Computers and Education Open 6 (2024) 100173

Contents lists available at ScienceDirect

Computers and Education Open

journal homepage: www.sciencedirect.com/journal/computers-and-education-open

A systematic review of AI literacy conceptualization, constructs, and implementation and assessment efforts (2019–2023)

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ARTICLE INFO

Keywords:
Adult learning
Information literacy
21st-century abilities
Human-computer interface
Evaluation methodologies
Education

ABSTRACT

The explosion of AI across all facets of society has given rise to the need for AI education across domains and levels. AI literacy has become an important concept in the current technological landscape, emphasizing the need for individuals to acquire the necessary knowledge and skills to engage with AI systems. This systematic review examined 47 articles published between 2019 and 2023, focusing on recent work to capture new insights and initiatives given the burgeoning of the literature on this topic. In the initial stage, we explored the dataset to identify the themes covered by the selected papers and the target population for AI literacy efforts. We identified that the articles broadly contributed to one of the following themes: a) conceptualizing AI literacy, b) prompting AI literacy efforts, and c) developing AI literacy assessment instruments. We also found that a range of populations, from pre-K students to adults in the workforce, were targeted. In the second stage, we conducted a thorough content analysis to synthesize six key constructs of AI literacy: *Recognize, Know and Understand, Use and Apply, Evaluate, Create,* and *Navigate Ethically*. We then applied this framework to categorize a range of empirical studies and identify the prevalence of each construct across the studies. We subsequently review assessment instruments developed for AI literacy and discuss them. The findings of this systematic review are relevant for formal education and workforce preparation and advancement, empowering individuals to leverage AI and drive innovation.

Introduction

The use of artificial intelligence (AI) driven applications has increased across all aspects of society. The use of machine learning (ML) approaches, the cornerstone of many AI applications, is now common in everyday applications like shopping, social media, and banking, and in domains such as health and education [5,11–13,50,64]. As people start to use AI-driven technology, it is also important for them to learn more about how these applications work to become informed consumers and, subsequently, producers and creators, and be able to provide governance for AI use [32]. This is necessary not only to become better users but also to understand changes in the nature of work that will require novel AI-related skills [58]. There is also a need to understand the privacy and ethical issues around AI and learn to be a critical user [57].

Furthermore, within education, there is a need to adopt a critical approach to the content generated by AI systems, and both teachers and students need to be aware the outputs generated through these technologies, especially GenAI, are prone to inaccuracies and errors. Furthermore, the outputs can be full of bias, favoring majority and mainstream perpectives, and the awareness of this complication is largely lacking among both faculty and students [19]. Finally, from a critical justice perspective, users also need to account for human labor, the financial resources required, and the negative environmental impact of using AI [17].

To address this gap, there has been a significant growth in efforts related to AI literacy across educational levels, the workforce, and informal spaces. These efforts are targeted toward imparting certain competencies to learners that range from developing a basic understanding of AI to higher levels of competence that support the creation of AI applications [47]. Given the significant amount of recent work that has been ongoing in this area, this paper presents findings from a systematic review of articles published in the past five years to examine the efforts and draw lessons to guide research and practice.

Prior review papers on AI literacy have either provided a bibliometric analysis of publications from 1989 to 2021 [51], or focused on specific target groups such as higher and adult education [30], K-12

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https://doi.org/10.1016/j.caeo.2024.100173
Received 9 January 2024; Received in revised form 12 March 2024; Accepted 27 March 2024
Available online 31 March 2024

education [3], and early childhood education [48]. This review is different as we have thoroughly analyzed conceptual and empirical papers from various perspectives. First, we examined the definitions and frameworks, which resulted in identifying the fundamental constructs. Second, utilizing these constructs, we thoroughly examined and analyzed the empirical papers to ascertain the constructs they include along with other related information such as the target population. Building on prior work, especially other review papers, we targeted the following elements and research questions related to AI literacy in our analysis:

AI literacy definition and constructs

Given the broad applications of AI and the different fields associated with it, defining AI literacy and outlining what constitutes AI literacy has been a challenge. Not surprisingly, scholars have used different definitions, and a range of constructs related to AI literacy are widely used [28]. Although some frameworks have found more favor compared to others, the variance is high. This is often an artifact of the domain in which AI literacy is being applied or the level of implementation, such as the high school level of higher education [28]. Therefore, there is a need to review and assess the literature to document the definitions and constructs. This will allow the creation of a framework to link different constructs within AI literacy so that aspects of AI literacy within an article can be documented to aid future research and practice. This leads us to our first research question for the review:

RQ1: How has AI literacy been defined and conceptualized in the literature and what constructs are commonly included within AI literacy?

AI literacy implementation efforts

In addition to conceptual papers that are common within a new field, many AI literacy-related interventions have already been implemented. These efforts have increased significantly in the last few years, and therefore, it is important to build a better understanding of what kinds of AI literacy projects are in place or have been tried and with what lessons. For instance, what population of users or learners have been targeted through these efforts. At a more basic level, we also need to know what aspects of AI literacy have found favor and the range and depth of these efforts. We use the framework consisting of six key constructs of AI literacy we identified from the initial review (RQ1) to categorize and assess these studies. The second research question we address is:

RQ2: What target populations and AI literacy constructs are present in AI literacy implementations?

AI literacy assessment

Finally, we present instruments that have been developed or used to measure and assess AI literacy in different contexts and with different target populations. We also focus on how these instruments have been validated, if they have, and the AI literacy constructs they cover. This is important to both have an understanding of the current state of the field but also for future research. By focusing on instruments that are used more, we can provide future researchers with easily implementable tools but also highlight what might be missing in terms of AI literacy research studies. This can lead to further refinement of instruments and the development of new instruments.

RQ3. What are the different assessment instruments developed and used to study AI literacy?

In the rest of the paper we first explain our methodology and process, present our findings, and end with a discussion of the findings. One definitional issue we want to clarify upfront is that within the literature, AI literacy and AI competency are sometimes used interchangeably. In our review, we have focused only on papers that specifically use AI literacy. They might refer to or use the term AI competency, but the condition to include them was that they focused on AI literacy.

Methodology

This study uses a systematic review to summarize and assess research relevant to a particular topic or research question. The goal is to contribute to understanding the research area under study, identify themes and gaps, and offer suggestions for future research. In this section, we will describe the protocol used in this process, which involves selecting sources, identifying search terms, and defining inclusion criteria. After that, we executed the searches and selected the relevant articles. The next phase is to extract information concerning the analysis goals and synthesize the findings according to the research questions.

Articles selection

This study has considered English-language articles published from 2019 to 2023. Three databases were chosen for this purpose. Web of Science and Scopus were selected as they present high-quality and impactful scientific articles. Meanwhile, Google Scholar was chosen to ensure a more inclusive and extensive literature search.

The search terms used were (“artificial intelligence literacy” OR “AI literacy”). All articles that have these keywords in the title were screened. We adopted a set of inclusion and exclusion criteria to avoid biases in article selection. The exclusion criteria were 1) short papers or papers that are commentary, editorials, or workshop papers because they either reflect a personal opinion or do not have enough space to provide useful information for the review, and 2) papers that did not focus on AI literacy although the term was present in their text. For instance, papers that discussed other literacies, such as data and digital literacy were excluded [33,46].

A PRISMA diagram (Fig. 1) presents an overview of the search protocol [42]. The initial search returned 323 articles. After removing duplicates, we screened 197 articles by reviewing the title and the abstract. In the following step, we examined the complete text of 68 and excluded one article that was not retrieved and 20 articles that were irrelevant according to the exclusion criteria. This yielded the final corpus of 47 articles considered for the analysis and synthesis of its content. The search was conducted on August 8, 2023.

Coding methodology

To better organize the papers retrieved, they were initially coded into categories based on the target population and the main themes presented in each article. This approach helped us organize the content and more efficiently address our research questions.

The target population was categorized into several groups, including 1) Students at different educational levels, early childhood education, K-12, and higher education; 2) Workforce, which includes various professional disciplines such as radiologists, developers, or business administrators; 3) Teachers, who are a special case of the workforce

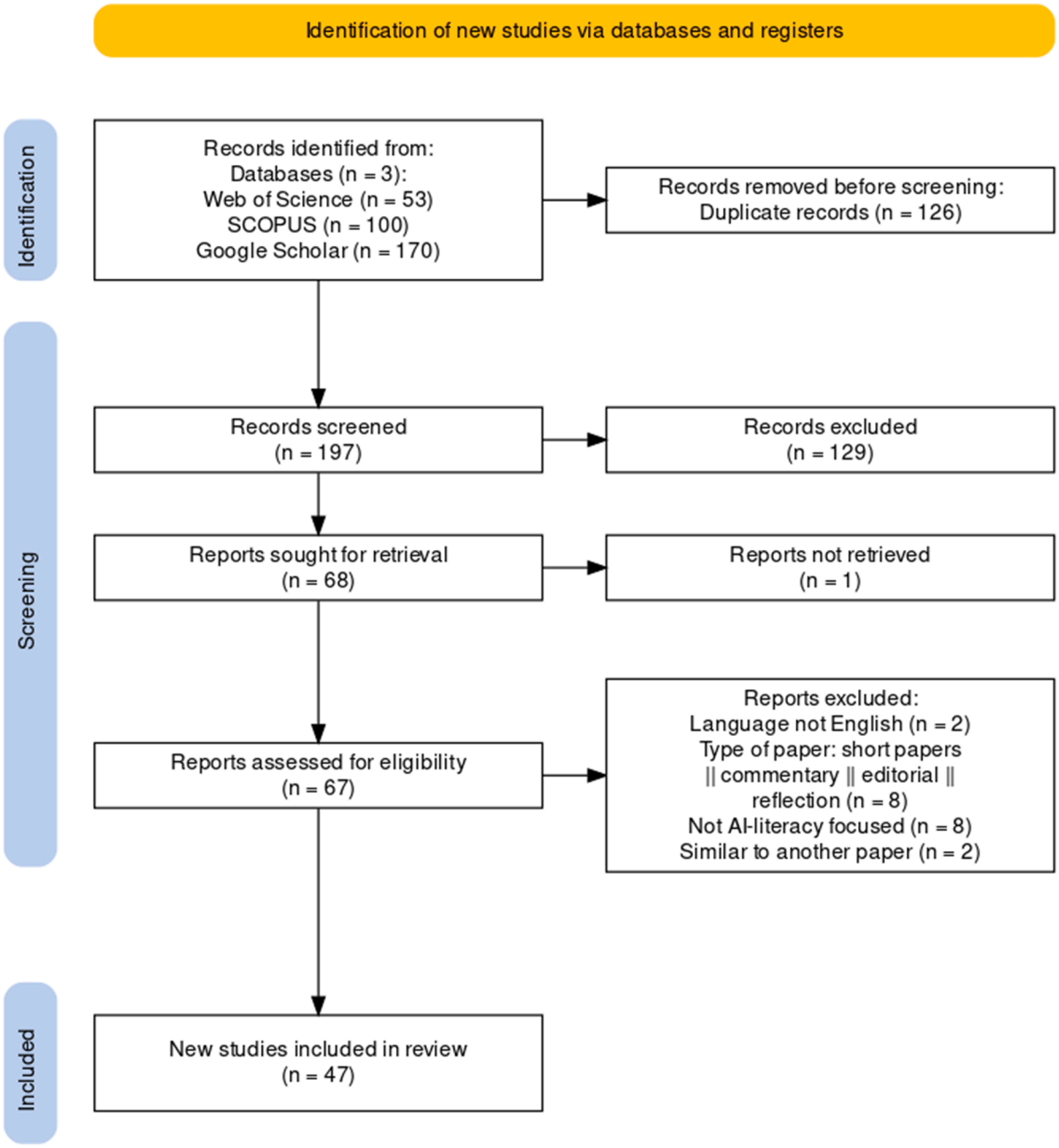

Fig. 1. Flow diagram showing the process of selecting eligible studies.

