International Journal of Artificial Intelligence in Education
https://doi.org/10.1007/s40593-025-00488-4

ARTICLE

A Conceptual Framework for AI Literacy with a Focus on Competency

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Accepted: 28 May 2025

Abstract

This conceptual paper outlines what artificial intelligence education can consider and aim for holistically by proposing a new competency framework for AI literacy. Although many researchers have agreed on the need to enhance artificial intelligence (AI) literacy through AI education, the existing studies introducing AI literacy tend to discuss the term using a variety of meanings. Since literacy is a fundamental ability to solve high-level problems as a competency, a holistic perspective is needed to ensure a full comprehension of AI education. To clarify this issue, this article starts by providing an overview of the various perspectives on AI literacy taken from 16 previous studies, classifying them into four main categories, and discussing each perspective. Since AI literacy is considered the major outcome of proper AI education, this article explores the concept of competency as a holistic lens through which to synthesize the classification. A competency learning framework (CoLeaF) is discussed as a rationale for proposing a new conceptual framework for AI literacy by mapping each component of knowledge, skills, dispositions, and context with the classifications derived in this study. A new conceptual framework, the AI Literacy Framework from a Competency Perspective, is then proposed by integrating various perspectives on AI literacy from existing studies into one holistic approach. Based on the proposed framework, this conceptual paper provides a holistic view of AI literacy from a competency perspective and highlights the need to continue discussing competencies within the field of AI literacy.

Keywords Artificial intelligence · K-12 AI education · AI literacy · AI literacy framework

The term AI was first coined as the "engineering and science of creating intelligent machines" at the Dartmouth Conference in 1956 (McCarthy et al., 2006).

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Published online: 05 June 2025

Since then, various AI applications such as AI assistants and ChatGPT have become increasingly common in everyday life with the advancement of technology. Alongside this trend, attention toward AI in education has been growing, not only within the field of computer science. As a result, many AI-embedded educational tools have been developed and adopted, sparking interest in the field of Artificial Intelligence in Education (AIED). There has also been increasing discussion around AI education that focuses on helping students solve problems using knowledge of AI (Kandlhofer et al., 2016; Ng et al., 2023). Although a universally accepted definition of AI education has yet to be established, recent discussions suggest that it encompasses more than simply using AI tools or covering AI-related concepts. Instead, it emphasizes learners' literacy, including problem-solving skills and creativity grounded in computational thinking (CT; Ng et al., 2023; Touretzky & Gardner-McCune, 2022).

In line with this trend, governments and institutions worldwide have started preparing to integrate AI education into their K-12 curricula. For example, governments in the United States, Singapore, China, South Korea, Australia, and many others have agreed on the need for AI education and have been preparing to implement it gradually (Steinbauer et al., 2021). However, since AI education is still in the early stages of use, previous research has mainly focused on the curricula and tools available for AI education, rather than on the AI literacy that learners need in order to understand AI (Lin et al., 2021; Williams et al., 2019). Further research on enhancing competencies for understanding and utilizing AI, i.e., AI literacy, is essential to prepare future generations (Long & Magerko, 2020; Zawacki-Richter et al., 2019). However, thus far, there has been little research on AI literacy, and this has resulted in the usage of the term utilizing a variety of meanings (Ng et al., 2021). Therefore, further discussion is needed to understand what AI education in K-12 can consider and aim for holistically. The lack of research may lead to limited opportunities for further expansion and application in AI education curricula (Lin & Van Brummelen, 2021; Lin et al., 2020; Sanusi et al., 2022). AI literacy thus requires further analysis to move on to the next step of introducing AI education into K-12 contexts (Williams et al., 2019).

In this context, this article begins by examining relevant previous studies analyzing the concept of AI literacy and classifying them according to each perspective. A competency learning framework (CoLeaF) is discussed as a rationale, with each of its components, i.e., knowledge, skills, dispositions, and context, being used to map the classification from this study. This article aims to organize and synthesize them into a new framework to conceptually coordinate AI literacy based on competency.

