as individuals must adapt to new technologies that reshape job roles and responsibilities (Panța & Popescu, 2023). Thus, fostering awareness of AI's practical applications is vital for preparing individuals to thrive in an AI-enhanced world.

Human-AI Collaboration

Human-AI collaboration is an emerging dimension of AI literacy that focuses on understanding human-in-the-loop AI systems and the concept of augmented intelligence. As AI technologies become more sophisticated, the collaboration between humans and AI systems is increasingly essential for achieving optimal outcomes (Gallardo Paredes et al., 2023). This collaboration involves recognizing the strengths and limitations of human judgment and AI capabilities, allowing for more informed decision-making processes.

Augmented intelligence enhances human cognitive abilities through AI technologies, enabling individuals to make better decisions and solve complex problems (Poquet & de Laat, 2021). Understanding how to collaborate with AI systems effectively requires individuals to develop skills in interpreting AI outputs, providing contextual insights, and integrating human expertise with AI capabilities. This dimension of AI literacy is particularly relevant in healthcare, where AI assists medical professionals in diagnosing conditions and recommending treatments while relying on human expertise for final decisions (Lameras et al., 2022). By fostering an understanding of human-AI collaboration, individuals better navigate the evolving landscape of work and decision-making.

AI Pedagogical Literacy

AI pedagogical literacy is a critical dimension for educators, focusing on their preparedness to integrate AI into teaching and learning environments. As AI technologies become more prevalent in education, teachers must develop the skills and knowledge necessary to effectively utilize AI-powered tools and resources (Temitayo Sanusi, 2021). This includes understanding how AI enhances personalized learning experiences, adapts to individual student needs, and facilitates data-driven instructional strategies.

AI-powered adaptive learning environments represent a significant advancement in educational technology, allowing for tailored learning experiences that respond to students' unique strengths and weaknesses (Woo et al., 2022). Educators must be equipped to leverage these technologies to create engaging and effective learning experiences while addressing AI's ethical implications in education. This involves fostering critical discussions about data privacy, algorithmic bias, and the role of AI in shaping educational outcomes (Musigmann et al., 2023). Educators better prepare students for a future where AI technologies are integral to learning and development by cultivating AI pedagogical literacy.

Theme 2 - AI Literacy in Different Educational Contexts

AI literacy is crucial in education and workforce development, shaping individuals' engagement with AI technologies across different contexts. From K-12 to higher education and professional training, AI literacy initiatives equip learners with essential technical, ethical, and critical thinking skills. This discussion explores the integration of AI literacy in diverse educational settings, emphasizing its impact on preparing individuals for an AI-driven world.

This theme comprises the most significant proportion of citations at 31.25% (20 out of 64), highlighting the emphasis on AI literacy across educational levels and workforce training. The sub-theme with the most citations is AI Literacy in Higher Education, which accounts for 14.06% (9 citations), reflecting the increasing integration of AI-related competencies in postsecondary education. AI Literacy for Workforce Development follows with 10.94% (7 citations), indicating a strong interest in equipping professionals with AI-related skills. The sub-theme AI Literacy in K-12 Education has the fewest citations in this category, with 6.25% (4 citations), implying a research gap in early AI education.

AI Literacy in K-12 Education

AI literacy initiatives in K-12 education are increasingly being integrated into school curricula, reflecting a growing recognition of the importance of understanding AI technologies among younger learners. These initiatives often aim to provide students with foundational knowledge about AI concepts, including machine learning, data analysis, and ethical considerations surrounding AI applications (Pagliara et al., 2024). For instance, educational frameworks such as AI4K12 advocate for incorporating AI education into K-12 curricula, emphasizing the need for students to develop critical thinking and problem-solving skills related to AI technologies (Pagliara et al., 2024). This approach prepares students for future careers in technology and equips them with the skills necessary to navigate an AI-driven world.

However, teaching AI concepts to children presents several challenges and opportunities. One significant challenge is the complexity of AI topics, which is difficult for younger students to grasp without appropriate pedagogical strategies (Dai et al., 2024). Educators must find ways to simplify these concepts while providing a comprehensive understanding of AI principles. Research has shown that analogy-based teaching methods enhance students' comprehension of AI mechanisms, making learning more engaging and

effective (Dai et al., 2024). Additionally, there is a need for professional development programs to equip teachers with the necessary skills and knowledge to teach AI effectively (Pagliara et al., 2024).