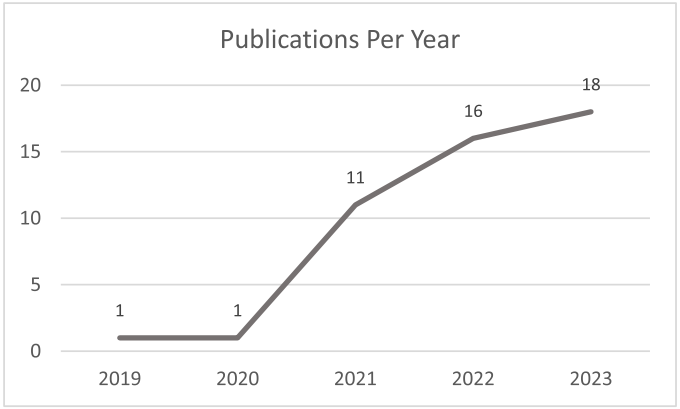

Fig. 2. Number of publications over the period (2019-August 2023).

interested in educating individuals; 4) Family, consisting of parents and their children; 5) Unspecified, for papers that do not specifically target any previous groups.

In terms of themes, the authors selected and analyzed a random sample of the studies to uncover the main themes. Three key themes emerged from the analysis, which are: 1) the conceptualization of AI literacy, 2) the initiatives aimed at promoting AI literacy, and 3) the development of instruments to assess AI literacy. The coding was reviewed by multiple authors to ensure reliability.

Descriptive analysis

This section provides a descriptive analysis to comprehensively understand the current state of research in AI literacy.

Publications over time

Fig. 2 demonstrates the increase in publications over the period, from 2019 to 2023, with 47 included papers. The topic gained attention in 2021, with 11 publications compared to only one in the first two years. This trend continued in the following years, with 16 and 18 papers published in 2022 and up to August 2023, respectively.

Target population distribution

The research population mainly comprised individuals from the education sector (see Fig. 3). There were 29 publications, targeting students from various educational levels: early childhood ($n = 3$), higher education ($n = 13$), and K-12 ($n = 15$) with few papers included K-12 in conjunction with another population. Additionally, some studies included families ($n = 4$), teachers ($n = 3$), and workforce ($n = 5$), while others did not specify the population ($n = 7$).

Theme distribution

We categorized the papers into 3 major themes (Fig. 4) – promoting AI literacy, conceptualizing AI literacy, and developing AI literacy assessment instruments. Sixty percent of the papers promoted AI literacy ($n = 28$), while 23 % of papers conceptualized AI literacy ($n = 11$), and 20 % developed AI literacy measuring instruments ($n = 9$). Some papers in the last category have also contributed to the conceptualization of AI literacy as part of the assessment instrument development. The remaining four papers were categorized into "Other," since they do not fall into any of the major themes. These four papers are review papers and have been mentioned in the introduction section.

In addition, plotting the distribution of the themes over the years (Fig. 5), shows that in 2021, researchers focused on defining and conceptualizing AI literacy, as well as promoting it. Another observed trend is the steady increase in the development of assessment tools intended to measure AI literacy, with 2023 marking the highest number of publications in this theme. Fig. 5 also indicates a notable increase in initiatives promoting AI literacy over the past two years. This suggests that there is a growing awareness of the importance of this topic in preparation for the future.

Findings

AI literacy definitions, frameworks, and constructs

> *RQ1: How has AI literacy been defined and conceptualized in the literature and what constructs are commonly included within AI literacy?*

To address RQ1, we compiled a comprehensive set of AI literacy definitions provided in our data. We then outlined conceptual frameworks that have been proposed to help understand the theoretical basis and constructs within different domains. Through this thorough examination, we identified six fundamental constructs for AI literacy, which serve as the basis for coding the remaining research questions.

Definitions

The definition of AI literacy has become a topic of discussion due to the widespread use of AI across various fields. According to Long and Magerko [35], who have put forth a widely accepted definition, AI literacy refers to "a set of competencies that enables individuals to critically evaluate AI technologies, communicate and collaborate effectively with AI, and use AI as a tool online, at home, and in the workplace" (p. 2). In other words, they have demarcated 'literacy' and 'competency' such that AI literacy consists of different competencies related to AI. Kong & Zhang [25] define AI literacy as, "understanding of AI concepts and competencies in using AI concepts for evaluation and using AI concepts for understanding the real world" (p.12). Wang et al. [55] used an information literacy framework in the educational domain and defined AI literacy as "the comprehensive expression of the knowledge and skills, processes and methods, emotional attitudes and values gradually formed in the process of students receiving AI education" (p. 36). In the context of workplaces and organizations, Cetindamar et al. [4] defined employees' AI literacy as "a collection of technology, work, human-machine, and learning capabilities. These capabilities could allow employees to actively join in on designing and utilizing AI at their workplaces" (p. 11).

Other scholars used different basis for their definitions such as the socio-technical perspective (IS theory) used by Pinski & Benlian [45] to define AI literacy as "humans' socio-technical competence consisting of knowledge regarding human and AI actors in human-AI interaction, knowledge of the AI process steps, that is input, processing, and output, and experience in AI interaction" (p. 165). Using the same theoretical framework in conjunction with Bloom's taxonomy, Weber et al. [56] differentiated between User AI literacy "as competencies regarding

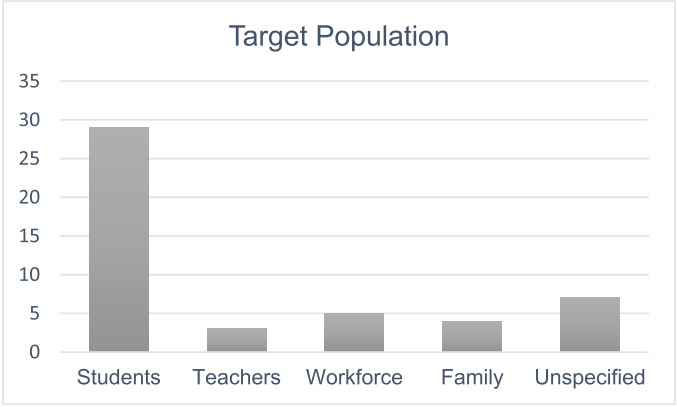

Fig. 3. Number of papers based on the target population.

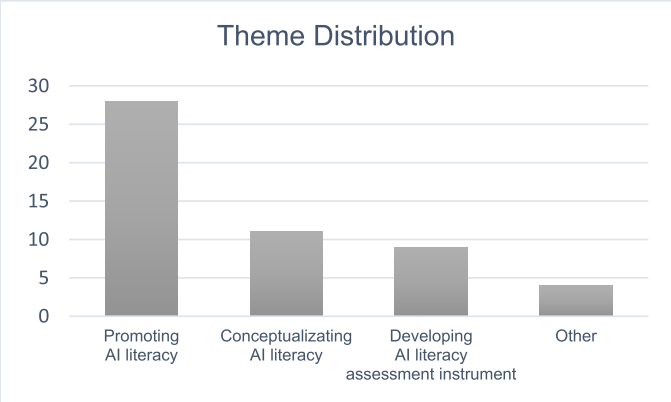

Fig. 4. Number of publications across themes.

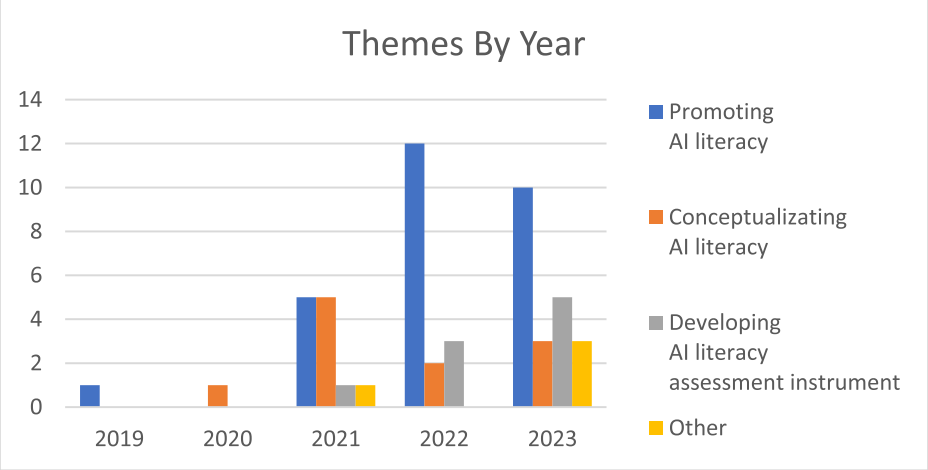

Fig. 5. The distribution of themes over the years.

recalling, understanding, and applying AI knowledge" (p. 7) and creator/evaluator AI literacy as "competencies regarding analysis, evaluation, and creation of human-AI systems" (p. 7). Wang et al. [54] provided a more detailed definition of AI literacy based on digital literacy frameworks and defined AI literacy as, "the ability to be aware of and comprehend AI technology in practical applications; to be able to apply and exploit AI technology for accomplishing tasks proficiently; and to be able to analyze, select, and critically evaluate the data and information provided by AI, while fostering awareness of one's own personal responsibilities and respect for reciprocal rights and obligations" (p. 3).

Overall, our analysis shows a wide variation in how AI literacy is defined depending on the purpose, target population, domain, and field of study. Yet, there are certain common characteristics across the definitions, such as a focus on awareness and ability and a focus on social awareness and the impact of the use of AI.

Conceptual frameworks

In this section, we will outline the various conceptual frameworks related to AI literacy proposed in the literature across domains. Frameworks enable educators and researchers to create impactful training programs and assessment tools and effectively communicate the fundamental components of the subject under study. Upon reviewing 11 articles that proposed conceptual frameworks for AI literacy, we found that the majority were tailored toward the education and industry sectors. Only three articles had a broader coverage ([25,35]; B. [54]). Notably, three articles targeted students, from K-12 to higher education [38,39,55]. One of these frameworks was specifically developed for evaluating K-12 students' AI literacy [55]. Five frameworks were designed to enhance AI literacy among the workforce or organizational staff members [4,15,45,56]. Lastly, one framework catered to the general public and families [8]. We now discuss these frameworks in detail with the goal of identifying the primary ideas and constructs they encompass.

Long and Magerko [35] introduced a broad framework for AI literacy. They identified 17 competencies people should learn, grouped into five main questions. The first question, "What is AI?", includes four competencies: Recognizing AI, Understanding Intelligence, Interdisciplinarity, and General vs. Narrow AI. The second question, "What can AI do?", covers two competencies: AI Strengths & Weaknesses and Imagining Future AI. The third question, "How does AI work?", encompasses nine competencies: Representations, Decision Making, Machine Learning Steps, The Human Role in AI, Data Literacy, Learning from Data, Critical Interpretation of Data, Action and Reaction, and Sensors. The fourth question, "How should AI be used?", is associated with one competency: Ethics. Finally, the fifth question, "How do people perceive AI?", is linked to one competency: Programmability.

Kong & Zhang [25], also proposed a broad framework for AI literacy that comprises three dimensions: cognitive, effective, and sociocultural. The cognitive dimension aims to impart fundamental AI concepts and equip learners with the skills to apply them for comprehending and evaluating the real world. The affective dimension focuses on empowerment, enabling individuals to collaborate seamlessly with AI in their day-to-day activities. Lastly, the sociocultural dimension endeavors to

promote the ethical usage of AI to foster sustainable global development.

