From Digital Literacy to AI Literacy: A Systematic Review and Integrative Framework for Education

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Abstract

Digital technology and associated literacies have expanded rapidly, with artificial intelligence (AI) literacy emerging as a critical area of focus. This shift underscores the need to understand AI and its role in supporting learning. While prior research has proposed various AI literacy frameworks and scales, existing reviews remain fragmented, and connections to foundational digital literacy models are often limited (D. R. Long et al., 2020). This study conducts a systematic literature review and applies a well-established digital literacy framework (Ng, 2012), which identifies cognitive, technical, and social-emotional dimensions, to examine how AI literacy has been conceptualized. A thematic analysis of selected studies is then used to identify gaps in existing frameworks and inform a more integrated conceptualization of AI literacy. A total of 516 studies were identified across Web of Science (292), Scopus (201), and Google Scholar (23), and following PRISMA screening, 72 studies were retained for analysis. The primary focus of AI literacy in each study was examined through thematic analysis and independent coding, followed by iterative consensus-building among the authors. Using this process, axial coding was conducted (Johnny Saldaña, 2016), which, in combination with the digital literacy framework, informed the development of a refined conceptualization of AI literacy. This study contributes by explicitly bridging AI literacy and digital literacy frameworks and reframing AI literacy as an extension of core literacy constructs.

Keywords: artificial intelligence literacy, AI literacy, education, conceptualization, frameworks, scale

Introduction

Through a systematic review of the literature and using an established model of digital literacy, this work aims to study the notions of Artificial Intelligence (AI) literacy from the lens of digital literacy in education by reviewing 72 studies. Findings further inform an AI literacy conceptualization extended from the digital literacy model.

In the introduction section, the purpose and research questions of the systematic review are shared, followed by a preliminary review of prior work and the seminal digital literacy model adopted in this work. The methods section outlines the procedure for conducting a systematic literature review, framework, and data collection and analysis methodology. The results section provides coding for each reviewed study against the digital literacy framework, followed by thematic analysis and axial coding of key foci of the reviewed research, leading to a proposed conceptualization of AI literacy and associated digital literacy dimensions. Finally, the discussion section provides the literature synthesis and suggestions for future work.

Purpose and research question

Prior work has examined and proposed AI literacy frameworks and scales (Almatrafi et al., 2024; Lintner, 2024; Long & Magerko, 2022; Ng et al., 2021). Yet, AI literacy reviews are fragmented (Almatrafi et al., 2024; Long & Magerko, 2022), and digital literacy foundations are rarely connected to AI literacy (Ferrari & Punie, 2013; Vuorikari et al., 2016). Given that AI is an extension of digital literacy, an established digital literacy framework is a necessary starting point to capture the needs of AI literacy (W. Ng, 2012). Classifying and assessing AI literacy against the digital literacy framework is important because technology is rapidly changing (Bacalja et al., 2022; Lankshear & Knobel, 2011). AI technology may replace itself with something more sophisticated (Russell & Norvig, 2010). However, digital literacy is considered a pivotal and enduring framework (Buckingham, 2007), so exploring any technology, including AI, against the digital literacy model is practical (Koltay, 2011).

Literature review

AI literacy is becoming an important 21st-century skill (Reed, 2020). With the advancements in technology integration and augmentation in daily human life, it is becoming more likely that educational and work landscapes will be impacted, if not molded, by technologies such as AI (Authors, 2023). As a result, students and educational practitioners need to understand AI literacy (Long et al., 2020). This goal intends not just to allow humans to co-exist and cooperate with AI technologies in work and education, but also to enable humans to have a positive and innovative role in developing AI technologies for the quality of life and places of living (Rampersad, 2020).

There are diverse notions of AI and digital literacy in the literature (Laupichler et al., 2022). To provide a few, Yi (2021) considered metacognition and anticipation of an uncertain future as competencies in AI literacy. On the other hand, Ng et al. (2021) propose four aspects (i.e., know and understand, use and apply, evaluate and create, and ethical issues) to conceptualize AI literacy. Some other authors consider defining notions such as critical AI literacy, which emphasizes not just knowing AI but, more so, understanding the limitations and affordances of AI technologies (Long & Magerko, 2020; Ng et al. 2021; Selwyn, 2019).

In education, efforts have been made to advance research, teaching, and learning of AI literacy. Sample research on AI literacy in education is shown in Table 1. The current research on AI literacy suggests converging gaps, namely:

- Limited theoretical integration and definition through isolated constructs with little linkage to digital literacy constructs (Almatrafi et al., 2024)
- Emphasis on skills and training programs without conceptual roots (Kong et al., 2023)
- Measurement focused on using narrow tools (Wang et al., 2023)
- The need for multi-dimensional understanding (Long, D., & Magerko, 2022; Ng et al., 2021)

Most importantly, AI literacy rarely connects to the constructs of digital literacy. Digital literacy thus remains an integral but underutilized theoretical anchor.