Existing Discussions of AI Literacy

The Meaning of AI Literacy

As literacy is the fundamental ability to solve high-level problems, it is important to provide learners with opportunities to familiarize themselves with the basic principles of AI to help them prepare for their future lives (Kandlhofer et al., 2016; Long & Magerko, 2020; Ng et al., 2021). Long & Magerko (2020) defined the term AI literacy as utilizing and communicating with AI with proper purpose as well as

collaborating with AI when solving life problems. With technology advancing rapidly, current K-12 students will be exposed to more AI in everyday life, and AI literacy will become as important as classical literacy skills such as reading and writing (Long & Magerko, 2020; Steinbauer et al., 2021; Zawacki-Richter et al., 2019). Several previous studies have highlighted the importance of AI literacy to ensure a proper understanding of it, avoid misconceptions (e.g. likening it to magic), and prevent its misuse (Fast & Horvitz, 2017; Lindner et al., 2019; Sanusi et al., 2022). Since 2014, many researchers have analyzed the use of AI in education systems (Paek & Kim, 2021), but research on AI education to improve AI literacy has been scarce (Chai et al., 2021). Indeed, several experimental studies have confirmed that learning about AI can help learners understand how to use and evaluate it (Druga & Ko, 2021; Kong et al., 2021). As part of this trend, many governments are preparing to integrate AI education into the K-12 curricula, but so far the focus has primarily been on the curricula and tools for using AI (Lin & Van Brummelen, 2021). However, because a curriculum addresses what learners can develop and learn, a discussion about the competencies that can be improved by learning about AI is essential (Steinbauer et al., 2021; Touretzky & Gardner-McCune, 2022). Although some previous research studies on AI education have discussed AI literacy, few have examined what learners can develop and learn from AI education in terms of AI literacy (Sanusi et al., 2022). This area deserves further discussion as AI education is still a relatively new topic of research. The following section presents a classification of AI literacy derived from previous research.

Various Focuses in the Previous Work on AI Literacy

To provide an overview of the usage of the term AI literacy, this article investigates the relevant previous articles that discussed the various meanings of the term between 2012 and 2023. Examining the 16 selected studies revealed various perspectives on the term usage of AI literacy, from which four classifications were derived: research focusing on the components of AI literacy, research focusing on the relationship between computational thinking (CT) and AI literacy, research focusing on the competence perspective of AI literacy, and research focusing on the ethical aspect of AI literacy.

Classification 1: Research Focusing on the Components of AI Literacy

This article formulates the first classification as research focusing on the components of AI literacy. Five previous studies have mainly discussed AI literacy by deriving its components (see Table 1).

Long & Magerko (2020) reviewed the detailed components of AI literacy, presenting four categories with 17 components to be learned and improved in AI education. The authors set the first component of What is AI? since they considered that discussing the meaning of AI can help learners understand what AI is. Specifically, they included four sub-components (e.g., recognizing AI / understanding intelligence / interdisciplinarity / general vs narrow) in the first component to enhance

Table 1 Previous research discussing the components of AI literacy

Articles	Components of AI literacy	Sub-components of AI literacy
Long & Magerko (2020)	What is AI?	Recognizing AI / understanding intelligence / interdisciplinarity / general vs narrow
	What can AI do?	AI's strengths and weaknesses / imagine future AI
	How does AI work?	Representations / decision-making / ML steps / human role in AI / data literacy / learning from data / critically interpreting data / action and reaction / sensors
	How should AI be used?	Ethics / programmability
Ng et al. (2021)	Know and understand AI	
	Use and apply AI	
	Evaluate and create AI	
	Ethical issues in AI	
Kong and Zhang (2021)	Cognitive dimension	Understanding AI concepts Using AI concepts for evaluation Using AI concepts for understanding the real world
	Affective dimension	AI self-efficacy Meaningfulness Impact and creative self-efficacy
	Sociocultural dimension	AI ethics Sustainability Ethical standards
Kim et al. (2021)	AI knowledge	K1: Definition and types of AI K2: Problem-solving and search K3: Reasoning K4: Data and machine learning K5: Applications
	AI skill	S1: Using AI tools S2: Computational thinking and programming
	AI attitude	A1: Social impact A2: Collaborate with AI

Table 1 (continued)

Articles	Components of AI literacy	Sub-components of AI literacy
Wang et al. (2023)	Awareness	
	Use	
	Evaluation	
	Ethics	

K Knowledge, *S* Skill, *A* Attitude

learners' understanding of AI. The authors set the second component of AI literacy as What can AI do? to provide learners with opportunities to understand the capabilities of AI to make better decisions with more information. This second component embraced two sub-components, namely AI's strengths and weaknesses and imagine future AI. The third component, How does AI work?, was set to give learners better and more accurate mental models of the systems when communicating with them. The authors described the nine specific sub-components of this component to ensure a better understanding of how AI works: representations / decision-making / ML steps / human role in AI / data literacy / learning from data / critically interpreting data / action and reaction / sensors. Their last component was How should AI be used? regarding positive and negative ways in which AI influences society. Finally, they set two sub-components, namely ethics and programmability, to discuss the impact of AI on society.

