AI LITERACY IN K-12 SYSTEM: AN UMBRELLA REVIEW

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Abstract

This umbrella review aims to map the teaching methods used to integrate Artificial Intelligence (AI) literacy into the K-12 system and to highlight the gaps in the literature on the subject. Scopus, Eric and Web on Science datasets were used for the search and a total of 12 articles published between 2022 and 2024 were reviewed. Most of the documents are scoping review published in 2023-2024, reflecting the emerging and growing interest on AI literacy topic, with research geographically concentrated in Hong Kong. Experiential learning (e.g., problem/project/case-based learning) and active learning (e.g., hands-on and game-based activities) are the most common pedagogical approaches, with experiential learning predominantly applied in secondary education. Learning content can be grouped into three categories: basic knowledge about AI, AI processes, and AI impacts, with ethical aspects highlighted as a key component in line with international frameworks but less addressed when compared to AI processes and knowledge. Software-based tools are the most widely used, while unplugged tools are less common and mainly employed with younger students. Studies point out a persistent lack of validated assessment methods, which limit a comprehensive understanding of learning outcomes. Moreover, the literature emphasizes the importance of teacher training and the integration of interdisciplinary AI literacy within existing disciplinary curricula.

Keywords: Artificial Intelligence, AI literacy, AI Education, Teaching practice, Twenty-first century skills, K-12 Education.

1 INTRODUCTION

The application of technologies based on artificial intelligence (AI) is increasing in many areas of society and its pervasiveness in our daily lives (e.g., social media, real time locations and search systems) requires future generations to understand both its potential and limitations. Yet, the scientific community has observed that such knowledge is still insufficient to enable citizens to critically engage with contemporary challenge [1, 2, 3].

AI-teaching was initially focused on the transmission of technical and operational skills, without promoting critical understanding and ethics – essential dimensions for the construction of digital citizenship [4]. Until 2021, AI education was mostly confined to universities and to the fields of computer science and engineering, limiting the development of AI literacy for citizenship at a more general level [5]. This was also due to the lack of tools for younger learners and non-technical audiences. Efforts to introduce AI in K-12 education have recently begun, but concrete methodological proposals for schools remain limited [6, 7]. To address this gap, the most recent edition of the DigComp framework includes a specific annex dedicated to artificial intelligence, with eighty examples of knowledge, skills, and attitudes related to citizens interacting with AI systems [8]. This updated framework highlights the acquisition of AI literacy as a key competence for citizens in the 21st century [9, 10, 11].

1.1 AI literacy

AI literacy was first introduced in 2016 by Kandlhofer et al. [12] as the ability to understand the techniques and concepts behind artificial intelligence. Later definitions expanded this notion: Long and Magerko [5] describe it as a set of skills enabling critical communication and collaboration with AI; Kong and Zhang [13] emphasize understanding and applying AI concepts in real-world contexts; Wang et al. [14], instead, highlight the integration of knowledge, skills, processes, methods, attitudes and values. Building on these definitions, several reference frameworks – such as the Five Big Ideas [15], Long & Magerko [5], Ng et al. [16], UNESCO [17], and OECD [18] have been developed to systematize competencies and guide educational pathways. For example, *Empowering Learners for the Age of AI: An AI Literacy Framework for Primary and Secondary Education* (AILit Framework) [18], published in May 2025, responds to the 2023 Council Recommendations on digital education and skills, and serves as a starting point establishing a common language about AI literacy. Dedicated to teachers and

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education policymakers, AILit framework offers different ways to introduce AI concept into concrete classroom practice, emphasizing interdisciplinary integration in learning environment.

Despite the growing body of literature on this topic [19], a gap persists in different areas, such as teacher training, objective assessment methods and practical integration of AI literacy curricula in school education [20]. To better understand the development of AI literacy – a rapidly evolving domain – we explored the field through an umbrella review and suggested future directions for teaching and learning AI in K–12 education. The following research questions (RQ) guided the analysis: What is the temporal and geographical distribution of the publications? (RQ1); What types of literature reviews are conducted? (RQ2); At which school level is AI literacy addressed (RQ3); How is AI literacy practices in K-12 system in terms of teaching approaches, learning content, outcome and learning tools? (RQ4); How are learning outcomes measured and evaluated? (RQ5).