Table 1
Some research examples on AI literacy in education

Key foci	**Reference**
Identify six constructs: Recognize, understand, apply, evaluate, create, and ethical use. Highlight limited theoretical integration.	(Almatrafi et al., 2024)
Identify key AI literacy constructs (blended learning model): • Introduction to Artificial Intelligence (IAI) • Advantages and Disadvantages of AI (ADAI) • Implications of AI (IAII) • Ethics and Laws of AI (ELAI) • Data Security and Privacy (DSP) Find advantages, risks, and implications to drive outcomes.	(Fathahillah et al., 2023)
Conduct pre- and post-course surveys on AI concepts, self-perception of AI literacy, and AI empowerment. Find differences in learner cognition and perceived AI competence	(Kong et al., 2021)
Offer a program comprising of learning nine hours of deep learning, seven hours of machine learning, and 14 hours of application development to foster AI literacy. Find that skills-based and applied AI literacy development can be facilitated through instructional design	(Kong et al., 2023)
Suggest that research on this topic is still in its infancy and needs refinement regarding defining AI literacy.	(Laupichler et al., 2022)
Offer underlying AI literacy competencies as • Understanding AI capabilities/limitations • Evaluating AI systems • Ethical awareness Find the topic is nascent and fragmented	(Long & Magerko, 2022)
Define AI literacy in educational contexts using dimensions of • Knowledge of AI concepts • Critical evaluation • Ethical understanding Position AI literacy with digital and information literacy	(Ng, et al., 2021)
Emerging generative AI tools as key drivers on students' AI literacy	(Pretorius, 2023)
Present a 12-item instrument for the quantitative measurement of AI literacy • Understanding of what artificial intelligence is • Ability to explain basic AI concepts • Familiarity with common AI applications • Use of AI tools for learning and problem-solving • Identification of appropriate AI application scenarios • Confidence in using AI technologies • Evaluation of AI strengths and limitations • Critical assessment of AI-generated outputs • Awareness of AI bias and errors • Understanding of ethical issues in AI use • Awareness of privacy and data concerns in AI	(Wang et al., 2023)

• Responsible and ethical use of AI technologies	

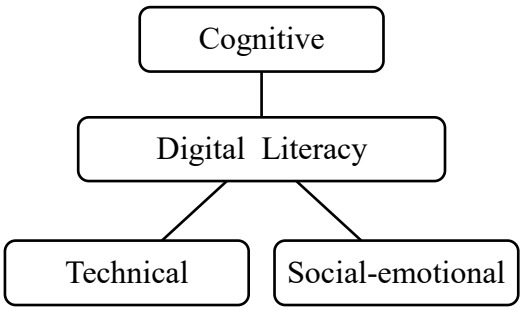
Digital Literacy Framework

The digital literacy framework by Ng (2012) is well established in the literature (Eshet, 2004; Ferrari & Punie, 2013; Martin, 2006). This digital literacy framework provides a broad classification by highlighting three dimensions: cognitive, technical, and social-emotional. A visual of the digital literacy framework is shown in Figure 1. The cognitive facets consider all the photo-visual, audio, gestural, spatial, and linguistic literacies and skills that learners may use during learning. It particularly examines whether students can think critically in searching, evaluating, and creating a cycle of handling digital information, in this case, AI information. Learners must develop the ability to select appropriate software or algorithms for specific tasks. Further, the learners must be aware of ethical, legal, and moral issues such as copyright and plagiarism. As such, the learner needs to understand multiliteracies. The technical aspect considers the operational literacies surrounding the use of technology. This dimension covers skills that enable students to use information and communication technology, AI, for everyday activities. To provide a simple example, to use an online video application in their learning, students need to understand internet connections, video structures, and concepts such as size, buffer, etc. The social-emotional affective factors need to be regulated, and technology, such as AI, is responsible for communication, socializing, and learning. This may be achieved, as Ng (2012) notes, by several different mechanisms, namely:

- Following similar rules as face-to-face communication such as respect
- Enacting privacy and not disclosing any personal information.
- Recognizing when the learner or others are being threatened and knowing how to act (e.g., dismiss, report) accordingly.

Ideally, the author suggests that digital literacy needs to incorporate all three facets. Ng (2012).

Figure 1
Digital literacy framework adapted from Ng (2012)



Methods

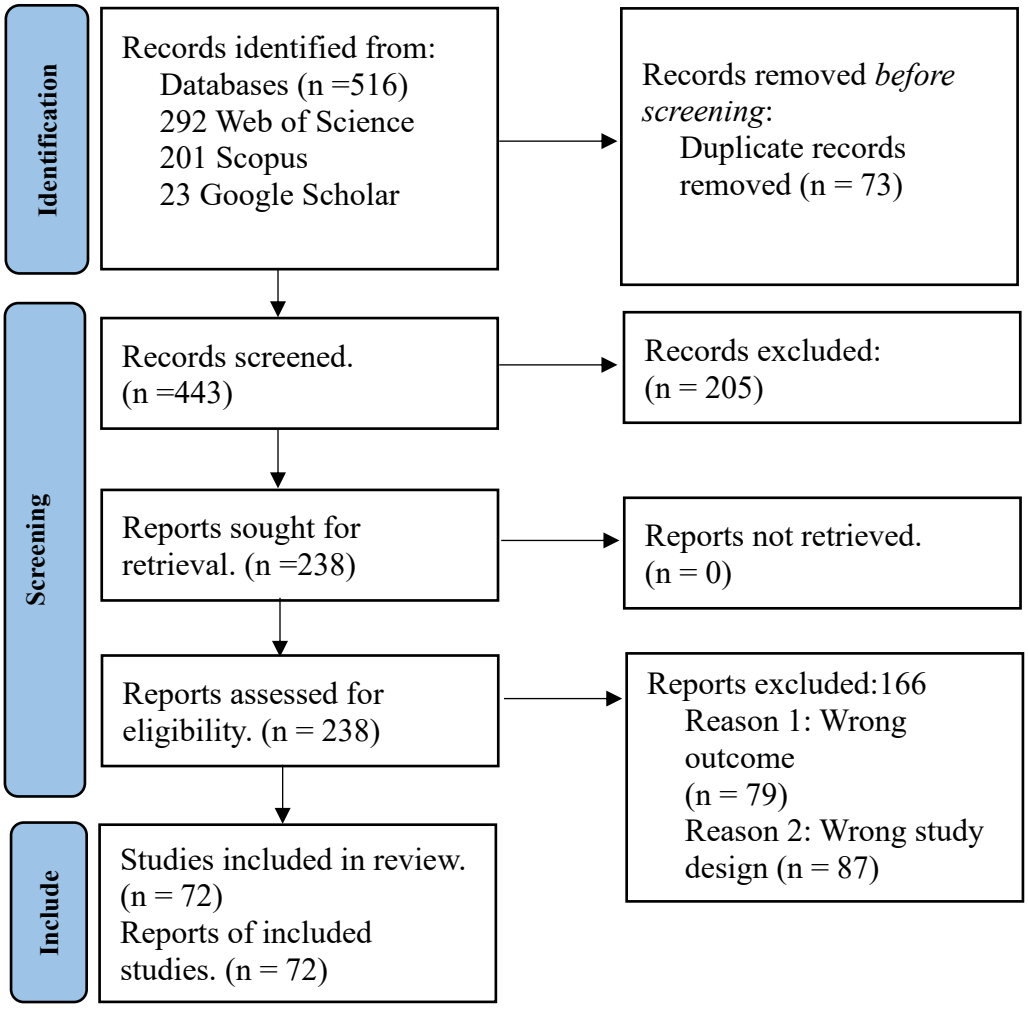
Using the established digital literacy framework by Ng (2012), the state of AI literacy is examined against the digital literacy framework. This examination informs which cognitive,