In the field of education, one of the frequently utilized frameworks is The Five Big Ideas. Although the original article describing the framework is not included in the reviewed articles due to search term limitations (the paper does not have the word "literacy" in the title), we include it here as it has been cited by multiple papers in our sample for RQ2. The Five Big Ideas framework highlights the knowledge K-12 students should acquire to understand how AI works and how it can shape the future. It covers the following concepts [52]: *Perception* or how AI systems 'see' or 'hear' the world around them; *Representation and Reasoning* or how computers transform, organize, and analyze data from the world; *Learning* which refers to how a machine learns and how do design and train models; *Natural Interaction* or how AI systems communicate and interact with humans; and, *Societal Impact*, including the potential benefits and harms of AI to society. Overall, the authors emphasize the importance of hands-on experiences with AI technologies and the need for critical thinking regarding the impacts of AI applications.

Another conceptual model was proposed based on the literature and Bloom's taxonomy to categorize AI competencies into four cognition domains [38,39]. The dimensions are organized from low to high thinking skills: know & understand, use & apply, evaluate & create, and ethics. Wang et al. [55] developed an AI literacy evaluation framework that they tested on junior high school students. It is based on the information literacy evaluation frameworks. The evaluation consists of four dimensions: artificial intelligence awareness, intelligent technology application, innovative thinking, and intelligent social responsibility.

Within organizations and workplaces, researchers have proposed several conceptual frameworks to measure or help employees improve their AI literacy. For instance, one model is based on digital literacy frameworks and identifies five core competencies: AI technology knowledge (TK), Human actors in AI knowledge (HK), AI steps knowledge (SK), AI usage experience (UE), and AI design experience (DE) [45]. Another approach has conceptualized AI literacy based on IS theory (socio-technical perspective) that identifies two dimensions of human-AI interaction: part and type. The *parts* are socio-AI literacy and technical-AI literacy, while the *types* of stakeholders are creator/-evaluator or user [56]. Additionally, Cetindamar and colleagues [4] identified four sets of capabilities associated with employees' AI literacy in workplaces through a bibliometrics analysis: technology-related capabilities, human-related capabilities, work-related capabilities, and learning-related capabilities. Lastly, Heyder and Posegga [15] extended the conceptualization of AI literacy in organizations by reviewing the literature and interviewing experts. They identified three dimensions of the conceptual framework that include functional, critical, and sociocultural. The results suggest that organizations should focus on the sociocultural dimension for employees. Organizations can increase the likelihood of successful employee engagement with this technology by creating a work culture that values and supports the integration of AI into daily operations.

Finally, AI literacy conceptualization has been considered for families and the broader public. Druga et al. [8] proposed four dimensions based on the ecological systems theory: ask, adapt, author, and analyze. Another study suggested four main constructs of public AI: awareness, technical understanding, normative assessment, and making critical links to broader structures of power [14]. The researchers emphasized the importance of fostering critical thinking among the public regarding the wider power structures when evaluating the role of technology, which includes questioning its existence [14].

Core constructs

There are certain constructs that have been prominently discussed in the discourse of AI literacy. Their prevalence indicates their significance as core components that form AI literacy. It has been observed that 91 % of the reviewed papers have considered the ability to engage in a critical evaluation of AI tools, and ethical considerations as fundamental constructs. Moreover, "use & apply" was found in 82 % of the papers, followed by "know & understand," which appeared in 73 % of the analyzed papers, and lastly, "recognize" and "create" appeared in 64 % of papers as shown in Table 1.

Before we delve into the description of the core constructs, we want to mention that about 20 % of the articles were randomly selected to establish coding reliability, and two researchers completed blind coding. The scores indicate a substantial to perfect agreement across the various constructs [27]. Cohen's kappa coefficients were 0.62, 1, 0.74, 1, 0.78, and 0.62 for recognize, know & understand, use & apply, evaluate, create, and navigate ethically, respectively. In the cases of discrepancies, the researchers engaged in a discussion to resolve any disagreement and reach a consensus.

Recognize (Be aware). AI is often unnoticeably integrated into commonly used applications, making many users unaware when engaging with AI. Thus, it is crucial to differentiate between technological tools that utilize AI and those that do not, which has been acknowledged in the question, "What is AI?" [35]. Awareness involves identifying and comprehending AI technology while utilizing AI-related applications [54]. Pinski & Benlian [45] also covered this aspect in the technical knowledge dimension, which refers to the knowledge of what distinguishes AI and its role in human-AI collaboration and interaction. Being aware of the different types of AI applications will enable people to make informed interactions with this technology and avoid blind reliance.

Know & understand. Knowledge and understanding of AI fundamental concepts and techniques is a recurring component in most research papers. This entails acquiring basic skills, knowledge, and concepts that do not require prior knowledge [39]. For example, understanding how AI processes input data through machine learning techniques and represents the output [35,45]. Additionally, it's essential to understand that sensors play a role in providing data to the AI, which then acts upon it according to its programming [35]. It is also important to know that humans play a significant role in the development of AI.

Use & apply. This construct focuses on the operational aspect, specifically, the ability to use AI applications and tools and the ability to apply and integrate AI concepts to accomplish tasks [39,54]. This is also related to the role of humans in the human-AI collaboration and interaction [45], work-related capabilities [4], and the ability to adapt AI tools to achieve an objective [8].

Evaluate. Evaluation is a fundamental component of AI literacy and has been consistently highlighted in the relevant studies. It involves the ability to analyze and interpret the outcomes of AI applications critically. As per Druga et al. [8], the AI literacy framework should not merely concentrate on knowledge acquisition but also on critical evaluation and usage of AI systems. Having a comprehensive understanding of the technical aspects of AI enables individuals to examine and form informed opinions about their interactions with AI technologies [54].

Create. "Create" is a debatable construct. It emphasizes an individual's ability to design and code AI applications. Pinski & Benlian [45] acknowledged this construct through the "experience in designing and setting up AI" construct. Ng et al. [38,39] combined "evaluate and create" into one construct, representing higher-order thinking skills. However, Carolus et al. [2] study showed that "create" does not correlate to AI literacy and thus should be considered a separate construct related to AI literacy.

Navigate ethically (Understand ethical and societal implications). AI ethics and societal implications are crucial to educating citizens to become socially responsible and ethical users of AI. Human-centered considerations such as fairness, accountability, transparency, ethics, and safety

Table 1
A summary of AI literacy definitions, frameworks, and constructs. (Note: R: Recognize, K: Know & Understand, U: Use & Apply, V: Evaluate, C: Create, and E: Navigate Ethically).

#	Title	AI literacy Definition	Target Population	Theory	AI Literacy Constructs						Notes
					R	**K**	**U**	**V**	**C**	**E**	
1	What is AI Literacy? Competencies and Design Considerations [35]	Define AI literacy as "a set of competencies that enables individuals to critically evaluate AI technologies; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace" (p.2).	Unspecified	Based on literature	X	X		X		X	The mapping is based on the list of the 17 competencies.
2	AI Literacy: Definition, Teaching, Evaluation and Ethical Issues [38]	NA	K-12 to Higher education	Literature review		X	X	X	X	X	Identified four common constructs, which are know & Understand, Apply, Evaluate & Create and Ethics.
3	Conceptualizing AI literacy: An exploratory review [39]	NA	K-12 to Higher education	Bloom's taxonomy		X	X	X	X	X	More developed than the previous paper [38]. Instead of "Apply", they used "Use & Apply."
4	The 4As: Ask, Adapt, Author, Analyze - AI Literacy Framework for Families [8]	NA	Family	Based on Ecological systems theory			X	X	X	X	Identified four constructs: ask, adapt, author, and analyze.
5	Extending the foundations of AI literacy [15]	NA	Workforce	Based on Literature and expert interviews	X	X		X		X	Three dimensions: functional, critical, and sociocultural dimensions. Sociocultural dimention includes *attituteds towards AI and corporate culture*.
6	A Conceptual Framework for Designing Artificial Intelligence Literacy Programmes for Educated Citizens [25]	"AI literacy as understanding of AI concepts and competencies in using AI concepts for evaluation and using AI concepts for understanding the real world" (p. 12).	Unspecified	NA		X	X	X		X	It involves three dimensions: cognitive, affective, and sociocultural.
7	Measuring user competence in using artificial intelligence: validity and reliability of artificial intelligence literacy scale [54]	"The ability to be aware of and comprehend AI technology in practical applications; to be able to apply and exploit AI technology for accomplishing tasks proficiently; and to be able to analyze, select, and critically evaluate the data and information provided by AI, while fostering awareness of one's own personal responsibilities and respect for reciprocal rights and obligations" (p. 3).	Unspecified	Based on digital literacy frameworks (e.g., technological–cognitive–ethical model)	X		X	X		X	The primary core constructs of AI literacy includes awareness, use, evaluation, and ethics.

(*continued on next page*)

Table 1 (*continued*)

#	Title	AI literacy Definition	Target Population	Theory	AI Literacy Constructs						Notes
					R	**K**	**U**	**V**	**C**	**E**	
8	Explicating AI Literacy of Employees at Digital Workplaces [4]	define the employees' AI literacy as "a collection of technology, work, human-machine, and learning capabilities. These capabilities could allow employees to actively join in on designing and utilizing AI at their workplaces" (p. 11).	Workforce	Based on Literature	X	X	X	X	X	X	Four dimensions: technology-, human-, work- and *learning- related capabilities*.
9	AI Literacy - Towards Measuring Human Competency in Artificial Intelligence [45]	General AI literacy is "humans' socio-technical competence consisting of knowledge regarding human and AI actors in human-AI interaction, knowledge of the AI process steps, that is input, processing, and output, and experience in AI interaction" (p. 165).	Workforce	socio-technical perspective (human-AI IS competence literature)	X	X	X	X	X		Five core competencies: technology knowledge (TK), Human actors in AI knowledge (HK), AI steps knowledge (SK), AI usage experience (UE), and AI design experience (DE).
10	Junior High School Artificial Intelligence Literacy: Connotation, Evaluation and Promotion Strategy [55]	"AI literacy is the comprehensive expression of the knowledge and skills, processes and methods, emotional attitudes and values gradually formed in the process of students receiving AI education" (p. 36).	K-12	Information Literacy Framework	X		X		X	X	The AI literacy evaluation framework encompasses four dimensions: AI awareness, intelligent technology application, practical innovative thinking and intelligent social responsibility.
11	Toward an Objective Measurement of AI Literacy [56]	They defined "User AI Literacy as competencies regarding recalling, understanding, and applying AI knowledge and Creator/Evaluator AI Literacy as competencies regarding analysis, evaluation, and creation of human-AI systems" (p. 7).	Workforce	IS theory (socio-technical perspective) and Bloom's taxonomy	X	X	X	X	X	X	Users should acquire the lower level of thinking skills while creators should acquair the higher ones. Ethics is common for both types of people, represented in the socio-AI literacy component.
	The percentage of a construct prevalence in 'Conceptualizing AI literacy' theme				0.64	0.73	0.82	0.91	0.64	0.91	

must be given priority [39]. In addition, key ethical issues related to AI, such as privacy, employment, misinformation, ethical decision-making, diversity, and bias, must be identified and described [35]. An AI-literate person must be able to understand and judge ethical issues to ensure that the use and development of future AI technology are based on principles such as inclusivity, equitable access, and minimizing the potential for bias [4,54].

AI literacy implementation

RQ2: What target populations and AI literacy constructs are present in AI literacy implementations?

A significant majority, 75 %, of the papers pertaining to this theme have been geared toward students. The aim to promote AI literacy has been observed almost equally in K-12 and higher education groups. In more specialized training, radiology students reported a lack of exposure to AI in their training and a willingness to learn about it [44,60]. Furthermore, a review study showed that while most AI literacy in K-12 education between 01/2020–01/2022 aimed to educate students about the technical aspects of AI systems, few focused on applying this knowledge to new areas (i.e., "Create") or considering sociocultural perspective (i.e., "Navigate Ethically") [41].