2 METHODOLOGY

An umbrella review specifically refers to a survey that synthesizes evidence from multiple reviews into a single, accessible, and practical document. It focuses on a broad condition or problem with competing interventions, emphasizing the reviews that examine these interventions and their outcomes [21]. This section illustrates the search strategies, inclusion and exclusion criteria, and methods for analyzing the collected evidence.

2.1 Procedure and tools

A search query was carried out in December 2024 on ERIC, Scopus and Web of Science (WoS) databases. Three strings shown below (Fig. 1) have been used. The search covered English-language articles in peer-reviewed journals and conference papers.

ERIC

("artificial intelligence" OR "AI") AND ("literacy" OR "digital literacy" OR "media literacy" OR "information literacy" OR "critical literacy").

Scopus

TITLE-ABS-KEY ("artificial intelligence" OR "AI") AND TITLE-ABS-KEY ("literacy" OR "digital literacy" OR "media literacy" OR "information literacy" OR "critical literacy").

Web of Science (WoS)

TS=("artificial intelligence" OR "AI") AND TS=("literacy" OR "digital literacy" OR "media literacy" OR "information literacy" OR "critical literacy").

Figure 1. Search strings on ERIC, Scopus and WoS.

2.2 Data Analysis

Results from the three queries were merged, and after removing 67 duplicates, a dataset of 275 records was obtained. The initial screening was based on reading the titles, abstracts, and keywords, applying three exclusion criteria: 1) articles that did not explicitly focus on AI literacy; 2) studies examining school levels other than K–12; 3) empirical, experiential, or quasi-experiential studies, as well as theoretical works, when the study was not a literature review.

From this step, 263 articles were excluded, and 12 were retained for full-text reading (see Fig. 2). To systematize the analysis, the studies were coded according to the dimensions outlined in Table 1.

Table 1. Encoding criteria.

Research Questions
Q1. Temporal and geographical distribution of publications
Q2. Type of literature review
Q3. Specific School Level
Q4. Didactic • Q4.1 Teaching approaches • Q4.2 Learning content • Q4.3 Learning outcomes/objectives • Q4.4 Learning tools
Q5. Assessment methods