On the other hand, the integration of AI into K-12 education also presents numerous opportunities. By exposing students to AI technologies early on, educators foster a generation of learners who are not only technologically proficient but also ethically aware of the implications of AI in society (Scott & White, 2024). Furthermore, interdisciplinary approaches that combine AI education with subjects such as mathematics, science, and social studies enhance students' overall learning experiences and promote critical thinking skills (Jeon et al., 2024). As such, K-12 education systems have the potential to play a pivotal role in shaping AI literacy among future generations.

AI Literacy in Higher Education

Integrating AI literacy is becoming increasingly important in higher education as universities adapt their curricula to include AI-related courses and interdisciplinary approaches. Many institutions now offer specialized programs focusing on AI technologies, machine learning, and data science, reflecting the growing demand for skilled professionals (Kavitha & Joshith, 2024; Schleiss et al., 2023). These courses often emphasize technical skills and the ethical implications of AI, preparing students to navigate the complexities of AI applications in various industries (Kavitha & Joshith, 2024; Schleiss et al., 2023).

Interdisciplinary approaches in higher education are also gaining traction, as they encourage collaboration between different fields of study. For example, integrating AI with disciplines such as healthcare, engineering, and social sciences allows students to explore the multifaceted applications of AI technologies (Semeniuk et al., 2024; Zhou et al., 2024). This approach enhances students' understanding of AI and fosters critical thinking and problem-solving skills essential in today's job market (Noy et al., 2017). Additionally, interdisciplinary learning environments promote innovation by encouraging students to draw connections between diverse fields and apply AI solutions to real-world challenges (Lim et al., 2024).

The role of AI in enhancing student learning and assessment is another critical aspect of AI literacy in higher education. AI-powered tools provide personalized learning experiences, allowing students to progress at their own pace and receive tailored feedback (Alm et al., 2021). Moreover, AI assists educators in assessing student performance more effectively by analyzing data to identify learning patterns and areas for improvement

(Marengo et al., 2024). However, implementing AI in educational settings raises ethical concerns, particularly regarding data privacy and algorithmic bias (Rony et al., 2024). Therefore, higher education institutions must address these challenges while promoting AI literacy among students and faculty.

AI Literacy for Workforce Development

As the demand for AI skills rises, workforce development initiatives increasingly focus on AI literacy to prepare professionals for the evolving job market. Industry expectations for AI skills have grown significantly, with employers seeking candidates with a solid understanding of AI technologies and their applications (Lu et al., 2024). This shift highlights the importance of integrating AI literacy into professional development programs and training initiatives (Oh & Sanfilippo, 2024).

AI upskilling and reskilling programs are essential for professionals looking to adapt to the changing work landscape. Many organizations now offer training programs focusing on AI competencies, enabling employees to enhance their skills and remain competitive (Valerio, 2024). These programs often cover various topics, including data analysis, machine learning, and ethical considerations related to AI applications (Salhab, 2024). By investing in AI literacy, organizations improve employee performance and foster a culture of innovation and adaptability (Joseph & Uzondu, 2024).

Furthermore, integrating AI literacy into workforce development initiatives helps bridge the skills gap in many industries. As AI technologies continue to advance, there is a pressing need for a workforce equipped with the necessary skills to leverage these tools effectively (Humble et al., 2023). By prioritizing AI literacy in professional training programs, organizations ensure their employees are prepared to meet the demands of an increasingly AI-driven economy (Wei, 2024). This proactive approach benefits individual professionals and contributes to industries' growth and competitiveness in the global market.

Theme 3 - Challenges and Gaps in AI Literacy Research

Despite the growing emphasis on AI literacy, significant challenges and gaps remain in research and implementation across different contexts. Issues related to accessibility, ethics, regulation, and pedagogical effectiveness hinder AI education's equitable and comprehensive integration. This discussion highlights key obstacles in AI literacy research, emphasizing the need for inclusive, ethical, and evidence-based educational approaches.

This theme comprises 20.31% (13 out of 64) of the citations. The most cited sub-theme here is Gaps in Pedagogical Approaches, at 7.81% (5 citations), indicating concerns regarding how AI literacy is taught. Accessibility and Equity Issues and Ethical and Regulatory Challenges are cited equally, at 6.25% (4 citations each), reflecting ongoing discussions about inclusivity in AI education and the complexities of AI governance.