social-emotional, and technical facets each study involves. Second, open and axial coding is iteratively conducted (Johnny Saldaña, 2016) to thematize AI literacy. Together, these inform an updated conceptualization of AI literacy.

Search process

An overview of the PRISMA chart is presented in Figure 2.

Figure 2
PRISMA chart



Overall, articles were included that had been published in international peer-reviewed journals and conference proceedings. The search included publications written in English during an unlimited time frame. The following string is searched in the Web of Science, SCOPUS, and Google Scholar:

("AI literacy" or "Artificial Intelligence Literacy")

We sought to include all studies that mentioned variations of Artificial Intelligence literacy or AI literacy terms; hence, we used the OR operator. A summary of the inclusion and exclusion criteria can be found in Table 2. The search was initially intentionally kept broad to gather all relevant literature. Then, the studies focusing on healthcare or specialized industries outside of educational settings were eliminated in the screening process. Further, studies that did not offer a description or model of AI literacy were removed.

A study was included if it met all or most of the following conditions:
AI Literacy Relevance

- Explicitly addresses AI literacy, AI education, or AI competency development
- OR includes AI learning constructs such as:
    - understanding AI concepts
    - applying AI tools
    - evaluating AI systems
    - ethical or societal implications of AI

Study Type Eligibility
Included:

- Empirical studies (experimental, quasi-experimental, mixed methods)
- Conceptual/framework papers
- Design-based research (HCI, AI tools, curriculum design)
- Systematic or scoping reviews

Minimum Content Requirement
A study must explicitly address at least one of the following:

- Why AI literacy is needed
- What AI literacy includes (competencies, frameworks, skills)
- How AI literacy is taught or developed (interventions, tools, curricula)
- How AI literacy is evaluated (assessment, scales, outcomes)
- Challenges or risks related to AI literacy adoption

A study was not included if it met all or most of the following conditions:
Wrong outcome:

- Does NOT mention AI literacy or AI education explicitly
- Focuses only on:
    - AI technical development (e.g., ML algorithms without learning context)
    - system performance or engineering optimization
    - AI applications with no educational dimension

Wrong study design:

- Purely technical papers (engineering, computer science only)
- No pedagogical, educational, or learning analysis
- No human participants OR no educational intervention context

No AI literacy construct:

- Mentions AI but does NOT define or operationalize:

- literacy
- competency
- understanding
- evaluation of AI knowledge or skills

A total of 516 studies were identified from Web of Science or WoS (292), Scopus (201), and Google Scholar (23). A total of 73 duplicate records were then removed. Following our initial inclusion and exclusion criteria, a total of 205 studies were excluded. The secondary screening examined the content of the manuscripts. Of the 238, 79 had the wrong outcome, and 87 had the wrong study design. This resulted in a total of 72 studies included in the review.

Table 2
Summary of inclusion and exclusion criteria

	Inclusion criteria	**Exclusion criteria**
Initial	Studies in English	Studies not in English
	Article and conference proceedings	Grey literature
Secondary	Focused on an understanding of AI literacy	Not focused on understanding AI literacy
	Focused on educational settings	Focused on healthcare or specialized industries

Data collection and analysis

An overview of the methodology can be found in Table 3. This study follows a systematic review design to provide a structured synthesis of research on AI literacy through the lens of digital literacy in education. A protocol-driven search was conducted across multiple academic databases using predefined Boolean search strings, following PRISMA guidelines. Studies were screened through a multi-stage process (title, abstract, and full-text) using clearly defined inclusion and exclusion criteria. Data were then extracted using a structured framework grounded in digital literacy dimensions, enabling consistent coding across studies, complemented with thematic extraction per study to explore areas where digital literacy coding falls short.

Table 3
Overview of methodology

Review Type	Purpose & Focus	Search Strategy	Screening & Selection	Coding Approach	Synthesis Method	Methodological Rigor Requirements
Systematic Review	Comprehensive, structured synthesis of existing empirical studies to study the notions of	Exhaustive, predefined search across multiple databases	Transparent inclusion/exclusion criteria; multi-stage screening (title,	Structured data extraction using the structured digital	descriptive aggregation of findings	Reproducibility, transparency, protocol-driven

	Artificial Intelligence (AI) literacy from the lens of digital literacy in education	(e.g., WoS, Scopus); use of Boolean strings; PRISMA-guided	abstract, full-text)	literacy framework		(e.g., PRISMA)

The data coding employed the following practices:
1. Unit of analysis
A single published study (article, conference paper, or review) addressing AI literacy.
Each study was coded as one complete analytical unit, with multiple constructs extracted where possible.

2. Coding approach and codebook development
- A preliminary deductive codebook was developed based on:
  - existing AI literacy frameworks (e.g., competencies, ethics, pedagogy)
  - prior literature categories (digital literacy)
- The codebook was then iteratively refined inductively during pilot coding of a subset of studies.

3. Coders and roles
- Coding was conducted by two independent reviewers.
- Coder 1: primary extraction and initial coding
- Coder 2: independent verification of all included studies

A subset of studies was jointly reviewed during calibration to ensure consistency before full coding commenced.