In early childhood education, Su & Yang [49] proposed an AI4KG curriculum that provides AI teachers with lesson plans, including

learning goals, learning activities, and teaching methods. It was found that kindergarten children can understand basic AI knowledge but cannot understand complex notions, such as data.

In K-12 education, several studies shared educational materials such as lesson plans and learning activities that educators can use to promote AI literacy for school students. Examples include a workshop curriculum [53], the Day of AI resources, which showed positive impacts of its adoption in classroom teaching [9], an AI literacy program of three courses for secondary students [21], and design-based learning [1]. There were also studies targeting K-12 education that have been proposed without an empirical evaluation of their effectiveness. For instance, Yetişensoy & Rapoport [62] presented lesson plans and activities to incorporate AI literacy in social studies classrooms, Eguchi et al. [10] proposed an AI curriculum based on culturally responsive approaches, [43] proposed a framework based on episodes of situated learning, and Druga et al. [7] suggested guidelines and learning activities for inclusive AI literacy.

There were several programs in higher education, including a program for university students to promote AI literacy across disciplines, but they have not yet been empirically evaluated [47]. Another example have designed a program consisting of three courses and assessed the development of students' conceptual understanding, literacy, empowerment, and ethical awareness throughout the courses [22–24]. Other AI courses have been evaluated for non-CS major undergraduates [31] and medical students [28].

Upon reviewing the different educational initiatives, several interesting findings have been revealed. First, programming knowledge is not a prerequisite to learning AI concepts [21]. Children as young as three can understand AI concepts [49]. Second, although these efforts showed that students were able to develop technical skills and ethical awareness [1,22], it seems that high-level ethical principles are challenging for K-12 students [21,53]. Project-based learning and developing applications effectively improved students' understanding and ethical awareness [23,31]. In fact, applying has shown a significant, positive effect on the other dimensions of AI literacy, namely, understanding, evaluating AI applications, and the ethics [65]. Third, one course is sufficient to empower participants and increase their perception of their own AI literacy [23]. Moreover, taking a single course showed a decrease in AI-related knowledge disparities between CS students and non-CS students as well as between women and men [24].

Moreover, some studies focused on evaluating the effectiveness of various teaching strategies in promoting AI literacy, which can help educators teach AI to students. Among these strategies include digital story writing for K-12 [40], flipped classrooms [20,26], and project-based learning for undergraduates [26]. The findings suggest that these approaches are highly effective in fostering AI literacy, which can be of significance to educators interested in developing and implementing effective educational practices. In addition, Wilton et al. [59] proposed a course for educators to better understand the implications of integrating AI applications into teaching.

A few studies have focused on ways to increase public awareness and understanding of AI, particularly in families. One study evaluated five exhibit prototypes [34], while another explored the potential for AI art to promote AI literacy [14]. Exhibits have been effective in improving the public's understanding and interest in AI. The researchers also noted the importance of focusing on ethical issues related to AI in the future and suggested that promoting discussion about these issues may contribute to the development of ethical AI design processes [14,34]. Additionally, some studies explored how parents can help their children develop AI literacy through engaging in learning activities [6,36].

A few research studies have explored students' perceptions of AI. For instance, a study revealed that students generally view AI as a technology that emulates human thinking, yet they may not fully grasp the significance of data in AI applications [37]. Another study demonstrated that students' perspectives on the intelligence and truthfulness of AI tools can differ based on their socioeconomic status [7]. Specifically, students from more affluent backgrounds may exhibit greater skepticism. These findings underscore the importance of implementing comprehensive AI literacy programs that promote inclusivity and provide accurate information to all.

How have core constructs been manifested in AI literacy interventions?

This section gives examples from the literature of how each construct (section 5.1.3.) manifested in the course, program, or curriculum design. As shown in Table 2, the majority of the efforts were focused on "Know & Understand". Then, come in second place "Use & Apply," "Evaluate," and "Navigate ethically," after that, "Recognize," and finally, "Create", which received the least amount of attention, with less than half of the efforts directed towards it.

Recognize. In order to facilitate AI literacy, preschool programs may introduce encounters with AI robots that are part of the children's daily lives [49]. It is recommended that K-12 and undergraduate students understand the fundamental principles of AI, including its defining characteristics and different types. They should also be able to recognize AI tools and applications [9,47,53,62]. Moreover, the public must be aware that AI is an integral component in various applications [14].

Know & understand. This category teaches technical aspects. Su & Yang [49] explained how machine learning works for preschoolers. In K-12 and higher education, this has been done by developing a basic understanding of how machine learning [1,10,31,40,48], deep learning [9,22,28], and transfer learning [53] work. In addition, students have been introduced to the data preparation [21,23], and the steps involved in applying machine learning techniques to the problem-solving [1,24,47]. For the general public, this has been demonstrated by showcasing the underlying mechanics [14] and experimenting with weights to observe their effect on the classification [34].

Use & apply. This construct allows learners to interact with AI machines and delve into practical applications. Tools like Teachable Machine have been introduced to preschool and K-12 classrooms, enabling students to train AI models; image classification is among the most widely used examples for practical applications [9,21,49]. Undergraduates are learning to select and apply AI tools and techniques in various contexts and applications [28,44,47], with one study showcasing students developing classification models and chatbots powered by natural language processing and AI [31]. Lastly, families have been experiencing the impact of AI technology through interactive exhibits that test the response of artifacts to different sounds.

Evaluate. Reflecting on how AI works and how data is collected and used is essential to convey this construct. Various courses have encouraged students to analyze and interpret the results of AI algorithms, identify potential biases, and compare different algorithms [1,7,21,43,44]. For undergraduate students, it is important to evaluate algorithms' limitations and assess the data quality [22,28,31,47]. In exhibits, activities have been designed to facilitate a connection between the weight of training data and potential bias [34], showing the public how agents make decisions [36].

Create. The courses and programs that activated the "Create" construct have engaged participants in developing AI projects [7,10,21,43]. This was accomplished through diverse methods, including requesting younger students to craft narratives and build prototypes for real-world problems [1,40]. In pursuit of this objective, undergraduates were assigned tasks to develop tools, hardware, data, and/or algorithms that employed AI solutions as a learning outcome [47]. Furthermore,

Table 2
A summary of AI literacy implementation efforts, and their mapping to the core constructs. (Note: R: Recognize, K: Know & Understand, U: Use & Apply, V: Evaluate, C: Create, and E: Navigate Ethically).

#	Title	Purpose	Target Population	AI Literacy Constructs						Examples of Constructs' Implementation	Implementation Results
				R	K	U	V	C	E		
1	Inclusive AI literacy for kids around the world [7]	Assessed children from multiple countries and socio-economic status perception and interaction with AI. Also, proposed guidelines for inclusive AI literacy.	K-12	X		X	X	X	X	From the inclusive AI literacy guidelines: 1) Instead of imitating human speech patterns, design intelligent systems that rely more on decision-making and emergent schema (Recognize), 2) Provide multiple ways for children to teach, customize, and program the machine (Use & Apply), 3) Make the reasoning behind the machine as transparent as possible and give children opportunities to understand different perspectives (Evaluation), 4) Involve participants in the process of developing AI technologies (Create), and 5) Emphasize the importance of learning, reflection, and collaboration (Ethics).	* Children from lower and middle socio-economic backgrounds are more collaborative but are less skeptical of AI's intelligence and truthfulness. * Three hands-on learning activities were proposed to foster inclusive AI literacy: lo-fi prototyping of AI agents, a mobile agent turtle activity, and role-playing activities where children embody the AI agents.
2	Teaching Tech to Talk: K-12 Conversational Artificial Intelligence Literacy Curriculum and Development Tools [53]	Evaluated the Conversational Agent Interface for MIT App Inventor and workshop curriculum with respect to some Long & Magerko AI competencies.	K-12	X	X	X	X	X	X	The course has 1) discussed whether various items (e.g., an automatic door) integrate AI or not (Recognize), 2) presented transfer learning and machine learning steps (Know & Understand), 3) asked students to contrast rule-based AI with ML-based AI (Evaluate), 4) programmed communication links between mobile apps and Alexa skills (Use & Apply), 5) developed final projects (Create), and 6) discussed the strengths and weaknesses of AI with respect to jobs (Ethics).	* Using an AI-design consideration-based curriculum proved effective in engaging students and teaching AI competencies. * AI ethics and machine learning emerged as the most challenging competencies for students
3	Contextualizing AI Education for K-12 Students to Enhance Their Learning of AI Literacy Through Culturally Responsive Approaches [10]	Proposed artificial intelligence literacy curriculum for middle school students in Japan.	K-12		X	X			X	Examples from the curriculum learning objectives: 1) Understand the basic mechanics of artificial intelligence systems (Know & Understand), 2) Apply both technical understanding of AI and knowledge of stakeholders in order to determine a just goal for a socio-technical system (Use & Apply), and 3) Consider the impact of technology on the world (Ethics).	* Designed a curriculum that is culturally responsive and promotes AI ethics awareness among middle school students in Japan.
4	The Effect of Artificial Intelligence Literacy Education on University Students' Ethical Consciousness of Artificial Intelligence [31]	Developed AI literacy program for non-major students.	Higher education	X	X	X	X		X	Examples from the program: 1) Understand the fundamental concepts and characteristics of artificial intelligence and explore various AI use cases (Recognize), 2) Know how machine learning methods work (Know &	* The study highlights the need for practical AI education in addition to theoretical knowledge. * The program led to a positive change in the perception of AI ethics sub-elements; particularly in "Safety and reliability," "responsibility and

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Table 2 (*continued*)

#	Title	Purpose	Target Population	AI Literacy Constructs						Examples of Constructs' Implementation	Implementation Results
				R	K	U	V	C	E		
										Understand), 3) Prepare data and train models (Use & Apply), 4) Understand the relationship between AI datasets and predictions (Evaluate), 5) Develop AI solutions for real-life problems (Create), and 6) Comprehend the positive and negative effects of AI technologies (Ethics).	publicity," "data utilization and bias," and "transparency and explanability." * Among these sub-elements, the "data utilization and bias" category showed the highest difference before and after the class.
5	Evaluation of an artificial intelligence literacy course for university students with diverse study backgrounds [24]	Evaluated an AI literacy course.	Higher education	X	X	X			X	Part (1) of an AI program * The participants were: 1) introduced to AI with a discussion of strong and weak AI (Recognize), 2) invited to share their views on the application and impact of AI (Ethics), 3) introduced to the five steps for applying machine learning to problem solving (Know & Understand), and 4) performed image recognition via online platforms (Use & Apply).	* The study revealed an increase in AI literacy, understanding, and empowerment. * The results also showed a decrease in the knowledge gap between CS students and non-CS students, as well as between gender groups.
6	Co-Designing AI Literacy Exhibits for Informal Learning Spaces [34]	Designed five exhibit prototypes—Magic Mirror, Sensor Wall, Neural Net, Semantic Network, and LuminAI—that aim to communicate a variety of different AI literacy competencies.	Family		X	X	X	X		Examples, 1) how weights would affect classification (Understand & Know), 2) drawing a connection between weight and bias in training data (Evaluate), 3) create personally meaningful networks depending on their interests (Create), and 4) participants tested out a variety of different sounds to see how the exhibit would respond (Use & Apply).	* The exhibit designs, which were based on the principles of interaction, collaboration, and creativity, proved effective in improving public understanding and interest in artificial intelligence. * The researchers have identified a need to address the aspects of "Recognize" and "Ethics" in the future.
7	Finnish 5th and 6th grade students' pre-instructional conceptions of artificial intelligence (AI) and their implications for AI literacy education [37]	Explored students initial conceptualization of AI.	K-12	X						1) What kind of technology is AI? 2) Where is AI? and 3) Why is AI used?	* Students had diverse perceptions of AI, often lacking knowledge about the role of data in AI training. * Students tended to view AI as technology with human-like abilities, influenced by media portrayals. * The study recommends exploring the technical principles behind AI solutions to help students better understand its behavior in daily life.
8	Integrating Ethics and Career Futures with Technical Learning to Promote AI Literacy for Middle School Students: An Exploratory Study [63]	Evaluated Developing AI Literacy (DAILy) workshop.	K-12	X	X	X	X		X	Examples from the curicculum include, in module 1, what is AI? and what is not? (Recognize), in module 3, learn about machine learning (Know & Understand). In addition, students use Teachable Machine to train supervised learning models (Use & Apply), and discuss how to mitigate the bias and generalize to other examples of algorithmic bias (Evaluate). In module 5, students play a game to	* Most students developed a basic understanding of AI, evaluating AI, and navigate ethically. * Incorporating ethics and career futures into AI education is effective for developing AI literacy among middle school students.