Ng et al. (2021) conducted an exploratory review of 30 previous works on AI literacy and derived three main components inspired by Bloom's taxonomy, which is related to categorizing the learning levels in the cognitive domain in the learning context. These were know and understand AI, use and apply AI, and evaluate and create AI. The authors mapped "know and understand AI" and "evaluate and create AI" with "know" and "understand", "use and apply AI" with "apply", and "evaluate and create AI" with "analyze", "evaluate", and "create" in Bloom's taxonomy. In addition to their three components, they added the ethical aspect of AI, finally setting four aspects for fostering AI literacy, namely know and understand AI, use and apply AI, evaluate and create AI, and ethical issues in AI. The first aspect, know and understand AI, refers to knowledge of the basic functions of AI and how to use AI applications. The second aspect, use and apply AI, concerns applying AI knowledge, concepts, and applications to different scenarios. The third aspect, evaluate and create AI, relates to higher-order thinking skills (e.g., evaluate, appraise, predict, design) using AI applications. The last aspect, AI ethics, includes human-centered considerations (e.g., fairness, accountability, transparency, ethics, and safety). In line with the above, they proposed a framework for AI literacy that focused on these areas (Ng et al., 2021).

Kong and Zhang (2021) developed a conceptual framework for designing AI literacy programs. They suggested that AI literacy comprises the cognitive dimension, the affective dimension, and the sociocultural dimension, each with its own components. In their proposed framework, the cognitive dimension relates to AI literacy incorporating AI concepts, using AI concepts for evaluation, and using AI concepts for understanding the real world. They emphasized the importance of using AI concepts to understand the real world for this dimension. They described the affective dimension in AI literacy as relating to AI self-efficacy, meaningfulness, impact, and creative self-efficacy. Lastly, they introduced the sociocultural dimension as being multidimensional and listed its components as AI ethics, sustainability, and ethical standards.

Kim et al. (2021) considered AI literacy as the main objective of elementary-level AI curricula and suggested the components of AI literacy with three competencies and subcategories: AI knowledge, AI skill, and AI attitude. They set the first category of AI literacy as AI knowledge and included five knowledge categories in AI:

definition and types of AI, problem-solving and search, reasoning, data and machine learning, and applications. In addition to the first category, the authors set the second component as AI skills by embracing two sub-components: using AI tools and computational thinking and programming. The third component was AI attitude and they set social impact and collaborate with AI as its sub-components. The authors then designed and developed an elementary school-level curriculum for AI education under consideration of their AI literacy components and validated it in terms of their classification.

Wang et al. (2023) developed the AI literacy scale to measure AI literacy in their study. They proposed the components of AI literacy in four constructs: Awareness, usage, evaluation, and ethics. Awareness is related to someone's ability to identify and comprehend AI when they use AI applications. Usage means someone's ability to apply AI technology to complete tasks proficiently. The authors described evaluation as someone's ability to analyze, select, and critically evaluate AI applications and outcomes from them. Lastly, they discussed ethics as someone's ability to recognize the responsibilities and risks of using AI technologies.

Classification 2: Research Focusing on the Relationship between Computational Thinking (CT) and AI Literacy