Accessibility and Equity Issues

Accessibility and equity issues represent significant challenges in pursuing AI literacy across educational contexts. The digital divide, characterized by disparities in access to technology and digital resources, exacerbates inequalities in AI education opportunities. Students from underprivileged backgrounds often lack the necessary tools and resources to engage with AI technologies effectively, leading to a widening gap in AI literacy (Biagini, 2024). This divide is particularly pronounced in rural and low-income urban areas, where schools may not have the infrastructure or funding to implement comprehensive AI education programs (Folmeg et al., 2024).

Moreover, socioeconomic and geographical disparities further complicate the landscape of AI literacy. Students from lower socioeconomic backgrounds may face additional barriers, such as limited exposure to technology and fewer role models in AI (Yang et al., 2024). Geographical disparities also play a role, as urban areas typically have more access to advanced educational resources and programs than rural regions (Xiao et al., 2024). Addressing these accessibility and equity issues is crucial for fostering a more inclusive approach to AI literacy that empowers all learners, regardless of their background.

Ethical and Regulatory Challenges

Ethical AI education is paramount as AI technologies become increasingly integrated into various aspects of society. Ethical considerations surrounding AI, such as bias, fairness, accountability, and transparency, must be addressed within AI literacy initiatives (Huang & Ball, 2024). Without a solid understanding of these ethical implications, individuals may inadvertently contribute to the perpetuation of biases and inequalities present in AI systems. Therefore, incorporating ethical discussions into AI literacy curricula is essential for preparing learners to navigate the complexities of AI responsibly (Ciampa et al., 2023).

Additionally, policies and regulations shaping AI literacy initiatives are still in their infancy. While some countries have begun to develop frameworks for AI education, there is a lack of standardized guidelines that ensure comprehensive AI literacy across different

educational contexts (Su & Yang, 2024). This regulatory gap leads to inconsistencies in the quality and scope of AI education, further exacerbating existing disparities. Moreover, as AI technologies evolve rapidly, regulatory bodies must keep pace with these changes to ensure educational practices remain relevant and practical (Ng et al., 2024). Establishing clear policies and ethical guidelines will be crucial for promoting responsible AI literacy and fostering a culture of accountability among educators and learners alike.

Gaps in Pedagogical Approaches

There are notable gaps in pedagogical approaches to AI literacy, particularly regarding the lack of comprehensive frameworks that address the needs of diverse age groups. While some frameworks exist for K-12 education, resources are scarce tailored to higher education and adult learning contexts (Blancia et al., 2024). This lack of a cohesive approach leads to fragmented learning experiences, where individuals may not receive the depth of understanding required to engage critically with AI technologies (Ng et al., 2021).

Furthermore, empirical studies on AI literacy interventions and their effectiveness are limited. While there is a growing body of literature on the importance of AI literacy, there is a need for more rigorous research that evaluates the impact of specific educational interventions (Zhai et al., 2024). Understanding which pedagogical strategies are most effective in fostering AI literacy will be essential for developing evidence-based practices that will be implemented across various educational settings (Boscardin et al., 2024). Additionally, research should explore how different demographic factors, such as age, gender, and socioeconomic status, influence the effectiveness of AI literacy interventions (Yetişensoy & Rapoport, 2023). By addressing these gaps in pedagogical approaches, educators better equip learners with the skills and knowledge necessary to thrive in an increasingly AI-driven world.

Theme 4 - AI Literacy Research and Practice

AI literacy research and practice must evolve to address AI's growing impact on education and society. Developing comprehensive curricula, engaging diverse stakeholders, and leveraging emerging technologies are key to fostering AI literacy. This theme explores these aspects, highlighting strategies for integrating AI education and ensuring equitable, ethical, and compelling learning experiences.

This theme comprises 21.88% (14 out of 64) of the citations. The most frequently cited sub-theme is Emerging Technologies and AI Literacy, accounting for 9.38% (6 citations), demonstrating the field's focus on the evolving nature of AI tools and their implications for education. Developing Comprehensive AI Literacy Curricula follows with 7.81% (5 citations), emphasizing efforts to standardize AI education. Enhancing AI Literacy for Different Stakeholders receives 4.69% (3 citations), suggesting that stakeholder-specific AI literacy initiatives remain an area of interest but require further exploration.

Developing Comprehensive AI Literacy Curricula

Developing comprehensive AI literacy curricula is essential for preparing learners to navigate the complexities of an AI-driven world. Strategies for integrating AI literacy into general education involve embedding AI concepts across various subjects rather than confining them to standalone courses. This interdisciplinary approach allows students to see the relevance of AI in different contexts, such as mathematics, science, and social studies (Barrera Castro et al., 2024; Wei, 2023). For instance, educators incorporate AI-related projects that require students to apply mathematical concepts to real-world problems, enhancing their understanding of AI and the subject matter (Pliushch & Sorokun, 2024).