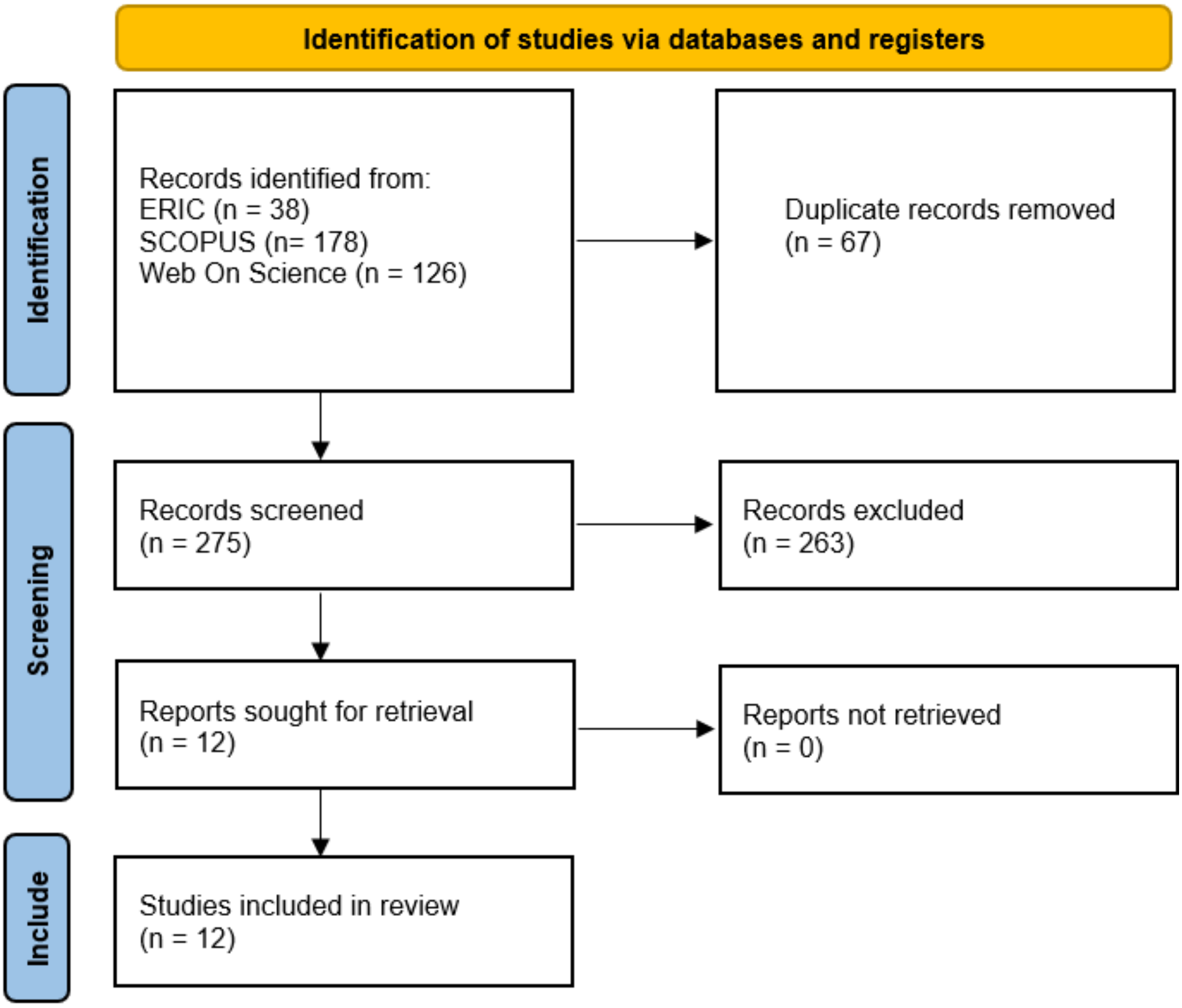

Figure 2. Study selection process.

3 RESULTS AND DISCUSSIONS

In this section, we present and discuss the results of the umbrella review. The findings are structured into five subsections, corresponding respectively to our research questions.

3.1 RQ1: Temporal and geographical distribution of publications

The selected reviews were published between 2022 and 2024: 5 in 2024 [22-26], 5 in 2023 [27-31], and 2 in 2022 [32, 33]. This indicates a growing interest in the topic of AI literacy in the last three years (Fig. 3). The findings suggest an increasing number of studies particularly following the release of ChatGPT as an accessible AI-tool and the publication of DigComp 2.2 with its annex to citizen's interaction with artificial intelligence. To analyze the geographical distribution of the selected articles, the country of affiliation of the first author of each study was considered. The highest number of publications was from Hong Kong [29-33], followed by China [25], Germany [28], Philippines [24], Portugal [23], Saudi Arabia [22], Spain [27], and Sweden [26], as shown in Fig. 4. This distribution reflects Hong Kong's investment in AI education. Indeed, AI has emerged as a growing field in Asian research, pedagogical practices, and policy development, with specific programs and initiatives demonstrating efforts to enhance students' AI literacy skills [33].

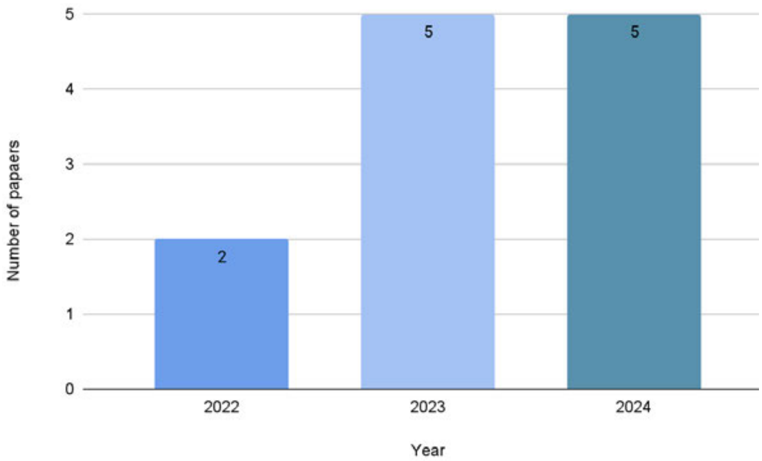

Figure 3. Temporal distribution of articles.