4. Coding procedure
- Stage 1: Title and abstract coding (eligibility confirmation)
- Stage 2: Full-text coding using structured codebook
- Stage 3: Extraction of constructs into a shared matrix (study-level coding sheet)
- Stage 4: Cross-checking and reconciliation

5. Disagreement resolution
- Any discrepancies between coders were resolved through:
  - discussion and consensus meetings
  - re-examination of full-text evidence
- If consensus could not be reached:
  - A third reviewer acted as adjudicator

6. Intercoder reliability/trustworthiness
- Trustworthiness was enhanced through:
  - audit trail of coding decisions
  - iterative refinement of code definitions

- triangulation across multiple study types (empirical, conceptual, reviews)

7. Theme development (how codes became themes)
The transition from codes to themes followed a structured process:

1. Open coding: extraction of AI literacy constructs from each study
2. Axial grouping: clustering into categories
3. Final themes were refined through:
    - constant comparison across studies
    - iterative team review
    - alignment with AI literacy conceptual models

The protocol included the following steps:

- Use the input string of search in both SCOPUS and WoS.
- Explore Google Scholar for additional peer-reviewed articles missing in SCOPUS or WoS.
- Download the complete records of all the papers.
- Upload the complete records to Covidence, used for the systematic review procedure.
- Use Covidence to identify duplicate studies and remove them.
- Review the title and abstract of each article and decide if it is relevant or not (following initial inclusion and exclusion criteria as noted in section 2.1).
- Download and review the full text of each article and decide if it is relevant or not (following secondary inclusion and exclusion criteria as noted in section 2.1).
- Gather the complete demographic records of studies selected for review.
- Extract and chart definitions of digital literacy by Ng (2012) (e.g., one or a combination of cognitive, technical, and social-emotional, as described below and in 1.3)
    - The cognitive facets consider all cognitive skills and the photo-visual, audio, gestural, spatial, and linguistic literacies and skills that learners may use during learning with AI.
    - The technical aspect considers the operational literacies surrounding the use of AI.
    - The social-emotional affective factors that need to be regulated, and having the ability to use AI responsibly for communication, socializing, and learning. This may be achieved by: a) Following similar rules as face-to-face communication, such as respect, b) Enforcing privacy and not disclosing any personal information, or c) Recognizing when the learner or others are being threatened and knowing how to act (e.g., dismissing, reporting) accordingly.
- Review each article and thematically analyze and code the key foci using open coding
- Review key foci from the 72 studies and use axial coding to determine higher-level code themes.
- Summarize each research as the coded combinations of digital literacy dimensions
- Using a comparative analysis of digital literacy codification and axial codes, identify areas where the digital literacy framework falls short, to inform a new conceptualization of AI literacy
- Create a synthesis of future recommendations and challenges based on analysis and results in the discussion section.

The digital literacy framework is used to examine the state of AI studies by following Ng (2012) Codification scheme. Once the information for each study is charted and summarized, it is examined whether other descriptions of AI literacy were provided that did not fit within the digital literacy model. Open and axial coding are used to thematize iteratively and group themes, leading to a proposed and updated conceptualization of AI literacy that builds from the digital literacy framework.

Results

A background summary of the reviewed studies can be found in Table 4. The findings reveal that AI literacy is less needed in a purely technical sense. Instead, it needs to be focused more on socio-technical literacy models as opposed to skills-based. The key foci reveal convergence on core domains such as conceptual understanding of AI, critical thinking and judgment, ethical awareness, social and humanistic implications, and impact with real and practical contextualization. The pedagogical shift towards contextual learning, increased ethics, lack of conceptual consistency, and growing need for integrated frameworks across the reviewed studies highlight the need for AI literacy frameworks embedded in the expressed needs.

Table 4
Summary of digital literacies covered by the reviewed studies.

Year	Key Foci / Constructs	Key Contribution	Type
Adams et al. (2021)	AI ethics, governance, policy	Global synthesis of AI ethics frameworks	Review
Benjamin et al. (2023)	AI + design, creativity	AI literacy via design research	Design
Brauner et al. (2023)	Trust, bias, perception	Maps public AI understanding	Empirical
Cardon et al. (2023)	AI writing, literacy, and ethics	AI literacy in academic writing	Conceptual
Casal-Otero et al. (2023)	AI literacy frameworks	Synthesizes K–12 AI literacy	Review
Celik (2023)	Digital divide, CT, cognition	Identifies predictors of AI literacy	Empirical
Cetindamar et al. (2022)	Workplace AI skills	Extends AI literacy to industry	Empirical
Chai, Lin, et al. (2020)	TPB, motivation	Models AI learning intention	Empirical
Chai et al. (2021)	Behavioral intention	Predicts AI learning adoption	Empirical
Chan & Hu (2023)	Perceptions, GenAI	Student perspectives on AI use	Qualitative
Chen & Lin (2023)	Risks vs benefits	Framework for responsible AI use	Conceptual
Chen et al. (2022)	Adoption, motivation	Factors influencing AI engagement	Empirical