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Table 2 (*continued*)

#	Title	Purpose	Target Population	AI Literacy Constructs						Examples of Constructs' Implementation	Implementation Results
				R	K	U	V	C	E		
										understand societal consequences of AI-generated media (Navigate ethically).	
9	Using digital story writing as a pedagogy to develop AI literacy among primary students [40]	Examined the use of digital story writing (DSW) in the classroom to address literacy development.	K-12		X	X	X	X	X	The course demonstrated the constructs as follows: 1) Understand the working principles of machine learning, (Know & Understand), 2) Convert the drawing into the art inspiration's style using AI tools (Use & Apply), 3) Learn how to critique students' work (Evaluate), 4) Make their story (Create), and 5) Discuss the present and future roles of AI-driven robots in our society (Ethics).	* DSW as an inquiry could effectively foster students' AI literacy in using and applying AI knowledge to solve real-life problems, far beyond merely knowing and understanding related concepts. * "AI literacy is a new set of technological attitudes, abilities and competencies that people use AI effectively and ethically in everyday life" (p. 2)
10	Evaluating artificial intelligence literacy courses for fostering conceptual learning, literacy and empowerment in university students: Refocusing to conceptual building [22]	Evaluated AI literacy courses focusing on conceptual understanding for university students from diverse backgrounds.	Higher education		X	X	X			Part (2) of an AI program. In this course participants learned about deep learning concepts (Know & Understand), reflected on the limitations of AI algorithms (Evaluate), and tried ways to remedy the shortcomings (Use & Apply). * Recognize was measured but was not an explicit part of learning in this course.	The participants made significant progress and felt empowered by their improved literacy and understanding of AI concepts.
11	Effect of a fipped classroom course to foster medical students' AI literacy with a focus on medical imaging: a single group pre-and post-test study [28]	Presented and evaluated a flipped classroom course designed to give undergraduate medical students an introduction to AI and increase their "AI readiness."	Higher education		X	X	X		X	Examples from the course content include, 1) an explanation of central concepts such as machine learning and deep learning (Know & Understand), 2) practical exercises on the use of a browser-based tool (Use & Apply) 3) a comparison of advantages and disadvantages of different AI methods (Evaluate), and 4) a reflection on the opportunities and risks of the use of AI in ophthalmology (Ethics).	The study showed a significant increase in the perceived readiness of medical students towards AI after attending the course; particularly in understanding the strengths, weaknesses, opportunities, and limitations of AI.
12	Pedagogical Delivery and Feedback for an Artificial Intelligence Literacy Programme for University Students with Diverse Academic Backgrounds: Flipped Classroom Learning Approach with Project-based Learning [26]	Evaluated students' feedback on flipped classroom learning for AI literacy course, and their understanding of AI and ethics using project-based learning.	Higher education	X	X	X	X	X	X	AI literacy program (same as #24, however the foucs here is on the teaching strategy).	* The feedback showed that the students appreciated the flipped classroom learning approach. * They also reported that project-based learning helped them develop their understanding of concepts and ethical awareness concerning AI.
13	Family as a Third Space for AI Literacies: How do children and parents learn about AI together? [6]	Explored parents' roles in helping their children develop AI literacies.	Family		X	X	X	X		The learning activities require participants to engage in multimodal and embodied practices (Use & Apply), learn AI concepts (Know & Understand), critically analyze AI (Evaluate), and design for future use (Create).	* Presented learning activities organized into four topics: image classification, object recognition, interaction with voice assistants, and unplugged AI co-design.
14	Family Learning Talk in AI Literacy Learning Activities [36]	Explored the types of dialogue family groups engage in when learning about AI in an at-home	Family	X	X		X		X	Learning activities covered the following competencies: strengths and weaknesses of AI, role	Provided suggestion to update the existing principles for designing AI

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Table 2 (*continued*)

#	Title	Purpose	Target Population	AI Literacy Constructs						Examples of Constructs' Implementation	Implementation Results
				R	K	U	V	C	E		
		learning environment to reflect on the implications for the AI literacy design principles.								of humans in programming AI, how agents make decisions, steps and practices of machine learning, and computers learn from data.	literacy educational interventions.
15	Where Is the AI? AI Literacy for Educators [59]	Analyzed the potential challenges of examining AI tools use in formal education environment.	Teachers	X	X		X		X	An AI literacy course for educators should aim to help them understand the concepts and terminologies of AI (Know & Understand), enable them to identify suitable AI tools (Recognize), and teach them how to evaluate factors that can affect issues of bias and explainability (Evaluate). Additionally, the course should emphasize the importance of safe and responsible use of AI in an educational context while maintaining ethical standards (Ethics).	* Highlighted the need for educators to better understand the implications of integrating AI applications into teaching.
16	Developing AI Literacy for Primary and Middle School Teachers in China: Based on a Structural Equation Modeling Analysis [65]	Explored correlations among different dimensions of AI literacy of teachers.	Teachers		X	X	X		X	Four dimensions: Understanding AI, Applying AI, Evaluating AI Applications, and AI Ethics.	* Applying AI has a significant, positive effect on the other three dimensions of AI literacy.
17	Towards AI literacy: A proposal of a framework based on the Episodes of Situated Learning [43]	Proposed a framework for developing an AI curriculum to support the integration of AI into education.	Teachers			X	X	X	X	The three verbs in the framewrok are: 1) anticipate (Use & Apply), 2) produce (Create), and 3) reflect (Evaluate & Ethics).	* Provided a representation of ESL-based AI framework. * In the reflection phase, students can analyze the technical aspects underlying the operation of AI tools and become fully aware of their advantages and limitations. * Conceptual, no experiment result.
18	Widening the Global Access of Artificial Intelligence (AI) Literacy Curriculum through the Participation of Day of AI [9]	Proposed several 4-modules based on the grade band that educators can use in the Day of AI (DoAI), which is an institutional wide initiative that invites educators to participate and adop AI literacy curriculum in their classrooms.	Early childhood education + *K*-12	X	X	X	X		X	Examples from the curicculum include: 1) Develop a basic understanding of what AI is and isn't (Recognize), 2) Develop a basic understanding of what GANs are and how they work (Know & Understand), 3) Train a machine to identify images (Use & Apply), and 4) Discuss some ethical implications of using AI, specifically in image recognition (Ethics).	* Teachers appreciated the availability of the DoAI resources and showed positive impacts of its adoption in classroom teaching.
19	Artificial Intelligence (AI) literacy in early childhood education: an intervention study in Hong Kong [49]	Evaluated the impact of an eight-week AI literacy program on young children.	Early childhood education	X	X	X	X		X	The learning goals for the proposed AI4KG curriculum include: 1) understand AI has its limitations (Ethics), 2) know AI robots in our daily life (Recognize), 3) understand how machine learning works (Know & Understand), and 4) train picture-based machine learning models with Teachable Machine (Use & Apply). Although the learning	* The paper provides teachers with lesson plans, including learning goals, learning activities, and teaching methods. * While most kindergarten children can understand basic AI knowledge, they cannot understand complex notions, such as data.

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Table 2 (*continued*)

#	Title	Purpose	Target Population	AI Literacy Constructs						Examples of Constructs' Implementation	Implementation Results
				R	K	U	V	C	E		
										goals covered multiple constructs, the focus of the learning activities was mainly on knowledge and usage.	
20	Introducing Artificial Intelligence Literacy in Schools: A Review of Competence Areas, Pedagogical Approaches, Contexts and Formats [41]	Systematically analyzed 31 school cases of AI literacy introduction.	K-12		X	X			X	The review analyzed studies from three persepctives: 1) The technological perspective assessed if students learned how AI functions, 2) The socio-cultural perspective evaluated if students understood the impact of technology, and 3) The user-oriented perspective assessed if students learned how to use AI.	* Most studies were concerned with developing students' ability to know how AI systems work and how to operate them but not what their effects are. * Students did not apply their knowledge to new domains. * Socio-cultural perspective is underrepresented in current practical studies.
21	Artificial intelligence literacy teaching in social studies education [62]	Explored the potential role of social studies in teaching AI literacy.	K-12	X					X	The lesson plan intended to teach students about the concept of AI, its characteristics, such as being divided into narrow, general, and super AI (Recognize), and its present and future effects on their lives (Ethics).	Presented a lesson plan with a hands-on activity (chatbots) that can be used to teach AI literacy in social studies classrooms.
22	Design-Based Learning and Constructionist Learning Principles to Promote Artificial Intelligence Literacy and Awareness in K-12, a Pilot Study [1]	Implemented an AI learning programme for children.	K-12		X	X	X	X		Based on the program outline, the proposed activities include 1) introduction to the machine learning workflow using Google Teachable Machine (Know & Understand), 2) train a machine learning model and then implement it in a Scratch-like platform (Use & Apply), 3) engage students in designing a prototype in groups focusing on AI for good to help to solve potential real problems (Create). In the findings, researchers point out discussion about ethical issues like bias in AI and how it could affect the outcome (Evaluate).	* Students developed critical thinking and ethics awareness alongside technical skills. * Teacher's preparation and adaptation were key to the program's success.
23	Evaluating an artificial intelligence literacy programme for empowering and developing concepts, literacy and ethical awareness in senior secondary students [21]	Examined the potential for senior secondary students to learn machine learning and deep learning concepts, and discuss the related ethical issues in project-based learning.	K-12	X	X	X	X	X	X	From the courses description, 1) introduced the concepts (Recognize), 2) presented data preparation and neural networks (Know & Undersatnd), 3) used computer vision as a practical example, 4) developed solutions (project) for self-defined real-life problems (Create), 5) analyzed and interpreted the results (Evaluate), and 6) built their awareness of AI ethics (Ethics).	* The program improved students' AI concepts and ethical awareness. * Understanding higher-level ethical principles remained challenging for senior secondary students. * Pre-programming knowledge is not a prerequisite to learn these AI concepts.
24	Evaluating an Artificial Intelligence Literacy Programme for Developing University Students' Conceptual Understanding, Literacy, Empowerment and Ethical	Designed and evaluated an AI literacy programme based on a multi-dimensional conceptual framework, which developed participants' conceptual understanding,	Higher education	X	X	X	X	X	X	Part (3) of an AI program. The third course focused on teaching ethics and applying knowledge in a project for the "application development" course. * Here the mapping of	* Developing AI application projects improved knowledge, experience, and ethical awareness. * Integrating ethical considerations into project work effectively taught AI

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Table 2 (*continued*)