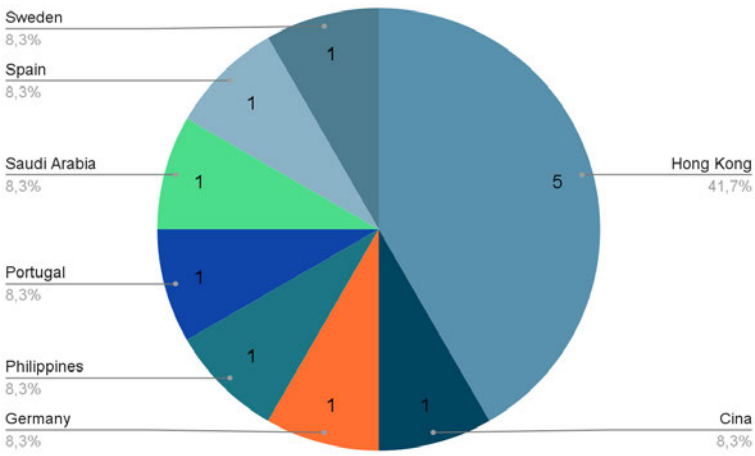

Figure 4. Geographical distribution of articles.

3.2 RQ2: Type of literature review

Only literature reviews were considered for our study. To determine the review categories, we referred to Grant & Andrew Booth classification [21], which labels 14 main review types distinguishing synthesis and analysis methods for each. The results of our study include 5 Scoping reviews [26, 28, 29-31], 4 Systematic [22, 25, 27, 32], 2 Meta-analysis [24, 33] and 1 literature review [23], as illustrated in Fig. 5. The predominance of scoping reviews indicates that this topic is still emerging within the academic field.

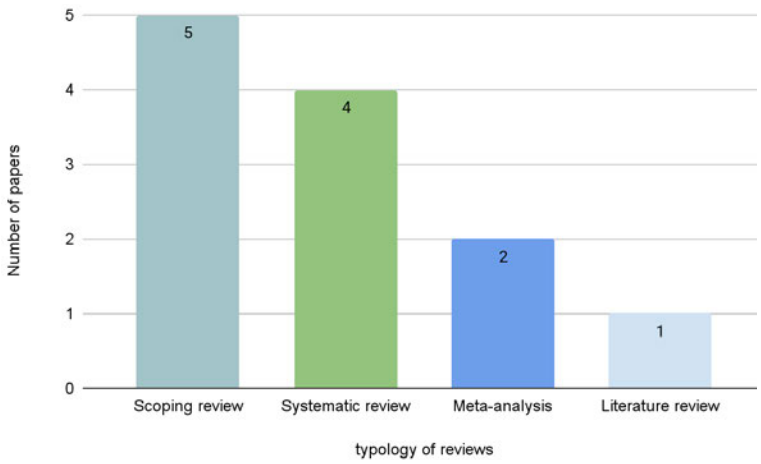

Figure 5. Type of literature review.

3.3 RQ3: Specific School Level

Concerning the educational level, most articles focus on the K–12 system [22, 24, 25, 26, 27, 32, 33]. Only 2 studies address secondary education [28, 29], and 2 refer to preschool education [30, 31]. In contrast, the article by Brandão et al. [23] pertains more broadly to both higher and non-higher education contexts. Notably, the systematic reviews by Marx et al. [28] and Ng et al. [29] underscore the importance of developing AI literacy courses for secondary education, supported by literature indicating that students at this level possess the cognitive capacities to comprehend more complex AI-related concepts [34, 35] and the ability to engage with advanced knowledge to develop AI-based products.

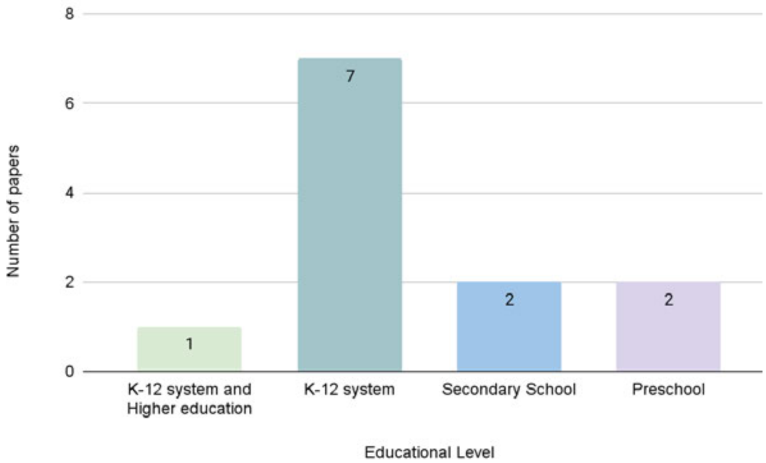

Figure 6. Specific school level.