In the investigation, four articles were classified in terms of mainly discussing the relationship between the concept of computational thinking (CT) and AI literacy, resulting in the second classification of research focusing on the relationship between CT and AI literacy. There have been multiple evolving discussions on CT, many of which have been based on Wing's (2006) suggestion (Tedre & Denning, 2016). To be specific, Wing (2006) defined CT as "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent". Previous studies have analyzed AI literacy from the perspective of CT (Tedre et al., 2021; Zeng, 2013; Zerega & Milrad, 2023), discussing the relevance of each of its elements (e.g., data, automation, pattern recognition, etc.) and the "five ideas of AI" from Touretzky et al. (2019). In particular, comparatively analyzing this topic, Zerega and Milrad (2023) suggested the possibility of an interrelationship between CT knowledge and the five big ideas on AI. For example, they linked the first idea on AI, perception, to computing concepts such as data and automation, and the third idea on AI, learning, to the ability to learn from data in CT. However, with advancing technology and with discussions on the definition of CT gradually expanding from the initial one (Selby & Woollard, 2013), they proposed an expansion of the algorithmic thinking-based traditional CT concept to CT 2.0 and AI Thinking to encompass data-based AI (Zeng, 2013).

Classification 3: Research Focusing on the Competence Perspective on AI Literacy

In the investigation, two main studies discussed AI literacy from a competence perspective, producing the third classification of research focusing on the competence perspective on AI literacy. Huang (2021) and Sanusi et al. (2022) suggested that

AI literacy needs to be based on competence. Their studies ground in the Students' Key Competence in Three Broad Categories framework suggested by the DeSeCo (Definition and Selection of Competencies) Project (OECD, 2005). The framework consists of three key competencies, namely knowledge, team, and learning, with two sub-competencies each, respectively skill and cultural competencies, teamwork and human-tool collaboration competencies, and cognitive and self-learning competencies (OECD, 2005). Based on this framework, Huang (2021) suggested that the competencies for AI literacy relate to knowledge, learning, team, and ethics. Consequently, the author developed seven categories, namely programming knowledge, image processing knowledge, natural language processing, robots, AI development, machine learning, and AI ethics (see Table 2).

Sanusi et al. (2022) complemented Huang's research (2021), analyzing AI literacy in terms of the competency that learners must have in order to learn AI. Their groups of competencies are knowledge competence, learning competence, team competence, and ethics of AI. Knowledge competence encompasses skill and culture, team competence includes teamwork and human-tool collaboration, and learning competence entails cognitive and self-learning. The authors added the ethics of AI to emphasize the ethical aspect of competence, considering the importance of the role of AI ethics as discussed in previous research (Brundage et al., 2018; Hagendorff, 2020; Long & Magerko, 2020). They concluded by proposing a framework of competencies for AI education (see Table 3).

Classification 4: Research Focusing on the Ethical Aspect of AI Literacy

Five studies covering the ethical aspect of AI were analyzed to derive the fourth classification, namely research focusing on the ethical aspect of AI literacy. Previous research on the ethical considerations of AI literacy has tended to be conducted on a separate track from its technical and knowledge aspects. However, what the ethical aspects of AI education should include remains a topic of debate (Ferguson et al., 2016). Regarding AI technology, the Montréal Declaration for Responsible

Table 2 The model of students' key competencies for AI education

Key Competence	Sub-Competence	Competence Description
Knowledge competence	Skill competence	Various basic knowledge and basic applicable methods
	Cultural competence	Cultural context and humanistic thinking
Team competence	Teamwork competence	Cooperation of team members
	Human-tool collaboration competence	Interaction between individuals and tools
Learning competence	Cognitive competence	The ability to feel, perceive and represent things
	Self-learning competence	Independent analysis, exploration, practice, questioning and creation

Adapted from Huang (2021)

Table 3 A framework of competencies for AI education

Key Competence		Sub-Competence
Ethics of AI	Knowledge competence	Skill competence Cultural competence
	Team competence	Teamwork competence Human-tool collaboration competence
	Learning competence	Cognitive competence Self-learning competence

Adapted from Sanusi et al. (2022)