#	Title	Purpose	Target Population	AI Literacy Constructs						Examples of Constructs' Implementation	Implementation Results
				R	K	U	V	C	E		
	Awareness [23]	literacy, empowerment and ethical awareness.								constructs are based on the full program (3 courses). * The AI program is similar to #23, but different target population.	ethics. * Participants' perception of AI literacy has increased significantly after the first course and then stabilized.
25	Examining the Impact of Flipped Learning for Developing Young Job Seekers' AI Literacy [20]	Evaluated the efficacy of flipped learning classroom for teaching AI literacy.	Higher education							The focus was on the teaching stratgy, without providing details about the course content.	* The study found that teaching AI literacy with flipped learning classroom improved the learning outcomes of both CS and non-CS students.
26	Artificial intelligence literacy: developing a multi-institutional infrastructure for AI education [44]	Evaluate the effectiveness of an AI literacy course on participants from nine radiology residency programs.	Higher education		X	X	X		X	Examples from the course plan: 1) introduction to basic AI term and methods (Know & Understand), 2) use an AI-assisted viewer for cancer detection (Use & Apply), 3) discuss algorthim biases (Evaluate), and 4) ethics.	* The majority of the participants reported a lack of sufficient exposure to AI in their radiology training. * The course showed significant improvement in the participants AI knowledge. * The majority of the participants showed interest in the inclusion of AI in radiology education.
27	Developing a model for AI Across the curriculum: Transforming the higher education landscape via innovation in AI literacy [47]	Developed AI across the curriculum for undergraduate programs in a research university.	Higher education	X	X	X	X	X	X	Examples of student learning outcomes from the curriculum: 1) Describe the characteristics of AI (Recognize), 2) Describe, and explain the components, requirements of AI (Know & Understand), 3) Utilize AI tools and techniques appropriate to a specific context and application (Use & Apply), 4) Assess the context-specific value or quality of AI tools and applications (Evaluate), 5) Develop tools, hardware, data, and/or algorithms utilized in AI solutions (Create), and 6) Apply, and/or evaluate contextually appropriate ethical frameworks to use across all aspects of AI (Ethics).	Provided 1) AI literacy curriculum model, 2) initiatives to promote AI for all students, and 3) student learning outcomes for AI across curriculum.
28	AI in the Public Eye: Investigating Public AI Literacy Through AI Art [14]	Explored how AI art, wheres AI is both a tool and a topic, can improve public AI literacy. The research asks: How can we promote AI literacy?	Unspecified	X	X		X		X	The literature on AI literacy suggests four main types of public AI literacy: 1) awareness, 2) technical understanding, 3) normative assessment, and 4) making critical links to broader structures of power.	* AI art can link underlying technical systems to bigger structural issues and facilitate experiential learning. * AI Art should focus mostly on important overarching issues.

families were encouraged to create personally meaningful networks based on their interests [34].

Navigate ethically. Courses incorporating this construct aim to educate young children about the limitations of the AI [49]. As students progress through K-12, their coursework has addressed ethical concerns related to the human-focused aspects of AI, such as fairness, accountability, transparency, ethics, and safety [9,40]. Additionally, students are encouraged to discuss and share their opinions on AI's role in our world and its impact on society, both present and future [10,40,44,53,62]. This helps to identify opportunities and risks across different areas of life [26,28,31]. In an undergraduate course, the authors suggested a learning outcome that emphasizes sharpening students' ability to apply and evaluate ethical frameworks for using AI in various contexts [47]. For the general public, art and exhibits can spark meaningful conversations about broader power structures related to AI [14].

AI literacy assessment

RQ3. What are the different assessment instruments developed and used to study AI literacy?

Given the increase in research on AI literacy, there has also been a corresponding rise in interest in creating reliable tools and instruments to measure and assess AI literacy across different target groups. The development of a valid instrument is crucial for several reasons. Firstly, it helps to evaluate the current level of AI literacy among the target population, which can help identify areas that require attention and intervention. This information can then be used to create effective courses and materials to address the identified shortcomings [2,45]. Secondly, having a way to measure AI literacy allows us to assess the effectiveness of the interventions, leading to refinement and improvement over time [55].

Table 3 presents a comprehensive summary of the developed AI literacy instruments identified in our data, including the target population and the number and type of questions. The table also includes information regarding the background theory upon which each instrument is based and details on the validity and reliability tests performed. Furthermore, each instrument has undergone evaluation to determine which constructs they cover. The "Notes" column provides additional insights into any extra constructs that have been evaluated or any comments from the researchers.

One way to characterize assessment instruments is whether they are subjective or objective. Subjective instruments are interpretive and rely on self-reporting. On the other hand, objective instruments involve standardized measurements that evaluate a participant's performance against specific criteria or tasks. Each type has its advantages and disadvantages. Subjective assessment can result in biases and inaccuracies but allows for collecting more descriptive and ecologically valid data. Objective instruments are less biased but very limited in scope and may fail to reflect the broader context, leading to limited generalizability of the findings. In our data, 75 % of the assessment instruments were subjective.

Some instruments had extensive coverage of all core AI literacy constructs. Wang and his colleagues [54] were the first to develop a scientifically rigorous psychometric scale to measure AI literacy. The scale consists of 12 items that cover four core constructs: "Recognize," "Use and Apply," "Evaluate," and "Ethics." The overall scale has satisfactory convergence validity, but using distinct constructs alone has yet to yield reliable results. Among the constructs examined, the "Usage" construct, aligned with the "Use & Apply," was the most significant predictor of AI literacy. Carolus et al. [2] presented a comprehensive "Meta AI Literacy Scale-MAILS," a subjective assessment scale with 34 items. In addition to items related to the core constructs, it includes "AI self-efficacy in learning and problem-solving" and "AI self-management". The confirmatory factor analysis results indicated that "Create" is not an inherent aspect of AI literacy but rather an independent factor. Moreover, the ability to "Evaluate" AI was found to be more closely related to "know & Understand" than to "Create." Another general instrument intended for non-experts in any discipline is the assessment tool developed by Laupichler and colleagues [29]. It consists of 38 items. The formulation of the items was based on two widely accepted definitions of AI literacy [35,40], employing the Delphi method. The researchers found that affective-related items such as "attitudes towards AI" were not included in the final set of items, indicating that they are not essential to AI literacy. However, the authors suggest that this needs to be further examined by conducting factor analyses. Although this instrument presents extensive coverage of all core AI literacy constructs, the number of items can be reduced to enhance the instrument's effectiveness.

Another set of instruments was directed toward the workforce. Pinski and Benlian [45] developed another scale to measure employee's AI literacy. Their instrument consisted of 13 items and was based on a human-AI interaction theory. The scale covers the knowledge part but misses AI literacy's "Navigate Ethically" construct. The researchers found that "Technology Knowledge" was the most significant predictor of AI literacy, which aligns with the "Know & Understand" construct. Weber et al. [56] developed an objective assessment tool grounded in the IS theory and Bloom's taxonomy. Its validity has been established by comparing two groups, one with prior technology experience and the other without. This tool consists of 16 knowledge-based multiple-choice questions grouped by the type of employee in the organization (user vs. evaluator/creator). The questions are context-specific and require constant revision and updates.

In the educational domain, several studies have used instruments to measure AI literacy among students and teachers. Wood et al. [60] presented a survey consisting of 15 questions. The survey aimed to assess the level of awareness of medical students and teachers regarding AI and their opinions on significant AI topics related to the medical and healthcare domains. Furthermore, Yau et al. [61] presented a pilot test consisting of 10 multiple-choice questions based on the Five Big Ideas for grades 7 to 9 students. The test was administered to measure AI literacy before and after enrolling in a one-year AI course. The questions covered the core constructs, except for "Create." Additionally, Zho et al. (2022) developed an instrument of 20 items grouped into four dimensions based on Ng et al.'s [38] work to assess teachers' AI literacy. Furthermore, Wang et al. [55] developed an AI literacy evaluation framework for K-12 based on the Information literacy evaluation frameworks. The evaluation framework provides 12 indicators grouped in four dimensions: artificial intelligence awareness, intelligent technology application, practical innovative thinking, and intelligent social responsibility, without explicitly offering the evaluation items as a tool.

Discussion

We conducted a systematic literature review focused on AI literacy publications between 2019 and 2023. Forty-seven studies were found to be eligible for inclusion in the review. The dataset consisted of both empirical and review/conceptual papers. Over several rounds of review, we analyzed the papers' content to respond to three research questions targeted toward understanding AI literacy definition and constructs, AI literacy implementation efforts, and the use and development of instruments for assessing AI literacy. Consistent with other work in this area [29,35], we found that AI literacy continues to be a novel and growing research area but with increasing contributions in recent periods. We also found that certain papers are already starting to become canonical and are cited highly within the field.

In response to research question 1, we found that scholars have forwarded a range of definitions for AI literacy with each including one or more dimensions of the framework we have put forward. We delineated specific elements of AI literacy that we used to categorize and compare articles in the dataset; these elements/constructs are: *Recognize, Know and Understand, Use and Apply, Evaluate, Create,* and *Navigate Ethically*. Apart from the fundamental constructs of AI, we found a few other dimensions in the literature. Kong & Zhang [25] related AI literacy to other elements. They proposed four elements to represent AI empowerment, which are AI self-efficacy, meaningfulness, impact, and creative self-efficacy [25].

Our analysis of the empirical papers, in response to research question 2, identified which elements of the constructs were present across the studies. "Recognize" was not that common and was taken for granted. In addition, "Navigate Ethically," which was defined broadly, including social impacts, has been considered in most studies, indicating a shift from prior literature in the field between 2020 and January 2022, as noted by Olari et al. [41]. Furthermore, although "Create" positively promoted AI literacy, its incorporation in AI literacy programs remains underrepresented. Notably, there appears to be a lack of efforts to promote AI literacy within organizations and workplaces, and this presents a significant challenge. Cetindamar et al. [4] emphasized the importance of ongoing, lifelong learning for employees, given that they are constantly encountering novel technologies that demand adaptability and agility. Therefore, as AI is becoming increasingly ubiquitous and is poised to reshape various industries in the near future, it is imperative for organizations to prioritize AI literacy.

Following our in-depth analysis of assessment tools designed to

Table 3
A summary of AI literacy used and developed assessment instruments. (Note: R: Recognize, K: Know & Understand, U: Use & Apply, V: Evaluate, C: Create, and E: Navigate Ethically).