3.4 RQ4: Didactic

3.4.1 Teaching approaches

With reference to Bonwell and Eison [36], we categorized teaching strategies as *traditional learning* (face-to-face lessons), *active learning* (e.g., game-based learning and hand-on activity), *collaborative learning* (structured teamwork), and *experiential learning* (including problem/project/case-based learning). Our analysis showed that experiential and active learning are the most common methods to promote AI literacy. It enables students to acquire knowledge, skills, and abilities through direct engagement with real or simulated situations, learning through trial and error and engaging in reflection – a key dimension of metacognition. Specifically, problem/project/case-based learning are student-centered approaches, with problem-based learning using the problem as a guide and vehicle for process [37], project-based learning emphasizing practical application of knowledge, and case-based learning focusing on the analysis of realistic cases. Game design, instead, is a common approach, allowing students to apply AI concepts in playful and interactive contexts. Among the reviewed articles, 7 focus on experiential learning [24, 25, 27, 29, 30, 32, 33], 6 on active learning [24, 25, 29-32], 4 on collaborative learning [25, 27, 29, 32], and 4 do not reference any specific learning methods, or if mentioned, they are only referred to in a general, non-specific way. [22, 23, 26 28]. None focus on traditional teaching approaches. Systematic reviews by Liu and Zhong [25], Ng et al. [29], and Su et al. [30] indicate that game-based learning strategies are predominantly used in kindergartens and primary schools, while collaborative and project-based learning is primarily applied in middle and high schools.

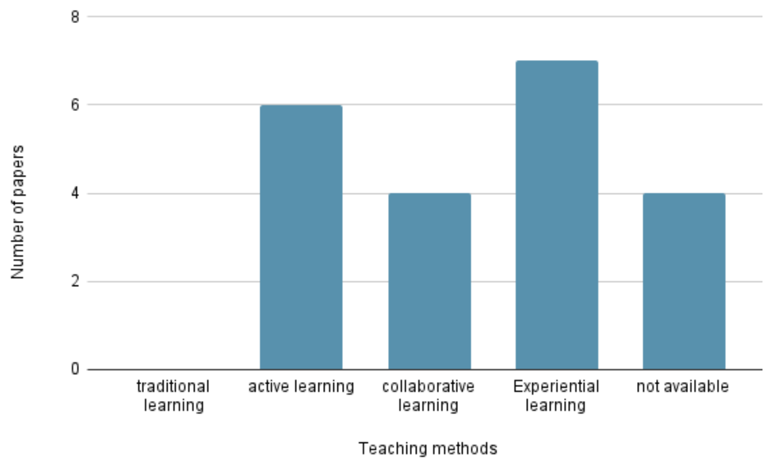

Figure 7. Pedagogical approaches for teaching AI.

3.4.2 Learning content

Learning contents were divided into 3 categories [38]: (1) *basic knowledge about AI* (e.g., definition, evolution, supervised learning and generative AI); (2) *processes in AI* (e.g., how algorithms work and Machine Learning); (3) *impacts of AI*, encompassing both ethical and social considerations (e.g., bias, privacy). All articles address the three categories, at least implicitly, except for 2 studies that do not cover learning content [24, 28]. Ethical aspects remain central in the discourse, highlighting the importance of understanding AI's societal impact, as emphasized by existing frameworks [5, 8, 16–18]. However, as the systematic review by Liu & Zhong [25] points out, the predominant focus of K-12 AI education is on learning how AI works—followed by its processes, impact, and knowledge. This indicates that, despite the frequent emphasis on ethics, K-12 AI education prioritizes the technical functioning of AI over its societal implications. The systematic review by Ng et al. [29] distinguishes content for younger and older students. At the junior level, learners engage with foundational concepts, including AI history, human–machine differences, and Scratch-based activities on machine learning and image recognition. At higher levels, students explore advanced topics such as natural language processing, information networks, computational sustainability, and technical components (e.g., correlation, graph search algorithms, computational game theory, probabilistic reasoning).