Cox & Mazumdar (2022)	AI definitions, literacy	AI literacy in LIS context	Conceptual
Dai et al. (2020)	Readiness, well-being	Links AI literacy to well-being	Empirical
Druga et al. (2021)	AI curriculum	Mapping AI teaching tools	Review
Druga et al. (2022)	Inclusion, equity	Promotes inclusive AI literacy	Conceptual
Druga et al. (2019)	Perception, ML	Children's understanding of AI	Empirical
Eguchi (2023)	Robotics, ML	AI literacy via robotics	Experimental
Eguchi (2022)	ML learning	Robotics-based AI education	Empirical
Eguchi et al. (2021)	Culture, AI literacy	Inclusive AI pedagogy	Conceptual
Ehrensberger-Dow et al. (2023)	AI in translation	Expands AI literacy domains	Conceptual
El-Zanfaly et al. (2023)	Co-creation, GenAI	Human-AI collaboration literacy	Experimental
Fyfe (2023)	Academic integrity	Reframes AI use in assessment	Conceptual
Guerreiro-Santalla et al. (2023)	Robotics interaction	AI learning via embodiment	Experimental
Hemment et al. (2023)	Public engagement	AI literacy through art	Empirical
Henry et al. (2021)	Game-based learning	AI literacy through role-play	Experimental
Hermann (2022)	Ethics, personalization	Ethical AI literacy	Conceptual
How & Hung (2019)	AI thinking	Early AI literacy integration	Conceptual
Hwang et al. (2023)	Measurement	AI literacy assessment tool	Instrument
Jang et al. (2022)	Curriculum	AI literacy intervention	Experimental
Kasinidou (2023)	Participation	Public AI literacy model	Conceptual
Kasinidou et al. (2023)	Participatory AI literacy, co-design, socio-technical & ethical awareness	AI literacy is learner-led, participatory, and socially situated beyond technical skills	Conceptual
Kaspersen et al. (2021)	ML, society	Tool for AI literacy	Design
Kim & Lee (2022)	Human-AI interaction	Improves learning performance	Experimental
Koçak et al. (2023)	Research quality	AI literacy in medicine	Review
Komasawa & Yokohira (2023)	Medical AI literacy	AI in healthcare training	Review

Kong et al. (2023)	Pedagogy, PBL	Effective AI literacy design	Empirical
Kong et al. (2022)	Concepts, ethics	Evaluates the AI literacy program	Empirical
Laupichler et al. (2023)	Measurement	Valid assessment instrument	Instrument
Lee et al. (2022)	PD model	Teacher AI literacy	Design
Lee & Park (2023)	Attitudes	AI mindset shift	Qualitative
Leichtmann et al. (2023)	Trust, XAI	AI literacy impacts trust	Experimental
Lin et al. (2023)	CT, AI learning	Structural relationships	SEM
Lo (2023)	Policy literacy	AI literacy in libraries	Conceptual
Long et al. (2021)	Informal learning	AI literacy outside school	Qualitative
Long & Magerko (2020)	Competencies	Foundational AI literacy model	Conceptual
Lubin et al. (2021)	Interdisciplinary	AI literacy across fields	Conceptual
McCallum (2023)	Communication	AI literacy in language learning	Conceptual
Ng et al. (2022)	Frameworks	Synthesizes AI literacy	Review
Ng et al. (2023)	Teacher skills	AI readiness framework	Empirical
Ng et al. (2023)			
Park et al. (2023)	Integration	Teacher experiences	Qualitative
Pinski et al. (2023)	Human-AI decision	AI literacy improves delegation	Empirical
Porlezza (2023)	Policy, media	Responsible AI literacy	Conceptual
Relmasira et al. (2023)	GenAI, STEAM	Emerging AI literacy	Conceptual
Robinson (2020)	Governance	Cultural AI literacy	Conceptual
Solyst et al. (2023)	Ethics, inclusion	Equity-centered AI literacy	Qualitative
Stanton (2023)	Macromarketing pedagogy, sustainability education, systems thinking, teaching innovations	Summarizes efforts to advance macromarketing teaching through systems thinking and sustainability-focused pedagogies in marketing education.	Commentary / conceptual synthesis
Steinbauer et al. (2020)	Curriculum	AI education framework	Conceptual

Thirunavukarasu et al. (2023)	Applied AI	Democratizing AI literacy	Tutorial
Velander et al. (2023)	Teacher perception	AI literacy in teaching	Qualitative
Voulgari et al. (2021)	Game design	AI literacy via games	Design
Wan et al. (2020)	Accessible ML, clustering, K-12 AI literacy	Simplifies ML (k-means) for K-12 learners through hands-on, inquiry-based activities linking data and scientific reasoning	Design / HCI study
Wang & Lester (2023)	Policy	Advocates AI literacy	Conceptual
Wen et al. (2022)	Teaching performance	AI literacy impacts teaching	Empirical
Wienrich & Carolus (2021)	Measurement	AI competency scale	Instrument
Wilby & Esson (2023)	Critical literacy	AI literacy in the discipline	Conceptual
Wiljer & Hakim (2019)	Professional literacy	AI literacy in health	Conceptual
Williams et al. (2023)	Ethics, curriculum	AI literacy through ethics	Experimental
Wilton et al. (2022)	Teacher literacy	Educator readiness	Empirical
Zammit et al. (2021)	Pedagogy	AI learning through games	Design
Zhao et al. (2022)	Teacher literacy	Structural model	SEM

Using the descriptions, definitions, or models of artificial literacy provided in the reviewed studies and the classification description presented in subsection 1.2, each study was coded if it had considered the cognitive, technical, and/or social-emotional factors surrounding AI literacy. A summary of the data coded can be found in Table 5.

Table 5
Summary of digital literacies covered by the reviewed studies.

Reference	**Cognitive, Social-emotional, Technical**	**Derived literacies noted in the reviewed studies**	**Digital and derived literacies combined**
Adams et al. (2021)	CT	1. Contextual factors such as problem space	CT1
Benjamin et al. (2023)	CT	1. Contextual factors such as problem space	CT1
Brauner et al. (2023)	T	2. Conceptualization of expertise	T2
Cardon et al. (2023)	ST	3. Objectives such as application, Authenticity	ST3