#	Title	#Items/ Assessment Type	Target population	Theory	AI Literacy Constructs						Validity	Notes
					R	K	U	V	C	E		
1	Are We Ready to Integrate Artificial Intelligence Literacy into Medical School Curriculum: Students and Faculty Survey [60]	15-questions (Subjective)	Higher education; Workforce	NA	X						No empirical validity	* The survey included questions on participant background, AI awareness, and participants' opinions about topics important to them. * Both students and faculty showed lack of awareness about AI technology applications in healthcare at the same time they showed an interest in learning about them.
2	Developing an AI literacy test for junior secondary students: The first stage [61]	Pilot (10 MCQs) (Objective)	K-12: Secondery	Five Big Ideas	X	X	X	X		X	Pre- and post-tests showed improvement in AI literacy after a one-year AI course.	The test aims to measure the changes of students' AI literacy before and after attending an AI course.
3	Developing AI Literacy for Primary and Middle School Teachers in China: Based on a Structural Equation Modeling Analysis [65]	20-items scale (Subjective)	Teachers	Based on Ng et al. [39]	X		X	X		X	Good validity	* AI Knowledge for educators. * "Knowing and Understanding"questions are aligned with "Recognize" not the technical knowledge.
4	Measuring user competence in using artificial intelligence: validity and reliability of artificial intelligence literacy scale (AILS) [54]	12-items scale (Subjective)	Unspecified	Based on digital literacy frameworks such as the technological–cognitive–ethical model and the KSAVE model	X		X	X		X	Internal reliability and construct validity	* "Usage" is the most predictor construct of AI literacy. * Some constructs showed low validity scores (using their items alone is not reliable), but the whole scale showed sufficient convergence validity.
5	AI Literacy - Towards Measuring Human Competency in Artificial Intelligence [45]	13-items scale (Subjective)	Workforce	socio-technical perspective (human-AI IS competence literature)	X	X	X	X	X		* no multicollinearity problems * sufficient discriminant validity * Good internal consistency	* Only 'AI technology knowledge' had a substantial and significant effect on general AI literacy.
6	Toward an Objective Measurement of AI Literacy [56]	16-MCQs (Objective)	Workforce	IS theory (socio-technical perspective) and Bloom's taxonomy	X	X	X	X		X	between-subject comparison (Technology-related vs. other educational background)	* A single study at A single point of time. * AI knowledge evolves constantly, which means consistant revision of the instruments questions.
7	Delphi study for the development and preliminary validation of an item set for the assessment of non-experts' AI literacy [29]	38-items scale (Subjective)	Unspecified	1. Long & Magerko's [35] AI literacy framework 2. Literature (book and AI literacy courses). 3. experts suggestions.	X	X	X	X	X	X	Content and item wording validity	* Strength: more than 50 experts repeatedly evaluating the relevance of the itemset (achieved a high content validity). * Factor analysis can be used to reduce the number of questions.
8	MAILS – Meta AI Literacy Scale: Development and Testing of an AI Literacy Questionnaire Based on Well-	34-items scale (Subjective)	Unspecified	Based on Ng et al. [39] + psychological competencies such as problem solving, learning, and emotion regulation	X	X	X	X	X	X	Confirmatory Factor Analysis	* No external Validity. * "Use & Apply AI," "Know & Understand AI," "Detect AI," and "AI Ethics" were loaded on "AI Literacy," while "Create AI" did not. * The ability to "Evaluate"

(*continued on next page*)

Table 3 (*continued*)

#	Title	#Items/ Assessment Type	Target population	Theory	AI Literacy Constructs						Validity	Notes
					R	K	U	V	C	E		
	Founded Competency Models and Psychological Change- and Meta-Competencies [2]											AI is more closely related to "Know & Understand" than to the ability to "Create" AI. * The instrument also incorporate psychological competencies: "AI Self-efficacy in learning and problem solving" and "AI Self-management".
9	Junior High School Artificial Intelligence Literacy: Connotation, Evaluation and Promotion Strategy [55]	12-items (MCQS and scale questions) (Subjective)	K-12: Secondery	Information literacy evaluation frameworks	X		X		X	X	Good reliability and structural validity	The itemset of the evaluation is not available. However, they cover intelligent recognition, mental disposition, explicit behavior, functional application, technical operation, divergent thinking, schema innnovation, problem solving, application innovation, consciousness, attitude, and accountability.

evaluate AI literacy, it has become apparent that these tools serve two primary purposes: assessing the knowledge level of a particular group and evaluating the efficacy of interventions. After categorizing the assessment studies according to the established framework, we have identified two instruments [2,29], as capable of covering the fundamental constructs. Nevertheless, we believe these instruments could be further refined by reducing the number of questions and validating their effectiveness across diverse contexts. Having valid and reliable tools is important to enable us to obtain more accurate and reliable data on individuals' AI literacy levels, thereby facilitating the identification of knowledge gaps and designing targeted interventions to address them.

Going forward, the constructs we have delineated and the framework they constitute can be used to analyze and design AI literacy approaches and assessment instruments. The framework includes almost all aspects of AI literacy that are important and can also be combined with other efforts. For instance, the framework can be used for discipline-based initiatives such as AI literacy in medicine or health, or even topics such as environmental engineering. For providing comprehensive AI literacy, educators can ensure that all framework elements are covered. It can be used to identify differences in how experts think about AI literacy by asking them to complete a table with the elements and comparing them. Examples can be added for each element and then students can be asked if they know them or what examples might be used for each. In other words, the framework can serve as a model. Finally, this framework can be used in conjunction with similar initiatives [54] to align them with specific roles to create an even more exhaustive way of studying and providing AI literacy.

This review suggests several directions for future research. We need more robust work on the use of instruments to assess AI literacy. This research needs to not only develop and test instruments that are general in nature and can capture basic skills related to AI literacy across domains, but we also need domain-specific instruments as beyond a few basic skills, AI literacy varies greatly based on the domain. One potential avenue for this is to use the constructs we have identified as part of this review as elements that the tool or instrument can address but then design more in-depth sub-elements within each. There is also potential for research to clarify and better define related terms such as literacy and competence so as to avoid overlap and confusion about what they specifically mean to convey, define, or assess. Currently, much of the work on AI literacy is top-down, driven by researchers but there is potential to undertake more situated, field study approaches that examine how users actually use these technologies and build a more inductive understanding of AI literacy. In general, there is a large potential for field studies of AI use to provide a more contextual understanding of AI literacy among users and learners. This will also shed more light on the human-AI aspects of literacy, how learning changes with augmentation and what kinds of literacies might be required in the future [18]. Finally, from an instructional perspective, there is a need to design, implement, and assess different pedagogical interventions for their efficacy in teaching AI literacy, and their potential to be scaled up [16].

Limitations

While our paper discussed AI literacy from different perspectives and drew upon recent studies in the field, it is important to acknowledge its limitations. For instance, our data collection spanned from 2019 to August 2023, meaning that not all papers published in 2023 were included. Additionally, we focused solely on studies that specifically mentioned ("AI" or "artificial intelligence") and "literacy" in the title, potentially overlooking related topics such as competency and education. Moreover, our analysis was limited to academic publications and did not consider reports from non-profit or government organizations like UNESCO that are contributing to this field. Despite these limitations, our research provides a basis for the research on AI literacy since it thoroughly examines the constructs studied in the literature and highlights areas that demand additional attention.

Conclusion

This systematic review examined 47 articles on AI literacy published between 2019 and 2023. We found that articles broadly contributed to one of the following areas: a) conceptualizing AI literacy, b) prompting AI literacy efforts, and 3) developing AI literacy assessment instruments. We also found that a range of populations were targeted, from students to adults in the workforce. Using a thorough content analysis, we identified six key constructs related to AI literacy: *Recognize, Know and Understand, Use and Apply, Evaluate, Create,* and *Navigate Ethically*. We then utilized this framework to classify the underlying constructs investigated in the empirical papers. The findings have significant implications for future studies as they advance our understanding of AI literacy and its implementations and assessment efforts across different disciplines. The findings are particularly relevant for individuals

interested in promoting or evaluating AI literacy in formal education and workforce preparation.

CRediT authorship contribution statement

Omaima Almatrafi: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Aditya Johri:** Writing – review & editing, Funding acquisition, Formal analysis, Conceptualization. **Hyuna Lee:** Writing – review & editing, Visualization, Formal analysis, Data curation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Aditya Johri reports financial support was provided by National Science Foundation. Aditya Johri reports financial support was provided by National Institute of Food and Agriculture. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This work partly supported by U.S. NSF Award# 2319137, 1939105, 1937950, USDA/NIFA Award #2021–67021–35329. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funding agencies. The authors would like to thank Karthika Suresh Kumar for assistance with data collection.

References

[1] * Amplo E, Butler D. Design-Based learning and constructionist learning principles to promote artificial intelligence literacy and awareness in K-12, a pilot study. In: Proceedings of the IAFOR international conference on education – Hawaii 2023 official conference proceedings; 2023. p. 807–18. https://doi.org/10.22492/issn.2189-1036.2023.66. March.

[2] * Carolus, A., Koch, M., Straka, S., Latoschik, M.E., & Wienrich, C. (2023). MAILS – Meta AI Literacy Scale: development and Testing of an AI Literacy Questionnaire Based on Well-Founded Competency Models and Psychological Change- and Meta-Competencies. http://arxiv.org/abs/2302.09319.

[3] * Casal-Otero L, Catala A, Fernández-Morante C, Taboada M, Cebreiro B, Barro S. AI literacy in K-12: a systematic literature review. Int J STEM Educ 2023;10(1). https://doi.org/10.1186/s40594-023-00418-7.

[4] * Cetindamar D, Kitto K, Wu M, Zhang Y, Abedin B, Knight S. Explicating AI literacy of employees at digital workplaces. IEEE Trans Eng Manage 2022:1–14. https://doi.org/10.1109/TEM.2021.3138503.

[5] Chui M, Manyika J, Miremadi M, Henke N. Notes from the AI frontier insights from hundreds of use cases. Can Electr Eng J 2018;4(3):22–5. www.mckinsey.com/mgi.

[6] * Druga S, Christoph FL, Ko AJ. Family as a third space for AI Literacies: how do children and parents learn about AI together?. In: Proceedings of the conference on human factors in computing systems - proceedings. 1. Association for Computing Machinery; 2022. https://doi.org/10.1145/3491102.3502031.

[7] * Druga S, Vu ST, Likhith E, Qiu T. Inclusive AI literacy for kids around the world. In: Proceedings of the ACM international conference proceeding series; 2019. p. 104–11. https://doi.org/10.1145/3311890.3311904.

[8] * Druga S, Yip J, Preston M, Dillon D. The 4 As: ask, adapt, author, analyze: AI literacy framework for families. In: Proceedings of the algorithmic rights and protections for children; 2021. p. 193–232. https://doi.org/10.1162/ba67f642.646d0673.

[9] * Du X, Taylor M, Blumofe N, Berman E. Widening the global access of artificial intelligence (AI) literacy curriculum through the participation of day of AI. & Teacher Education; 2023. p. 1896–903. https://www.learntechlib.org/p/222217/.

[10] * Eguchi A, Okada H, Muto Y. Contextualizing AI education for K-12 students to enhance their learning of AI literacy through culturally responsive approaches. KI - Kunstliche Intelligenz 2021;35(2):153–61. https://doi.org/10.1007/s13218-021-00737-3.

[11] Esmaeilzadeh P. Use of AI-based tools for healthcare purposes: a survey study from consumers' perspectives. BMC Med Inform Decis Mak 2020;20(1). https://doi.org/10.1186/S12911-020-01191-1.

[12] Gupta M, Akiri C, Aryal K, Parker E, Praharaj L. From ChatGPT to ThreatGPT: impact of generative AI in cybersecurity and privacy. IEEE Access 2023;11:80218–45. https://doi.org/10.1109/ACCESS.2023.3300381.

[13] Gursoy D, Chi OH, Lu L, Nunkoo R. Consumers acceptance of artificially intelligent (AI) device use in service delivery. Int J Inf Manage 2019;49:157–69. https://doi.org/10.1016/J.IJINFOMGT.2019.03.008.

[14] * Hemment D, Currie M, Bennett SJ, Elwes J, Ridler A, Sinders C, Vidmar M, Hill R, Warner H. AI in the public eye: investigating public AI literacy through AI art. In: Proceedings of the ACM international conference proceeding series; 2023. p. 931–42. https://doi.org/10.1145/3593013.3594052.

[15] * Heyder, T., & Posegga, O. (2021). Extending the foundations of AI literacy. 0–9. https://aisel.aisnet.org/icis2021/is_future_work/is_future_work/9.

[16] * Hingle A, Johri A. Role-Play case studies to teach computing ethics: theoretical foundations and practical guidelines. In: Proceedings of the 2024 Hawaii international conference on system sciences; 2024.

[17] Holmes W, Persson J, Chounta IA, Wasson B, Dimitrova V. Artificial intelligence and education: a critical view through the lens of human rights, democracy and the rule of law. Council of Europe; 2022.

[18] Johri A. Augmented sociomateriality: implications of artificial intelligence for the field of learning technology. Research in Learning Technology; 2022. p. 30.