Moreover, integrating AI literacy into curricula should also focus on developing critical thinking and problem-solving skills. This is achieved through project-based learning, where students engage in hands-on activities that require them to design, implement, and evaluate AI solutions (Yuan et al., 2018). Such approaches foster technical skills and encourage collaboration and creativity, which are vital in the modern workforce. Additionally, educators must be equipped with the necessary training and resources to effectively teach AI concepts, ensuring that they guide students in understanding AI technologies' ethical implications and societal impacts (Basnawi & Koshak, 2024).

Enhancing AI Literacy for Different Stakeholders

Enhancing AI literacy is not limited to students; it is crucial for various stakeholders, including policymakers, educators, and the general public. For policymakers, understanding AI literacy is essential for developing regulations and policies that promote equitable access to AI education and address ethical concerns related to AI deployment (Trang & Thi Thu, 2024). By fostering AI literacy among policymakers, they make informed decisions that support the responsible integration of AI technologies in society.

Educators also play a pivotal role in enhancing AI literacy. Professional development programs should focus on equipping teachers with the knowledge and skills necessary to teach AI concepts effectively. This includes understanding AI technologies, their applications, and the ethical considerations surrounding their use (Masrek et al., 2024). Furthermore, community-driven initiatives and outreach programs help raise awareness about AI literacy among the public, ensuring that individuals from diverse backgrounds access AI education and resources (Pan, 2024). Such initiatives include workshops, seminars, and online courses that cater to different learning needs and preferences.

Emerging Technologies and AI Literacy

Emerging technologies, particularly generative AI and large language models (LLMs) are reshaping the landscape of AI literacy education. Generative AI tools, such as ChatGPT, have the potential to enhance personalized learning experiences by providing tailored feedback and resources based on individual learners' needs (Bing et al., 2024; Kucirkova & Leaton Gray, 2023). These technologies facilitate adaptive learning environments where students receive real-time support and guidance, promoting deeper engagement and understanding of AI concepts (Familoni & Onyebuchi, 2024).

AI-driven personalized learning is expected to become a significant trend in the future of education. By leveraging data analytics and machine learning algorithms, educational platforms create customized learning pathways that align with each student's strengths, weaknesses, and learning styles (Bezzina et al., 2021). This approach not only enhances educational effectiveness but also addresses the diverse needs of learners, making education more inclusive and accessible (Abbas et al., 2023). However, as these technologies evolve, addressing ethical considerations, such as data privacy and algorithmic bias, is crucial to ensure that AI-driven personalized learning promotes equity and fairness in education (Adeleye et al., 2024).

In conclusion, integrating AI literacy into educational practices requires a multifaceted approach encompassing comprehensive curricula, stakeholder engagement, and emerging technologies. By fostering AI literacy across various contexts, educators prepare learners to thrive in an increasingly AI-driven world while addressing these technologies' ethical implications and societal impacts.

Discussion

Dimensions of AI Literacy

AI literacy encompasses multiple dimensions, equipping individuals with the necessary skills to engage effectively with AI technologies (Hattenhauer, 2024).

Technical Literacy involves understanding AI algorithms, models, and machine learning principles, including supervised and unsupervised learning, neural networks, and decision trees (Bulashevska et al., 2024). Knowledge of programming languages like Python and R and data science skills such as data cleaning and visualization are essential for implementing and assessing AI technologies (Haleem et al., 2023; Lukkien et al., 2023).

Ethical and Societal Awareness addresses concerns regarding AI biases, fairness, accountability, and transparency, particularly in high-stakes applications like hiring and law enforcement (Huang et al., 2023). Awareness of AI's impact on privacy and surveillance enables individuals to advocate for their digital rights and engage responsibly with AI systems (Ryan et al., 2021; Zhao et al., 2022).

Critical AI Literacy evaluates AI-generated content, recognizes misinformation, and understands algorithmic biases (Kurmis, 2023). With the rise of deepfakes and AI-generated news, individuals must critically assess AI outputs and question the motivations behind algorithmic decision-making (Kurmis, 2023).

AI in Everyday Life highlights AI's presence in communication, education, healthcare, and business (Teikari et al., 2019). From virtual assistants to predictive analytics in healthcare, AI enhances efficiency while raising ethical concerns (Hannink et al., 2023). Understanding its implications prepares individuals to navigate an AI-driven world effectively (Panța & Popescu, 2023).