Casal-Otero et al. (2023)	C	4. Frameworks that have a/an: Interdisciplinary approach, Competency-based approach, Global approach, Active approach	C4
Celik (2023)	C	5. Human factors such as motivation	C5
Cetindamar et al. (2022)	C	1. Contextual factors such as problem space, Teaching, and learning setting	C1
Chai, Lin, et al. (2020)	CT	5. Human factors such as confidence	CT5
Chai et al. (2021)	C	5. Human factors such as motivation	C5
Chan & Hu (2023)	C	1. Contextual factors such as teaching and learning setting	C1
Chen & Lin (2023)	CS	5. Human factors such as personalization (learning, interactive support, accessibility)	CS5
Chen et al. (2022)	S	5. Human factors such as satisfaction	S5
Cox & Mazumdar (2022)	CT	2. Conceptualization of data literacy	CT2
Dai et al. (2020)	S	5. Human factors such as confidence	S5
Druga et al. (2021)	C	4. Frameworks such as TPACK	C4
Druga et al. (2022)	C	2. Conceptualization of smart toys	C2
Druga et al. (2019)	CT	3. Objectives such as inclusiveness	CT3
Eguchi (2023)	CT	2. Conceptualizations or future professions	CT2
Eguchi (2022)	CT	2. Conceptualizations or future professions	CT2
Eguchi et al. (2021)	S	1. Contextual factors such as culture	S1
Ehrensberger-Dow et al. (2023)	T	1. Contextual factors such as language	T1
El-Zanfaly et al. (2023)	C	3. Objectives such as explainability	C3
Fyfe (2023)	S	3. Objectives such as multimodal communication	S3
Guerreiro-Santalla et al. (2023)	S	3. Objectives such as natural interaction	S3
Hemment et al. (2023)	C	3. Objectives such as explainability	C3
Henry et al. (2021)	C	2. Conceptualization of Media literacy	C2
Hermann (2022)	S	3. Objectives such as social good	S3
How & Hung (2019)	C	2. Conceptualization of AI thinking	C2
Hwang et al. (2023)	CT	5. Human factors such as communication	CT5
Jang et al. (2022)	CS	3. Objectives such as creativity	S3
Kasinidou (2023)	S	5. Human factors such as perceptions	S5

Kasinidou et al. (2023)	C	3. Objectives such as responsibility	C3
Kaspersen et al. (2021)	C	2. Conceptualization of machine learning	C2
Kim & Lee (2022)	CT	5. Human factors such as collaboration skills	CT5
Koçak et al. (2023)	CTS	3. Objectives such as High-quality data, Open and transparent science	CTS3
Komasawa & Yokohira (2023)	C	2. Conceptualization of non-technical skills	C2
Kong et al. (2023)	C	4. Frameworks that have a multidimensional approach	C4
Kong et al. (2022)	S	5. Human factors such as self-efficacy and AI empowerment	S5
Laupichler et al. (2023)	C	2. Conceptualization of AI assessment	C2
Lee et al. (2022)	C	4. Frameworks that have a Professional development approach	C4
Lee & Park (2023)	C	3. Objectives such as symmetry between AI-literate and illiterate	C3
Leichtmann et al. (2023)	C	3. Objectives such as explainability	C3
Lin et al. (2023)	C	2. Conceptualization of computational thinking	C2
Lo (2023)	C	2. Conceptualization of AI literacy for libraries	C2
Long et al. (2021)	S	4. Frameworks that have an informal approach	S4
Long & Magerko (2020)	S	2. Conceptualization of user-friendly technology with AI/HCI	S2
Lubin et al. (2021)	C	4. Frameworks that have a university classroom approach	C4
McCallum (2023)	T	1. Contextual factors such as language	T1
Ng et al. (2022)	C	1. Contextual factors such as teaching and learning setting	C1
Ng et al. (2023)	S	5. Human factors such as collaboration skills	S5
Ng et al. (2023)	C	1. Contextual factors such as teaching and learning setting	C1
Park et al. (2023)	CT	4. Frameworks such as TPACK	CT4
Pinski et al. (2023)	CS	2. Conceptualization of task delegation with AI/HCI	CS2
Porlezza (2023)	S	2. Conceptualization of disinformation	S2
Relmasira et al. (2023)	C	4. Frameworks that have a design approach	C4
Robinson (2020)	S	3. Objectives such as transparency	S3

Solyst et al. (2023)	C	1. Contextual factors such as teaching and learning setting	C1
Stanton (2023)	C	4. Frameworks that have a business-driven approach	C4
Steinbauer et al. (2020)	C	1. Contextual factors such as the level of education	C1
Thirunavukarasu et al. (2023)	C	4. Frameworks that have a hands-on approach	C4
Velander et al. (2023)	CT	4. Frameworks such as TPACK	CT4
Voulgari et al. (2021)	C2	2. Conceptualization of game-based learning environments	C2
Wan et al. (2020)	C	2. Conceptualization of machine learning	C2
Wang & Lester (2023)	C	4. Frameworks that have a research-based approach	C4
Wen et al. (2022)	C	3. Objectives such as creativity,	C3
Wienrich & Carolus (2021)	CTS	2. Conceptualization of conversational agents	CTS2
Wilby & Esson (2023)	C	3. Objectives such as responsibility	C3
Wiljer & Hakim (2019)	CT	2. Conceptualization of data literacy	CT2
Williams et al. (2023)	C	3. Objectives such as creativity,	C3
Wilton et al. (2022)	C	3. Objectives such as symmetry between AI-literate and illiterate	C3
Zammit et al. (2021)	C2	2. Conceptualization of game-based learning environments	C2
Zhao et al. (2022)	CT	2. Conceptualization of AI assessment	CT2

The codes and their counts across the 72 studies are presented below.

C. Cognitive: 54/72 (75%)
T. Technical: 54/72 (75%)
S. Social-emotional: 19/72 (26%)

Moreover, AI literacies that did not fit well within the digital literacy framework and were an amalgam of cognitive, technical, and social-emotional literacies were coded via open and axial coding. The iterative grouping resulted in five factors emerging from the 72 reviewed studies. The rationale was to thematize high-level attributes that each constitute an array of topics and whose nature is distinguishable. The five high-level themes from this systematic review were: 1. Contextual factors describe situational elements; 2. Conceptual describes existing and emerging concepts related; 3. Objectives describe high-level goals and constraints; 4. Frameworks describe underlying perspectives and epistemological/theoretical/methodological lenses, and 5. Human factors describe demographic characteristics that impact AI literacy's characterization, pedagogy, and use. The themes had associated codes within the reviewed studies, as presented below.