Development of Artificial Intelligence (2018) announced human-centered principles (e.g., privacy, equity, and diversity), but more discussion is still needed regarding AI education (Dilhac et al., 2018). The ethical aspect of AI literacy is not limited to simply understanding that AI systems should operate ethically (e.g., with fairness, responsibility, transparency, bias, autonomy, subjectivity, inclusiveness, confidentiality, and anonymity), and it should incorporate preventive aspects to determine ethical AI and utilize AI and data ethically (Holmes et al., 2022). Therefore, these previous studies suggest that it should go beyond a mere understanding of the principles and utilization of AI, and that the future of AI education should be foreseen via a holistic lens that considers ethical aspects. In line with this, recognizing the importance of an ethical framework based on these considerations is needed, although some researchers have been wary of turning it into a checklist as if it were a research ethics approval process (Bietti, 2020; Holmes et al., 2022). In this regard, Holmes et al. (2022) presented a framework for the ethics of AI education based on 17 responses to a survey. Their framework comprised six areas relevant to AI education, namely big data, algorithms and computation, education, and the overlaps between them. However, ethical aspects cannot be limited to these areas, and the authors highlighted the need for further discussion extended through horizontal scanning and interdisciplinary conversations. They suggested further discussion on the ethical aspects of the overlapping areas between each subdomain (e.g., ethics of algorithms in education between the algorithms and computation and education subdomains; ethics of data use in AI between the algorithms and computation and big data subdomains; and ethics of learning analytics between the education and big data subdomains).

An AI Literacy Framework Development Integrating the Classifications

Competency as a Rationale

Based on the analysis, the previous studies on AI literacy all present knowledge, ethics, and problem-solving skills as aspects that can be learned and improved through AI education. However, these studies were conducted separately and

despite some commonalities also had differences. Although some studies described AI literacy using the concept of competency (e.g., Kim et al., 2021), they used the term competency as an umbrella term for what students can achieve, thereby focusing on AI literacy and its components rather than discussing the meaning of competency. Lin and Van Brummelen (2021) suggested that if there is little research on competency, AI education may become a stand-alone curriculum found only in the computer science discipline; this will make it challenging to apply it to other contexts related to the approach of problem-solving skills based on CT.

Of course, the term competency lacks clarity despite the numerous discussions of its definition (Klink & Boon, 2002). Previous research examining competency has referred to characteristics such as the knowledge, skills, abilities, and attitudes that enable people to perform tasks proficiently in terms of behavioral areas (Frezza et al., 2018; Passow, 2012). In this respect, it can be said that previous studies on AI literacy analyzed it in terms of competency, but mostly focused on the knowledge or skills aspects of AI (machine learning, deep learning, etc.). Consequently, they did not encompass the overall characteristics of AI literacy in terms of all the competency aspects. Additionally, Huang (2021) and Sanusi et al. (2022) based their competence frameworks, consisting of knowledge competence, team competence, and learning competence, on the DeSeCo core competence framework (OECD, 2005). However, at this point it is important to distinguish between *competence* and *competency*. Armstrong (1996) defined competence as something functional that one can do in order to perform a desired task well. The author defined competency as the dimension of behavior underlying competent performance, i.e., focusing on the behavioral aspect when someone successfully carries out their jobs. Based on these definitions, a set of competencies grounding in Huang (2021) and Sanusi et al. (2022) can refer to those things that learners need to have in order to learn AI effectively, considering the term competence. However, since many of the previous studies on AI literacy introduced above focused on the output that can be achieved through AI education, this article uses the term competency rather than competence. In light of this, it draws on the CoLeaF (Competency Learning Framework) of Frezza et al. (2018), which consists of the four competency components of knowledge (K), skills (S), dispositions (D), and context (C).

The meaning of each component from Frezza et al. (2018) is as follows. First, knowledge relates to cognitive aspects that indicate mastery of key concepts and content knowledge. Skills refers to characteristics that are developed and learned through practice and interaction. Dispositions refers to an emotional trait that includes attitudes and affective traits concerning how to apply knowledge and skills to solve problems. The last, context, refers to the authentic situation related to the problems in which the competencies manifest. Each competency in a learning environment depends on the preceding competencies and there are dependencies (Frezza et al., 2018). This characteristic of competency can be appropriate in representing the relationship between the classification of AI literacy since they can mapped with each classification from the discussions on AI literacy of prior studies.

Development of an AI Literacy Framework Based on Competency

Based on the CoLeaF (Frezza et al., 2018), a new AI literacy framework can be derived from the analysis of the previous research on AI literacy by synthesizing it through the lens of competency. At the beginning of the synthesis of a framework, the context, knowledge, skills, and dispositions components were each assumed to consist in a linear way. This is because the term competence is generally considered to refer to functional areas, while competency pertains to behavioral areas (Delamare Le Deist & Winterton, 2005). In terms of this, the initial work was conducted in this article and presented a linear diagram to present AI literacy with competency as a framework (see Fig. 1).