Human-AI Collaboration emphasizes the synergy between human expertise and AI capabilities in decision-making processes (Gallardo Paredes et al., 2023). Augmented intelligence supports healthcare professionals by integrating AI insights with human judgment, enhancing cognitive abilities and problem-solving skills (Lameras et al., 2022; Poquet & de Laat, 2021).

AI Pedagogical Literacy is crucial for educators to integrate AI into teaching (Temitayo Sanusi, 2021). AI-powered adaptive learning enhances personalized education, requiring teachers to understand algorithmic biases, data privacy concerns, and ethical considerations in AI-driven instruction (Meylani, 2024; Musigmann et al., 2023; Woo et al., 2022).

AI Literacy in Different Educational Contexts

AI literacy initiatives in K-12 education are increasingly being integrated into school curricula, reflecting a growing recognition of the importance of understanding AI technologies among younger learners (Pagliara et al., 2024). Initiatives like AI4K12 emphasize critical thinking and problem-solving skills related to AI technologies, preparing students for AI-driven careers (Pagliara et al., 2024). However, AI education in K-12 presents challenges, including the complexity of AI topics and the need for teacher professional development programs (Dai et al., 2020). Effective pedagogical strategies, such as analogy-based teaching methods, improve student comprehension (Dai et al., 2020). Furthermore, integrating AI education with subjects like mathematics and social studies enhances critical thinking and ethical awareness (Jeon et al., 2024; Scott & White, 2024).

Higher education institutions increasingly incorporate AI-related courses and interdisciplinary approaches to prepare students for AI-driven industries (Kavitha & Joshith, 2024; Schleiss et al., 2023). Interdisciplinary learning fosters innovation by applying AI in diverse fields, including healthcare, engineering, and social sciences (Semeniuk et al., 2024; Zhou et al., 2024). AI-powered tools enhance personalized learning, enabling students to receive tailored feedback and progress at their own pace (Alm et al., 2021). However, ethical concerns such as data privacy and algorithmic bias require careful consideration in AI education (Marengo et al., 2024; Rony et al., 2024).

With increasing demand for AI skills, workforce development initiatives emphasize AI upskilling and reskilling to prepare professionals for the evolving job market (Lu et al., 2024; Oh & Sanfilippo, 2024). Training programs focusing on data analysis, machine learning, and ethical AI applications enhance workforce adaptability (Salhab, 2024; Valerio, 2024). Organizations investing in AI literacy foster innovation and competitiveness, ensuring employees remain relevant in an AI-driven economy (Humble et al., 2023; Joseph & Uzondu, 2024; Wei, 2024).

Challenges and Gaps in AI Literacy Research

Accessibility and equity issues represent significant challenges in pursuing AI literacy across educational contexts. The digital divide, characterized by disparities in access to technology and digital resources, exacerbates inequalities in AI education opportunities (Biagini, 2024). Students from underprivileged backgrounds often lack the necessary tools and resources to engage with AI technologies effectively, leading to a widening gap in AI

literacy (Folmeg et al., 2024). Socioeconomic and geographical disparities further complicate the landscape, as urban areas tend to have better access to AI education than rural regions (Yang et al., 2024). Addressing these issues is crucial for fostering an inclusive approach to AI literacy.

As AI becomes more integrated into society, ethical AI education is essential. Issues such as bias, fairness, and accountability must be incorporated into AI literacy initiatives (Huang & Ball, 2024). However, policies and regulations shaping AI literacy remain inconsistent globally, leading to discrepancies in educational quality (Su & Yang, 2024). Rapid advancements in AI necessitate dynamic regulatory frameworks to ensure responsible AI literacy (Ng et al., 2021; Ng et al., 2024). Establishing clear policies will foster a culture of accountability among learners and educators alike (Ciampa et al., 2023).

Pedagogical gaps in AI literacy stem from the lack of comprehensive frameworks for different age groups and learning contexts. While some frameworks exist for K-12 education, higher education and adult learning remain underdeveloped (Blancia et al., 2024). Empirical research evaluating AI literacy interventions is limited, hindering the development of evidence-based practices (Zhai et al., 2024). Investigating the impact of AI education across demographic factors, including age and socioeconomic status, will provide insights into effective pedagogical strategies (Boscardin et al., 2024; Yetişensoy & Rapoport, 2023). Closing these gaps will ensure that AI literacy initiatives are more effective and inclusive.