1. Contextual factors: Resultant codes were Problem space, Teaching and learning setting, Culture, Language, and Level of education.

2. Conceptual: Expertise, data literacy, innovative toys, future professions, media literacy, AI thinking, machine learning, Non-technical skills, AI assessment, computational thinking, user-friendly technology/HCI, task delegation with AI/HCI, disinformation, game-based learning environments, conversational agents.

3. Objectives: Application, Authenticity, Inclusiveness, Explainability, Social good, Creativity, Responsibility, High-quality data, Open and transparent science, and the symmetry between AI-literate and illiterate.
4. Frameworks: Interdisciplinary approach, Competency-based approach, Global Approach, Active approach, TPACK, Multidimensional approach, Professional development approach, Community-based approach, Informal approach, University classroom approach, Design approach, Business-driven approach, Hands-on approach, Research-based approach.
5. Human (Learner/user dependent) factors: Motivation, confidence, personalization (learning, interactive support, accessibility), satisfaction, communication, perceptions, collaboration skills, self-efficacy, and AI empowerment conceptions.

The codes and their counts across the 72 studies are presented below.

1. Contextual factors: 11/72 (15%)
2. Conceptual: 21/72 (29%)
3. Objectives: 17/72 (24%)
4. Frameworks: 12/72 (17%)
5. Human factors: 11/72 (15%)

Conceptual themes were most prevalent in the reviewed studies, followed by Objectives, Frameworks, and Contextual and Human factors. Analysis of combined codes from the digital literacy framework and derived themes revealed 22 distinct trends across the 72 studies. The coding entails C. Cognitive, T. Technical, S. Social-emotional (established digital literacy model) and 1. Contextual, 2. Conceptual, 3. Objectives, 4. Frameworks, and 5. Human factors (proposed AI literacy model). The combined codes and their counts across the 72 studies are presented below.

- C2: 11 counts of the trend
- C4, C3: 9 counts of each trend
- C1: 6 counts of the trend
- S3, S5, CT2: 5 counts of each trend
- CT5: 3 counts of the trend
- C5, CT4, S2, T1, CT1: 2 counts of each trend
- CS2, CS5, CT3, CTS2, CTS3, S1, S4, ST3, T2: 1 counts of each trend

The trend list shown in the bullet points above attests that the five themes identified were an amalgam of Cognitive, Technical, and Social-emotional codes from the digital literacy framework. Therefore, the derived themes capture AI literacy more comprehensively than the digital literacy framework alone.

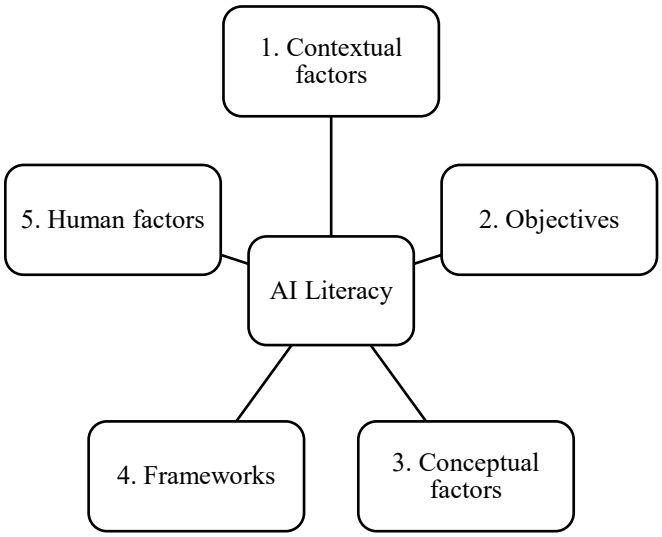
Discussion

This work examined AI literacy against an established digital literacy framework by Ng (2012). The codification of 72 reviewed studies against the three themes of cognitive, technical, and social-emotional within the digital literacy framework showed that the reviewed studies explain most of the cognitive aspects, followed by technical aspects, and the social-emotional aspects are explored the least. However, many factors did not fit within the three-level digital literacy framework. This led to open and axial coding of themes emerging surrounding AI literacy across the reviewed studies and the discovery of five emergent themes to describe AI literacy.

Summary of Findings

Our thematic analysis of AI literacy, which did not fit well within the digital literacy framework, led to five high-level themes. The findings from the analysis of digital and derived themes surrounding AI literacy showed that AI literacy often requires an amalgamation of cognitive, technical, and social/emotional dimensions, where a clean-cut percentage contribution for each is not known. An updated conception of AI literacy was needed to account for higher-level attributes. The proposed conceptualization, shown in Figure 3, highlights that AI literacy requires attention to contextual, conceptual, and Objective frameworks and human factors.

Figure 3
The proposed AI literacy conceptualization



The framework proposes:

1. Contextual to encompass all the dynamic non-human factors that impact the understanding and use of AI literacy from one scenario to the next.
2. Objectives to encompass the goals or constraints surrounding the achievement of AI literacy.
3. Conceptual to encompass all existing and emerging concepts that relate to or impact AI literacy but may not qualify as an established framework or objective.
4. Frameworks to encompass the underlying epistemological, theoretical, or methodological perspectives set around AI literacy.

5. Human factors encompass all the human user-dependent factors, such as demographics and the predispositions of learners that shape the achievement and understanding of AI literacy.