[19] Johri A, Hingle A. Students' technological ambivalence toward online proctoring and the need for responsible use of educational technologies. J Eng Educ 2023;112(1):221–42.

[20] * Kim HJ, So HJ, Suh YJ. Examining the impact of flipped learning for developing young job seekers' AI literacy. In: Proceedings of the lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics): Vol. 13916 LNAI. Springer Nature Switzerland; 2023. https://doi.org/10.1007/978-3-031-36272-9_77.

[21] * Kong SC, Cheung WMY, Tsang O. Evaluating an artificial intelligence literacy programme for empowering and developing concepts, literacy and ethical awareness in senior secondary students. Educ Info Technol 2023;28(4):4703–24. https://doi.org/10.1007/S10639-022-11408-7/TABLES/14.

[22] * Kong SC, Cheung WMY, Zhang G. Evaluating artificial intelligence literacy courses for fostering conceptual learning, literacy and empowerment in university students: refocusing to conceptual building. Comput Human Behav Rep 2022;7:100223. https://doi.org/10.1016/j.chbr.2022.100223. July.

[23] * Kong SC, Cheung WMY, Zhang G. Evaluating an artificial intelligence literacy programme for developing university students' conceptual understanding, literacy, empowerment and ethical awareness. Educ Technol Soc 2023;26(1):16–30. https://doi.org/10.30191/ETS.202301_26(1).0002.

[24] * Kong SC, Man-Yin Cheung W, Zhang G. Evaluation of an artificial intelligence literacy course for university students with diverse study backgrounds. Comput Educ Artif Intell 2021;2:100026. https://doi.org/10.1016/j.caeai.2021.100026.

[25] * Kong SC, Zhang G. A Conceptual framework for designing artificial intelligence literacy programmes for educated citizens. In: Proceedings of the conference proceedings (english paper) of the 25th global Chinese conference on computers in education (GCCCE 2021); 2021. p. 11–5. September.

[26] * Kong SC, Zhang G, Cheung MY. Pedagogical delivery and feedback for an artificial intelligence literacy programme for university students with diverse academic backgrounds: flipped classroom learning approach with project-based learning. Bull Tech Committee Learn Technol 2022;22:8–14. September, https://ieeecs-media.computer.org/tc-media/sites/5/2021/10/25204858/bulletin-tclt-2022-0101016.pdf.

[27] Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33(1):159. https://doi.org/10.2307/2529310.

[28] * Laupichler Matthias C, Hadizadeh DR, Wintergerst MWM, von der Emde L, Paech D, Dick EA, Raupach T. Effect of a flipped classroom course to foster medical students' AI literacy with a focus on medical imaging: a single group pre-and post-test study. BMC Med Educ 2022;22(1):1–10. https://doi.org/10.1186/s12909-022-03866-x.

[29] * Laupichler Matthias Carl, Aster A, Raupach T. Delphi study for the development and preliminary validation of an item set for the assessment of non-experts' AI literacy. Comput Educ Artif Intell 2023;4:100126. https://doi.org/10.1016/j.caeai.2023.100126. January.

[30] *Laupichler Matthias Carl, Aster A, Schirch J, Raupach T. Artificial intelligence literacy in higher and adult education: a scoping literature review. Comput Educ Artif Intell 2022;3:100101. https://doi.org/10.1016/j.caeai.2022.100101. September.

[31] * Lee A. The effect of artificial intelligence literacy education on university students ethical consciousness of artificial intelligence. J-Institute 2021;6(3):52–61. https://doi.org/10.22471/ai.2021.6.3.52.

[32] Leikas J, Johri A, Latvanen M, Wessberg N, Hahto A. Governing ethical AI transformation: a case study of AuroraAI. Front Artif Intell 2022;5:836557.

[33] Lensing K, Haertel T. How AI in engineering education can help to foster data literacy and motivation. In: SEFI 48th annual conference engaging engineering education, proceedings; 2020. p. 950–61. September.

[34] * Long D, Blunt T, Magerko B. Co-Designing AI literacy exhibits for informal learning spaces. Proc ACM Human-Comput Interact 2021;5(CSCW2). https://doi.org/10.1145/3476034.

[35] * Long D, Magerko B. What is AI literacy? Competencies and design considerations. In: Proceedings of the conference on human factors in computing systems - proceedings; 2020. p. 1–16. https://doi.org/10.1145/3313831.3376727.

[36] * Long D, Teachey A, Magerko B. Family learning talk in AI literacy learning activities. In: Proceedings of the conference on human factors in computing systems - proceedings; 2022. https://doi.org/10.1145/3491102.3502091.

[37] * Mertala P, Fagerlund J, Calderon O. Finnish 5th and 6th grade students' pre-instructional conceptions of artificial intelligence (AI) and their implications for AI literacy education. Comput Educ Artif Intell 2022;3:100095. https://doi.org/10.1016/j.caeai.2022.100095. May.

[38] * Ng DTK, Leung JKL, Chu KWS, Qiao MS. AI literacy: definition, teaching, evaluation and ethical issues. In: Proceedings of the association for information science and technology. 58; 2021. p. 504–9. https://doi.org/10.1002/pra2.487.
[39] * Ng DTK, Leung JKL, Chu SKW, Qiao MS. Conceptualizing AI literacy: an exploratory review. Comput Educ Artif Intell 2021;2:100041. https://doi.org/10.1016/j.caeai.2021.100041.
[40] * Ng DTK, Luo W, Chan HMY, Chu SKW. Using digital story writing as a pedagogy to develop AI literacy among primary students. Comput Educ Artif Intell 2022;3:100054. https://doi.org/10.1016/j.caeai.2022.100054. February.
[41] * Olari V, Tenório K, Romeike R. Introducing artificial intelligence literacy in schools: a review of competence areas, pedagogical approaches, contexts and formats. IFIP advances in information and communication technology, 685. AICT. Springer Nature Switzerland; 2023. https://doi.org/10.1007/978-3-031-43393-1_21.
[42] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, Moher D. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372. https://doi.org/10.1136/BMJ.N71.
[43] * Panciroli C, Allegra M, Gentile M, Rivoltella PC. Towards AI literacy : a proposal of a framework based on the episodes of situated learning. In: Proceedings of the 3rd national conference on artificial intelligence; 2023.
[44] * Perchik JD, Smith AD, Elkassem AA, Park JM, Rothenberg SA, Tanwar M, Yi PH, Sturdivant A, Tridandapani S, Sotoudeh H. Artificial intelligence literacy: developing a multi-institutional infrastructure for AI education. Acad Radiol 2023;30(7):1472–80. https://doi.org/10.1016/j.acra.2022.10.002.
[45] * Pinski M, Benlian A. AI literacy - towards measuring human competency in artificial intelligence. In: Proceedings of the annual hawaii international conference on system sciences, 2023-January; 2023. p. 165–74.
[46] Schüller K. Data and AI literacy for everyone. Stat J IAOS 2022;38(2):477–90. https://doi.org/10.3233/SJI-220941.
[47] * Southworth J, Migliaccio K, Glover J, Glover JN, Reed D, McCarty C, Brendemuhl J, Thomas A. Developing a model for AI Across the curriculum: transforming the higher education landscape via innovation in AI literacy. Comput Educ Artif Intell 2023;4:100127. https://doi.org/10.1016/j.caeai.2023.100127. January.
[48] * Su J, Ng DTK, Chu SKW. Artificial Intelligence (AI) literacy in early childhood education: the challenges and opportunities. Comput Educ Artif Intell 2023;4:100124. https://doi.org/10.1016/j.caeai.2023.100124. January.
[49] * Su J, Yang W. Artificial intelligence (AI) literacy in early childhood education: an intervention study in Hong Kong. Interactive Learning Environments; 2023. p. 1–15. https://doi.org/10.1080/10494820.2023.2217864.
[50] Taddeo M, Floridi L. How AI can be a force for good. Science, 361. American Association for the Advancement of Science; 2018. p. 751–2. https://doi.org/10.1126/science.aat5991.
[51] * Tenório K, Olari V, Chikobava M, Romeike R. Artificial intelligence literacy research field: a bibliometric analysis from 1989 to 2021. In: Proceedings of the SIGCSE 2023 - proceedings of the 54th ACM technical symposium on computer science education. 1; 2023. p. 1083–9. https://doi.org/10.1145/3545945.3569874.
[52] Touretzky D, Gardner-McCune C, Martin F, Seehorn D. Envisioning AI for K-12: what should every child know about AI?. In: Proceedings of the AAAI conference on artificial intelligence. 33; 2019. p. 9795–9. https://doi.org/10.1609/AAAI.V33I01.33019795.
[53] * Van Brummelen J, Heng T, Tabunshchyk V. Teaching tech to talk: K-12 conversational artificial intelligence literacy curriculum and development tools. In: Proceedings of the 35th AAAI conference on artificial intelligence, AAAI 2021. 17B; 2021. p. 15655–63. https://doi.org/10.1609/aaai.v35i17.17844.
[54] * Wang B, Rau PLP, Yuan T. Measuring user competence in using artificial intelligence: validity and reliability of artificial intelligence literacy scale. Behav Info Technol 2022:1–14. https://doi.org/10.1080/0144929X.2022.2072768. May.
[55] * Wang X, Li X, Huang J. Junior high school artificial intelligence literacy: connotation, evaluation and promotion strategy. Open J Soc Sci 2023;11(05):33–49. https://doi.org/10.4236/jss.2023.115004.
[56] * Weber P, Pinski M, Baum L. Toward an objective measurement of AI literacy. In: Proceedings of the PACIS 2023 proceedings; 2023. https://aisel.aisnet.org/pacis2023/60.
[57] Whittaker M, Crawford K, Dobbe R, Fried G, Kaziunas E, Mathur V, Schwartz O. AI now report 2018. New York: AI Now Institute at New York University; 2018. p. 1–62.
[58] Wilson HJ, Daugherty PR. Creating the symbiotic AI workforce of the future. MIT Sloan Management Review 2019;61(1):1–4.
[59] * Wilton L, Ip S, Sharma M, Fan F. Where is the AI? AI literacy for educators. In: Proceedings of the lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics). 13356 LNCS; 2022. p. 180–8. https://doi.org/10.1007/978-3-031-11647-6_31.
[60] * Wood EA, Ange BL, Miller DD. Are we ready to integrate artificial intelligence literacy into medical school curriculum: students and faculty survey. J Med Educ Curr Develop 2021;8. https://doi.org/10.1177/23821205211024078. 238212052110240.
[61] * Yau KW, Chai CS, Chiu TKF, Meng H, King I, Wong SWH, Saxena C, Yam Y. Developing an AI literacy test for junior secondary students: the first stage. In: Proceedings of the 2022 IEEE international conference on teaching, assessment and learning for engineering. 2022. TALE; 2022. p. 59–64. https://doi.org/10.1109/TALE54877.2022.00018.
[62] * Yetişensoy O, Rapoport A. Artificial intelligence literacy teaching in social studies education. J Pedag Res 2023;7(3):100–10. https://doi.org/10.33902/JPR.202320866.
[63] * Zhang H, Lee I, Ali S, DiPaola D, Cheng Y, Breazeal C. Integrating ethics and career futures with technical learning to promote AI literacy for middle school students: an exploratory study. Int J Artif Intell Educ 2022;33(2):290–324. https://doi.org/10.1007/s40593-022-00293-3.
[64] Zhang K, Aslan AB. AI technologies for education: recent research & future directions. In: Proceedings of the computers and education: artificial intelligence. 2; 2021, 100025. https://doi.org/10.1016/J.CAEAI.2021.100025.
[65] * Zhao L, Wu X, Luo H. Developing AI literacy for primary and middle school teachers in china: based on a structural equation modeling analysis. Sustainability 2022;14(21):1–16. https://doi.org/10.3390/su142114549.