However, as Delamare Le Deist & Winterton (2005) pointed out, the usage of the terms competence and competency is not generally consistent. In addition, Frezza et al. (2018) suggested that the components of knowledge, skills, dispositions, and context are not linear but rather interrelated. Following the definitions from Armstrong (1996) and Frezza et al. (2018), competence focuses on performing actions to obtain desired results, confirming that there are desired results in a broader context based on the performed actions. Meanwhile, competency focuses on the behavioral aspects of successfully performing tasks, and it can be associated with aspects of knowledge and skills for appropriate behavior. Therefore, this article distinctly follows their definitions of the terms competence and competency and presents the revised framework with a diagram that shows the mapped components: the component of context hereby embraces the other components of knowledge, skills, and dispositions (see Fig. 2).

The following presents the descriptions of each component in the framework.

Knowledge (K)

Among the previous research studies on AI literacy, some of the constructs of the first and second classifications of this article, i.e., research focusing on the components of AI literacy and research focusing on the relationship between CT to AI literacy, are mapped to this component. All the previous studies introduced in the first classification commonly embrace the knowledge (cognitive) aspect of AI literacy, as shown in Table 4.

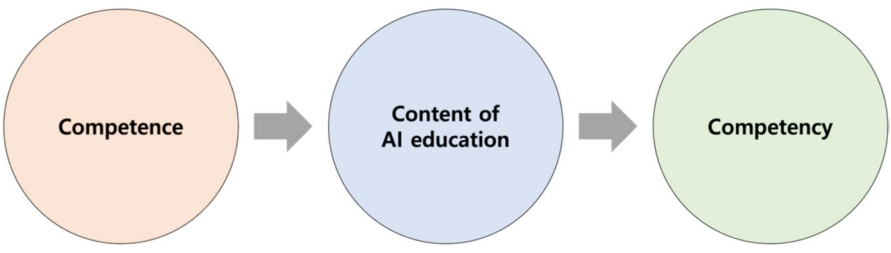

Fig. 1 The initial synthesis work of AI literacy with competency

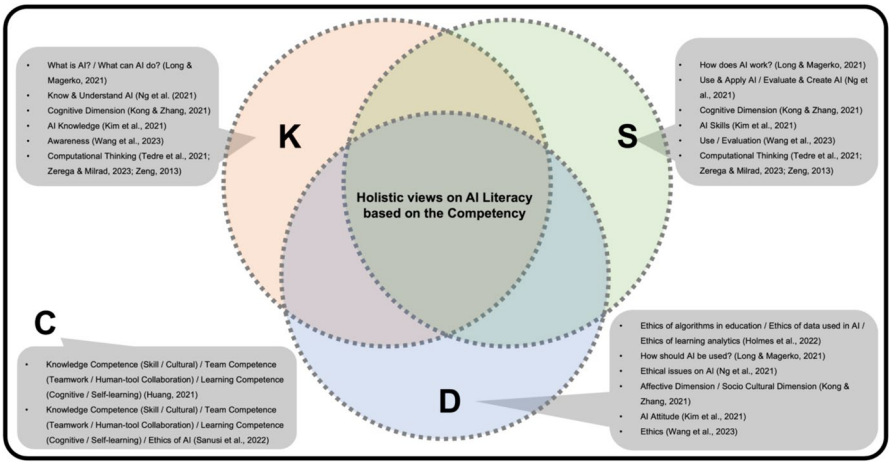

Fig. 2 AI literacy framework from a competency perspective. *Note*. K = Knowledge; S = Skills; D = Dispositions; C = Context

Table 4 The knowledge components from the previous studies on AI literacy

Articles	Knowledge component related
Long & Magerko (2020)	**What is AI? / What can AI do?**
Ng et al. (2021)	**Know and understand AI**
Kong and Zhang (2021)	**Cognitive dimension**
Kim et al. (2021)	**AI knowledge**
Wang et al. (2023)	**Awareness**
Tedre et al., 2021; Zerega & Milrad, 2023; Zeng, 2013	**Computational thinking**