AI Literacy Research and Practice

Developing Comprehensive AI Literacy Curricula: Comprehensive AI literacy curricula prepare learners to navigate AI complexities (Barrera Castro et al., 2024; Wei, 2023). Interdisciplinary approaches embed AI concepts into various subjects, enhancing student engagement (Pliushch & Sorokun, 2024). Project-based learning fosters technical skills and ethical considerations (Basnawi & Koshak, 2024; Yuan et al., 2018).

Enhancing AI Literacy for Different Stakeholders: Policymakers need AI literacy to develop equitable regulations (Trang & Thi Thu, 2024). Educators benefit from professional development programs (Masrek et al., 2024), and community-driven initiatives promote AI awareness (Pan, 2024).

Emerging Technologies and AI Literacy: Generative AI and LLMs enhance personalized learning (Kucirkova & Leaton Gray, 2023). AI-driven adaptive learning supports individual

needs (Abbas et al., 2023; Familoni & Onyebuchi, 2024), but ethical concerns regarding data privacy and bias must be addressed (Adeleye et al., 2024).

Gaps in Research Literature and Suggestions for Future Research

Despite significant advancements in AI literacy research, several gaps warrant further investigation. One key area is the longitudinal impact of AI literacy education, as most existing studies focus on short-term outcomes rather than long-term retention and application of AI knowledge (Zhai et al., 2024). Future research should track learners over extended periods to assess how AI literacy influences their critical thinking, problem-solving skills, and career trajectories.

Another critical gap is the cultural and contextual variations in AI literacy approaches. Current studies predominantly focus on AI literacy in Western educational contexts, leaving a lack of research on how different cultural and socio-economic factors influence AI learning experiences (Biagini, 2024). Comparative studies between different education systems and demographic groups would provide valuable insights into tailored AI literacy strategies.

Furthermore, the role of AI in enhancing inclusive education requires deeper exploration. While AI is often promoted as a tool for personalized learning, research is needed to examine how AI-powered educational interventions impact learners with disabilities or marginalized communities (Pagliara et al., 2024). Future studies should assess the effectiveness of AI-driven adaptive learning systems in bridging educational disparities.

Additionally, ethical AI literacy and its real-world applications need further investigation. While many studies discuss AI ethics conceptually, there is limited empirical research on how individuals apply ethical principles when interacting with AI systems in professional and personal settings (Huang & Ball, 2024). Future research should explore case studies of AI ethics training and its influence on decision-making in various industries.

Finally, AI literacy assessment frameworks remain underdeveloped. Existing assessment tools primarily measure technical proficiency, but comprehensive frameworks that evaluate ethical reasoning, critical engagement, and social implications of AI literacy are needed (Ng et al., 2021). Future studies should focus on developing standardized assessment methodologies to ensure a holistic approach to measuring AI literacy across diverse learning environments.

By addressing these research gaps, scholars and educators will enhance AI literacy education, ensuring learners develop the knowledge and skills necessary to navigate an increasingly AI-driven world responsibly and effectively.

Suggestions for Policy and Practice

To enhance AI literacy education and ensure equitable access to AI knowledge, policymakers and educators must implement strategic measures that address systemic and practical challenges. The following recommendations provide a framework for improving AI literacy policies and instructional practices.

- *Integrating AI Literacy into National Education Policies:* Governments and education ministries should embed AI literacy into national curricula, ensuring that students at all levels receive structured AI education. Establishing AI competency standards within STEM subjects and humanities fosters interdisciplinary learning and prepares students for an AI-driven workforce (Barrera Castro et al., 2024).
- *Expanding Access and Reducing the Digital Divide:* To address accessibility and equity concerns, policymakers must invest in digital infrastructure, especially in underserved rural and low-income communities. Initiatives such as subsidized AI learning resources, open-access educational platforms, and public-private partnerships will help bridge the AI literacy gap (Biagini, 2024; Folmeg et al., 2024).
- *Enhancing Teacher Training and Professional Development:* AI literacy programs should include comprehensive professional development for educators, equipping them with the necessary knowledge and tools to teach AI concepts effectively. This includes integrating AI-related content into teacher certification programs and offering workshops on ethical AI use, algorithmic bias, and data privacy (Masrek et al., 2024).
- *Promoting Ethical AI Awareness and Regulation:* Governments and organizations should establish clear AI ethics policies addressing algorithmic bias, data security, and accountability in AI-driven decision-making. AI literacy programs must emphasize ethical considerations, ensuring that students and professionals critically engage with AI technologies in a socially responsible manner (Huang & Ball, 2024).
- *Supporting Lifelong AI Learning and Workforce Development:* AI literacy should not be confined to formal education settings but should extend to workforce training and lifelong learning programs. Employers and policymakers should collaborate to

develop upskilling AI initiatives tailored to different industries, enabling professionals to adapt to the evolving technological landscape (Lu et al., 2024; Oh & Sanfilippo, 2024).