3.4.3 Learning outcomes

With regard to learning outcomes, literature is heterogeneous. In some cases, they are not examined [23, 26, 27] or receive only limited attention [24, 31, 32]. In the other articles, there is no consistency in how learning outcomes are categorized, and little attention is given in the analysis. Ng et al. [29] classified learning outcomes into affective, behavioral, cognitive, and ethical dimensions. Liu and Zhong [25], in line with Ng et al. [29], identified three dimensions of AI-related outcomes: AI knowledge, AI affectivity, and AI thinking. Su et al. [30] considered knowledge and skills as learning outcomes. Su et al. [33] distinguished between cognitive and non-cognitive constructs, the latter included participants' attitudes, dispositions, and motivations towards AI learning. Almatrafi et al. [22] describe outcomes as key constructs of AI (Recognize, Know and Understand, Use and Apply, Evaluate, Create, and Navigate Ethically) and Marx et al. [28] focus the research on term of mental models and students' attitude. The limited exploration of learning outcomes is partly due to the lack of validated assessment tools in this area. As noted by Ng et al. [29] and Su et al. [33], AI learning assessment is still at an early stage, with few instruments available and none rigorously validated.

3.4.4 Learning tools

Analysis of the documents identified 4 main categories of learning tools for AI literacy, each with a distinct role in the learning process [29]. (1) *Hardware* is mainly represented by robotics (e.g., Lego, Cozmo), which provide hands-on experiences that make abstract AI concepts tangible; (2) *software* includes block-based programming environments (e.g., Scratch) for beginners and text-based languages (e.g., Python) for more advanced students; (3) *intelligent Agents* enable to create and train machine learning models; (4) *unplugged tools* include activities that do not require computers, such as board games, paper-based exercises, and role-playing. They are particularly effective for introducing complex AI concepts in a simple and accessible way, especially for early childhood and primary students.

Except for 4 studies [22, 23, 26, 28] that do not focus on learning tools, all other articles highlight the use of multiple types. Although many of the studies did not explicitly focus on the description or categorization of the tools, the examples provided, however, made it possible to recognize the nature of the tools mentioned. Specifically: software tools are the most mentioned [24, 25, 27, 29-33], followed by intelligent agents [24, 25, 29-33], hardware [25, 27, 29-33] and unplugged tools [25, 29]. Hardware, software and unplugged tools are typically used for introductory learning activities in the lower grades. In contrast, intelligent agents are generally applied to advanced learning activities in higher grades [25].

3.5 RQ5: Assessment methods

Among different assessment methods, the following are mentioned: pre-/post questionnaires, individual/semi-structured interviews, motivational surveys, lesson observation, teaching documents, meeting minutes, school-based curriculum documents and student artefacts [33]. All the reviewed articles address the topic of assessment, except for one [23]; however, only 4 of them explicitly include assessment among their research questions or focus on this dimension [22, 25, 29, 30]. Liu & Zhong [25], as Ng et al. [29] and Almatrafi et al. [22], divided assessments into qualitative, quantitative and mixed methods. The use of questionnaires, assessment tests, interviews and direct observation by teachers is recurrent in literature. The studies indicate that the most widely used assessment methods are qualitative [25], with most evaluations being subjective (75%), interpretative, and based on self-reporting [22]. Moreover, to assess young children's AI skills, studies employed knowledge and theory of mind tests, questionnaires, and observations [30]. These results underscore the need to design and develop tools for assessing AI literacy skills, integrating quantitative and qualitative approaches to more effectively evaluate students' learning outcomes.