For example, the research of Long & Magerko (2020) introduced the term AI literacy as an aspect of the core concepts of AI, and their definition relates to conceptually understanding the principles of AI. Specifically, they introduced their first and second classifications, i.e., What is AI? and What can AI do?, for learners to be able to understand AI, using verbs like identify or understand to describe the knowledge aspect of each component. In addition, the suggestion of Ng et al. (2021) is based on Bloom's taxonomy, which in turn is based on cognitive aspects, and their work classified the first component as know and understand AI, which relates to the knowledge aspect of AI. Since Kong and Zhang (2021) suggested the understanding of AI concepts component in the cognitive dimension in their classification, which relates to learning about basic AI concepts, this paper maps it to the knowledge component. Kim et al. (2021) also suggested the knowledge aspect as one of the components in the AI knowledge classification in their framework (e.g., definition and types of AI, problem-solving and search, reasoning, data and machine learning, and applications); hence, these facets are mapped with the knowledge component. In addition,

Wang et al. (2023) introduced the awareness component to describe the knowledge aspect of AI.

Tedre and Denning (2016) systematically reviewed the term CT, sharing their view that CT pertains to the characteristics of behaviors but is also based on the body of knowledge. Therefore, in line with their perspective, the second classification in this paper, which views AI literacy as being related to CT, also allows the core concepts of CT to be mapped to this component (Tedre et al., 2021; Zeng, 2013; Zerega & Milrad, 2023).

Skills (S)

This component has some points in common with the first component, (knowledge) because the part in which learners understand the principles of AI and practice and utilize it is connected to skills. Table 5 shows which components are related to the skills aspect in each of the studies introduced in the first and second classifications in this paper.

For example, Long & Magerko (2020) suggested their third classification as How does AI work?, and the descriptions for some of the components showed action verbs like describe, which relates to demonstrating one's skills. They suggested three areas in the classification, namely cognitive systems, machine learning, and robotics, and these are expected to be covered by implementing understanding. Considering their description, this aspect was mapped with the skills component in this paper. Ng et al. (2021), Kim et al. (2021), and Wang et al. (2023) all directly introduced each of their second classifications (e.g., use and apply AI, evaluate and create AI, AI skills, use, and evaluation) as concerning the skillful aspect of AI by using and applying AI skills. Kong and Zhang (2021) introduced their first classification, the cognitive dimension, with three components, namely understanding AI concepts, using AI concepts for evaluation, and using AI concepts for understanding the real world. Of these, using AI concepts for evaluation and using AI concepts for understanding the real world are related to applying the learners' AI understanding as skills; hence, they are mapped with this skills component in this paper.

Demonstrating and using AI skills are based on learners' AI understanding, and thus Fig. 2 shows the common shared areas between the knowledge and skills components. In the same context, the second classification in this paper, i.e., research focusing on the

Table 5 The skills components from the previous studies on AI literacy

Articles	Skills component related
Long & Magerko (2020)	**How does AI work?**
Ng et al. (2021)	**Use and apply AI / evaluate and create AI**
Kong and Zhang (2021)	**Cognitive dimension**
Kim et al. (2021)	**AI skill**
Wang et al. (2023)	**Use / evaluation**
Tedre et al., 2021; Zerega & Milrad, 2023; Zeng, 2013	**Computational thinking**

relationship between CT and AI literacy, is also mapped with this skills component since it embraces practicing and demonstrating learners' understanding of CT concepts. To distinguish each component clearly, each circle for the components has the same size, but the borders are dotted or grey to represent the interchangeable aspects of the classifications. Further studies should discuss the subcategories and the relations between them.

Dispositions (D)

The dispositions component was mapped with research focusing on the ethical aspect of AI as they mainly relate to emotional, affective, and attitudinal traits. In this regard, the ethical aspects of AI described in the first classification (e.g., How should AI be used?, ethical issues on AI, ethics, the sociocultural dimension, AI attitudes) were linked to this construct, as shown in Table 6.

In Fig. 2, the dispositions component is represented as a separate circle to clearly distinguish between the components; however, it can be considered in all contexts, so there is the potential possibility for it to be represented as a larger circle encompassing other elements. This requires more discussion in further research.

Context (C)

This component can be mapped to the research focusing on competence perspective on AI literacy, as shown in Table 7. This is because the previous research studies have left significant space to consider further achievable ideals based on AI literacy learned through AI education from the perspective of competence. They can lead to not only skill competence, but also the suggested sub-competencies, such as cultural competence, teamwork competence, and so on.