- *Encouraging Interdisciplinary and Hands-on Learning Approaches:* Educational institutions should incorporate interdisciplinary, project-based learning approaches that allow students to apply AI knowledge in real-world contexts. Engaging students in AI-driven problem-solving fosters creativity, innovation, and a deeper understanding of AI applications across multiple fields (Basnawi & Koshak, 2024; Tümen Akyildiz, 2024; Yuan et al., 2018).
- *Establishing AI Literacy Research and Evaluation Mechanisms:* To ensure continuous improvement, policymakers and educators must develop standardized frameworks for assessing AI literacy. Research on AI education interventions should be encouraged, focusing on long-term impacts, cross-cultural comparisons, and the effectiveness of different teaching methodologies (Ng et al., 2021).

By implementing these policy and practice recommendations, stakeholders will create an inclusive AI literacy ecosystem that equips individuals with the skills necessary to navigate the complexities of AI technologies responsibly and effectively.

Conclusion

Key Findings and Answers to Research Questions

This study systematically reviews AI literacy dimensions, identifying key themes, challenges, and future directions. The findings address the study's core research questions.

1. What are the essential dimensions of AI literacy?

The study has identified six key dimensions of AI literacy:

- *Technical Literacy:* Foundational knowledge of AI algorithms, machine learning principles, and programming (Bulashevska et al., 2024; Haleem et al., 2023).
- *Ethical and Societal Awareness:* Understanding AI biases, fairness, privacy concerns, and digital rights (Huang et al., 2023; Zhao et al., 2022).
- *Critical AI Literacy:* Ability to assess AI-generated content, recognize misinformation, and understand algorithmic decision-making (Kurmis, 2023).
- *AI in Everyday Life:* Practical applications of AI in communication, healthcare, and business (Hannink et al., 2023; Teikari et al., 2019).

- *Human-AI Collaboration:* Integrating human expertise with AI decision-making in various fields, including healthcare (Gallardo Paredes et al., 2023; Poquet & de Laat, 2021).
- *AI Pedagogical Literacy:* Educators' preparedness to *incorporate* AI into teaching and learning environments (Temitayo Sanusi, 2021; Woo et al., 2022).

2. *How do these dimensions manifest in educational settings?*

AI literacy is increasingly integrated into educational contexts:

- *K-12 Education:* AI literacy initiatives, such as AI4K12, promote critical thinking and problem-solving skills. However, challenges include the complexity of AI topics and the need for teacher training (Dai et al., 2020; Pagliara et al., 2024).
- *Higher Education:* Universities incorporate AI-related courses, interdisciplinary learning, and AI-powered tools for personalized education. However, ethical concerns such as data privacy persist (Kavitha & Joshith, 2024; Rony et al., 2024).
- *Workforce Development:* AI upskilling and reskilling programs are essential for adapting to an AI-driven economy (Lu et al., 2024; Oh & Sanfilippo, 2024).

3. *What challenges and opportunities exist in integrating AI literacy into curricula?*

Challenges:

- *Digital Divide:* Socioeconomic disparities limit access to AI education (Biagini, 2024; Folmeg et al., 2024).
- *Ethical Concerns:* AI bias, fairness, and data security require careful policy implementation (Huang & Ball, 2024; Su & Yang, 2024).
- *Pedagogical Gaps:* Comprehensive AI literacy frameworks tailored to different learning stages are lacking (Blancia et al., 2024; Zhai et al., 2024).

Opportunities:

- *Interdisciplinary Learning:* AI concepts are integrated across subjects such as STEM and social sciences (Barrera Castro et al., 2024; Wei, 2023).
- *Project-Based Learning:* Hands-on engagement fosters technical and ethical AI competencies (Yuan et al., 2018).
- *AI-Powered Personalized Learning:* Adaptive AI tools cater to students' learning needs (Familoni & Onyebuchi, 2024).