The proposed conceptualization derived from the review of 72 studies contributes to a nuanced understanding of AI literacy. Existing frameworks on AI literacy often take on a rigid approach to characterize AI literacy, which can, in turn, become confusing or obsolete considering changes or advancements made to AI. This work acknowledges and distinguishes between dimensions that characterize AI literacy and further classifies each with the three established dimensions of digital literacy. It was found that:

- Contextual factors are cognitive the most, followed by technical and social, the least. Future work may consider more of what technical and social contextual (non-human dependent) factors of AI literacy may encompass.
- Conceptual factors are cognitive the most, followed by technical and social, the least. This finding may suggest that concepts relating to or impacting AI literacy are primarily cognitive and technical. There may thus be a need to recognize the social concepts of AI literacy more formally.
- Objectives are cognitive the most, followed by social, and technical, the least. Future work may need to characterize socially and technically constructed objectives within AI literacy.
- Frameworks are cognitive the most, followed by technical, and social, the least. The frameworks, specifically the socially constructed epistemological and philosophical constructs, need to be more clearly elaborated in future work on AI literacy.
- Human factors are cognitive and social the most, followed by technical factors, with the least. This makes sense, as humans are inherently social and cognitively complex beings with advanced capacities for communication, collaboration, and adaptive reasoning. However, the augmentation of technology into human decision-making processes introduces complex socio-technical challenges concerning human factors such as cognitive load, trust, bias, and accountability.

Contributions and novelty

This work aims to conceptualize and understand AI literacy by reviewing the literature instead of one- or limited-time experimentation and analysis of self-reported measures. This allows us to take on a holistic, more comprehensive, open, and non-rigid understanding of AI literacy. It uses an established digital literacy framework as the starting point and test bed to characterize existing research on AI literacy. By thematizing the key foci of 72 reviewed research articles and using iterative open and axial coding among authors, a conceptualization of AI literacy is proposed. This work bridges the gap between digital literacy dimensions and AI literacy factors examined in the reviewed literature. It also offers a blueprint to understand AI literacy using the conceptualization and the associated cognitive, technical, and social-emotional dimensions.
The integral contributions of this work are:

- Bringing coherence to a topic currently diversified and scattered across higher education disciplines
- Anchoring AI literacy with digital literacy theory

- Structured mapping and gap finding of the digital literacy model to inform a proposed conceptualization of AI literacy

The novel contributions of this work are:

- Bridging AI literacy with digital literacy by reframing AI literacy as an extension of digital literacy
- Conducting an exhaustive systematic review to inform gaps in AI literacy conceptualization with digital literacy and offering a proposed conceptualization
- Reframing AI literacy as socio-technical, multidimensional, and contextual, offering an adaptive conceptualization that can prompt learning in context and meet the expressed framework needs reported by the literature

Implications

Ideally, the digital literacy framework suggests that digital literacy needs to incorporate all three facets: cognitive, technical, and social-emotional. Ng (2012). Similarly, an enhanced AI literacy conceptualization is found to consider all five of the following:

1. Contextual factors
2. Objectives
3. Conceptual factors
4. Frameworks
5. Human factors

Moreover, further account for the digital literacy dimensions as follows:

1. Contextual to encompass all the dynamic non-human factors that impact the understanding and use of AI literacy from one scenario to the next. Contextual may be more Cognitive, such as teaching and learning space, more Technical, such as the educational system, or more Social-emotional, such as culture.
2. Objectives to encompass the goals or constraints surrounding the achievement of AI literacy. Objectives may be more Cognitive, such as creativity, more Technical, such as achieving high-quality data analysis and problem-solving, or more Social-emotional, such as achieving more comprehensive and universal social good.
3. Conceptual to encompass all existing and emerging concepts that relate to or impact AI literacy but may not qualify as an established framework or objective. Conceptual may be more Cognitive, such as machine or deep learning theories, more Technical, such as programs or applications of AI, or more Social-emotional, such as interactions between humans and technology.
4. Frameworks to encompass the underlying epistemological, theoretical, or methodological perspectives set around AI literacy. Frameworks are more underlying than objectives. Frameworks may be more Cognitive, such as ways humans learn, more technical, such as the empirical AI frameworks, or more Social-emotional, such as psycho-social frameworks.
5. Human factors encompass all the human user-dependent factors, such as demographics and the predispositions of learners that shape the achievement and understanding of AI literacy. Human factors may be more Cognitive, such as schemas, technical, and technological readiness, or more Social-emotional, such as trust and confidence.

Limitations

This study has some limitations. Studies specifically noted Artificial Intelligence or AI and literacy in their publication were reviewed. Other similar terms and studies were thus not included in this systematic review. Further, studies that explored this topic in languages other than English were also not included. Also, it should be noted that different studies interpret AI literacy differently. However, as noted in the introduction, this work did not assume a fixed notion of AI literacy. Caution should be given that the conceptualization is more holistic than being set in a specific context. As such, the conceptualization combined with the three dimensions of the digital literacy framework can present a closer look at the different considerations for developing AI literacy, rather than defining a specific lens for AI literacy.

Conclusion

A systematic literature review was conducted to gather existing work on AI literacy. Following an established digital literacy framework by Ng (2012), this study examined which cognitive, social-emotional, and technical facets each study involves. A roadmap for future research was derived using the digital literacy framework and open and axial coding. The proposed conceptualization was derived from the review of 72 studies to contribute to a nuanced understanding of AI literacy. Contextual factors were found to be cognitive the most, followed by technical and social, the least. Conceptual factors were found to be cognitive the most, followed by technical and social, the least. Objectives were found to be cognitive the most, followed by social, and technical the least. Frameworks were found to be cognitive the most, followed by technical and social, the least. Human factors were cognitive and social, with the most, followed by technical factors, with the least. This systematic review aimed to conceptualize and understand AI literacy by reviewing the literature instead of one- or limited-time experimentation and analysis of self-reported measures. This allows for a holistic, more comprehensive, open, and non-rigid understanding of AI literacy. This can also bridge the gap between digital literacy dimensions and AI literacy factors examined in the reviewed literature and offer a blueprint to understand AI literacy not only by the conceptualization, but also with the associated cognitive, technical, and social-emotional dimensions involved.

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