In addition, since competence relates to being able to do in order to perform a desired task well, the desired task can be a broader context of learning, such as problem-solving, ethical aspects, etc., and is not limited to specific learning topics. Therefore, it is described here in a form that embraces the entire framework.

Considering the description of each component, the suggested framework shows the overall big picture of the term AI literacy, embracing various views taken from previous studies. Since the framework is based on the competency components of Frezza et al. (2018), it is expected to become one of the references showing the

Table 6 The dispositions components from the previous studies on AI literacy

Articles	Dispositions component related
Holmes et al. (2022)	**Ethics of algorithms in education / ethics of data use in AI / ethics of learning analytics**
Long & Magerko (2020)	**How should AI be used?**
Ng et al. (2021)	**Ethical issues in AI**
Kong and Zhang (2021)	**Affective dimension / socio-cultural dimension**
Kim et al. (2021)	**AI attitudes**
Wang et al. (2023)	**Ethics**

Table 7 The context components from the previous studies on AI literacy

Articles	Context component related
Huang (2021)	**Knowledge competence (skill / cultural) / team competence (teamwork / human-tool collaboration) / learning competence (cognitive / self-learning)**
Sanusi et al. (2022)	**Knowledge competence (skill / cultural) / team competence (teamwork / human-tool collaboration) / learning competence (cognitive / self-learning) / ethics of AI**

future direction of AI education that embraces various perspectives on AI literacy holistically, rather than as part of a fragmented competency.

Discussion and Implications

This conceptual paper presents a preliminary overview for future empirical research by proposing a competency framework based on previous studies discussing AI literacy in AI education. Presenting the competencies that learners can develop in a discipline serves as an essential framework of the significant predictors of the learners' performance in that discipline hence, this paper tentatively outlines the scope for future AI education by presenting an AI literacy framework in terms of competency. Since the classification is based on the focuses of previous research, the framework can be enriched through the discussion and validation of more detailed sub-components in further research. Additionally, since the components of AI literacy in the suggested framework are interrelated, it does not represent sequential learning. Also, for the same reason, each mapping has a weak link, and new mapping should commence based on the preliminary mapping as part of further discussion. As technology advances and AI becomes increasingly prevalent in daily life, it will not be a skill limited to the computer science discipline, but rather one that will contribute to everyone's 21st-century technical literacy (Ng et al., 2021). This can be combined with the idea of the interdisciplinary knowledge of problem-solving skills and computational thinking, followed by future study of their interrelationships. To expand the scope of AI education, further research may cover the measurement and scale of AI literacy to design instructions for AI education and improve learners' AI literacy. Finally, this paper has a limitation in that no corresponding empirical experiment was conducted to validate the claims, considering the exploratory nature of this paper. Since this article is a conceptual paper, it focused on an overview and presentation of a conceptual framework, and left room for empirical study in future studies. Future studies are expected to refer to the proposed framework in this article and validate its effectiveness through experiments. AI education is a relatively new topic and there has been a growing number of experiments in AI education, further research with more experts should be conducted to verify this preliminary framework of AI literacy in AI education.

Conclusion

This conceptual paper has identified that the previous research on the AI literacy that learners develop and learn through AI education is fragmented and poorly integrated. To compensate, it presents a new competency framework for AI literacy to clarify what AI literacy embraces in terms of the future AI education for K-12 based on the competency aspect. Each competency component in the framework is mapped with a classification of AI literacy drawing on previous studies, thereby considering the term AI literacy holistically.

Many previous studies have highlighted that AI literacy will not be limited to the field of computer science, but will become a necessary skill for all learners to prepare for their future lives. Learners will be able to develop this skill through AI education. In order for learners to use AI appropriately, a proper understanding and leveraging of AI in terms of their competencies is essential as it will improve their AI literacy. Accordingly, the proposed framework from this article is expected to become one of the fundamental references for instructional design for AI education in the future in terms of opening the floor for the discussion about what AI education can and should aim for holistically. Furthermore, this article is expected to lay a foundation to provide insights for scholars, educators, and education policymakers aiming to holistically consider AI literacy through the lens of competency, thereby contributing to the foundation of AI education as its own discipline.

Author Contribution This manuscript was solely authored by Wonjin Yu.

Data Availability No datasets were generated or analysed during the current study.

Declarations

Ethical None.

Competing interest The authors declare no competing interests.

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