4. *How do educators and policymakers promote AI literacy among diverse populations?*

- *Policy Integration:* National curricula must include AI literacy standards to ensure equitable access (Barrera Castro et al., 2024).
- *Teacher Training:* Professional development programs should equip educators with AI teaching competencies (Masrek et al., 2024).
- *Community Outreach:* Public engagement through AI workshops and open-access resources enhances awareness (Pan, 2024).
- *Regulatory Frameworks:* Governments should establish policies addressing ethical AI education and workforce preparedness (Huang & Ball, 2024; Trang & Thi Thu, 2024).

These findings emphasize the importance of a structured, inclusive, and interdisciplinary approach to AI literacy, ensuring that all learners, educators, and professionals are equipped to navigate an AI-driven future.

Limitations of the Study

While this study provides valuable insights into AI literacy's dimensions, challenges, and future directions, several limitations should be acknowledged.

- *Limited Empirical Data on AI Literacy Interventions:* This study's significant limitation is its reliance on existing literature rather than primary empirical data. While the review synthesizes findings from various sources, it lacks direct experimental or longitudinal studies that assess the impact of AI literacy interventions over time. Future research should incorporate experimental designs or long-term observational studies to evaluate the effectiveness of AI literacy programs across different educational and professional settings.
- *Variability in AI Literacy Definitions and Frameworks:* The study highlights the evolving nature of AI literacy, with multiple frameworks and conceptualizations presented in the literature. However, no universally accepted definition or standardized framework leads to inconsistencies in AI literacy assessment and curriculum development. This variability makes comparing findings across studies and developing unified policy recommendations complex.
- *Cultural and Contextual Bias in AI Literacy Research:* Most reviewed studies focus on AI literacy in Western or technologically advanced regions, limiting the generalizability of findings to diverse global contexts. More research is needed on how AI literacy manifests in developing countries, rural areas, and underrepresented communities, where access to AI technologies and education may be limited.

- *Ethical and Privacy Considerations in AI Literacy Education:* While the study emphasizes ethical AI literacy, limited research exists on how learners apply ethical principles in real-world AI interactions. Additionally, concerns regarding data privacy in AI-driven education remain underexplored. Future studies should investigate the ethical decision-making processes of AI-literate individuals and assess the privacy risks associated with AI-integrated learning environments.
- *Lack of Standardized AI Literacy Assessment Tools:* Although the study identifies multiple AI literacy dimensions, there is no universally accepted framework for measuring AI literacy across different age groups and professional sectors. The absence of validated assessment tools limits the ability to track progress and evaluate the effectiveness of AI literacy interventions. Future research should focus on developing standardized assessment methodologies that consider technical, ethical, and critical AI literacy competencies.
- *Rapid Evolution of AI Technologies and AI Literacy Needs:* The rapid advancements in AI technologies create challenges in maintaining up-to-date AI literacy curricula. Today's essential AI knowledge may become outdated within a few years. This study does not fully address the mechanisms by which AI literacy education adapts to technological changes. Future research should explore adaptive learning models and dynamic curricula that evolve with AI advancements.
- *Limited Examination of AI Literacy in Non-Educational Sectors:* While this study focuses on AI literacy in K-12 education, higher education, and workforce development, it does not extensively address AI literacy needs in other sectors, such as healthcare, law, and governance. Future studies should investigate AI literacy training in various professional domains as AI continues to influence multiple industries.

This study acknowledges these limitations and highlights the need for further empirical research, cross-cultural comparisons, and standardized assessment tools to advance AI literacy education and policy development.

Concluding Remarks

This study highlights the critical role of AI literacy in preparing individuals to navigate an increasingly AI-driven world. By examining the key dimensions of AI literacy—technical proficiency, ethical awareness, critical engagement, and practical applications—the

study underscores the need for comprehensive, interdisciplinary, and inclusive AI education across various contexts.

Despite significant progress in AI literacy research and practice, challenges such as accessibility gaps, ethical concerns, and the lack of standardized assessment frameworks persist. Addressing these challenges requires coordinated efforts from educators, policymakers, and industry leaders to integrate AI literacy into national curricula, professional development programs, and community-based learning initiatives.

Future research should focus on developing longitudinal studies, cross-cultural comparisons, and adaptive AI literacy models that respond to the rapid evolution of AI technologies. By fostering AI literacy at all levels of education and workforce development, societies will ensure that individuals are equipped with the knowledge and critical thinking skills necessary to engage with AI responsibly and ethically.

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Author Contribution Statement

Roza KAPLAN: *Conceptualization, literature review, language editing*

Ruşen MEYLANİ: *Data curation, methodology, implementation, data analysis, original draft, language editing, organization, and writing*

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