4 CONCLUSIONS

This umbrella review examined 12 articles on AI literacy in K-12 education, published between 2020 and 2024. The study indicates rapid growth in this field following ChatGPT's public release in 2022, with research geographically concentrated in Hong Kong, a region actively investing in AI education through different initiatives [33]. The majority of the reviewed documents are scoping reviews generally focus on K-12 education, reflecting that AI literacy is an emerging area of research. Learning approaches are not always specified; however, experiential methods – such as problem/project/case-based learning – are the most frequently cited and more common in middle and high schools, while activity learning – such as hands-on activity and game-based learning – is primarily applied in early childhood and primary education. Although not explicitly stated in all articles, the learning content can be grouped into three main categories (Basic Knowledge about AI, Processes in AI, and Impacts of AI), with ethics framed as a core element of AI literacy, yet K-12 education predominantly emphasizes the technical functioning of AI over its ethical and societal implications [25]. Based on Ng et al. [29] tools classification, software-based tools are the most widely used for AI literacy courses, while unplugged tools are less common and mainly employed with younger students. The literature also shows that qualitative assessment methods dominate, but a lack of validated assessment persists, which consequently limits research on learning outcomes. Finally, the reviewed articles highlight 3 main priorities: (1) the need to further develop AI curricula through an interdisciplinary approach that integrates AI literacy into school subjects [27, 32]; (2) insufficient teachers preparation and knowledge in AI [23, 25-27, 30, 32, 33]; and (3) the urgent need for well-defined assessment methods to evaluate students' learning outcomes [22, 27, 28, 30, 31, 33].

Limitations: The review was conducted in December 2024, in a rapidly evolving field, so it may not include significant articles on the topic. Moreover, potential biases may result from language restrictions and the exclusion of relevant articles from other datasets not considered in this review.

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Table 1. Descriptive Information of the Included Studies.

Authors and Titles	Year of publication	First Author's Country	Type of Review	Educational Level	Teaching Methods	Learning Content	Learning outcomes	Learning Tools	Assessment
Su J.; Zhong Y.; Ng D.T.K. [33]	2022	Hong Kong	Meta-analysis	K-12	Experiential learning	Knowledge of AI, process in AI and impact of AI	Cognitive and non-cognitive constructs	Hardware, software and intelligent agents	Mentioned
Ng, DTK; Lee, M; Tan, RJY; Hu, X; Downie, JS; Chu, S.K.W. [32]	2022	Hong Kong	Systematic review	K-12	Experiential, collaborative, and active learning	Knowledge of AI, process in AI and impact of AI	Mentioned but not explored	Hardware, software and intelligent agents	Mentioned
Almatrafi, O; Johri, A; Lee, H. [22]	2024	Saudi Arabia	Systematic review	K-12	X	Knowledge of AI, process in AI and impact of AI	Outcomes described as key constructs of AI	X	Addressed
Liu X.; Zhong B. [25]	2024	China	Systematic review	K-12	Experiential, collaborative, and active learning	Knowledge of AI, process in AI and impact of AI	AI knowledge, AI affectivity, and AI thinking	Hardware, software, intelligent agents and unplugged tools	Addressed
Casal-Otero L.; Catala A.; Fernández-Morante C.; Taboada M.; Cebreiro B.; Barro S. [27]	2023	Spain	Systematic review	K-12	Experiential and collaborative learning	Knowledge of AI, process in AI and impact of AI	X	Hardware and software	Mentioned
Ng D.T.K.; Su J.; Leung J.K.L.; Chu S.K.W. [29]	2023	Hong Kong	Scoping review	Secondary School	Experiential, collaborative, and activity learning	Knowledge of AI, process in AI and impact of AI	Affective, behavioral, cognitive and ethical dimensions	Hardware, software, intelligent agents and unplugged tools	Addressed
Su J.; Ng D.T.K.; Chu S.K.W. [30]	2023	Hong Kong	Scoping review	Preschool	Experiential and active learning	Knowledge of AI, process in AI and impact of AI	Outcome described as knowledge and skills	Hardware, software and intelligent agents	Addressed
Su J.; Yang W. [31]	2023	Hong Kong	Scoping review	Preschool	Active learning	Knowledge of AI, process in AI and impact of AI	Mentioned but not explored	Hardware, software and intelligent agents	Mentioned
Sperling, K; Stenberg, CJ; Mcgrath, C; Akerfeldt, A; Heintz, F; Stenliden, L. [26]	2024	Sweden	Scoping review	K-12	X	Knowledge of AI, process in AI and impact of AI	X	X	Mentioned
Funa A.A.; Gabay R.A.E. [24]	2024	Philippines	Meta-analysis	K-12	Experiential and active learning	X	Mentioned but not explored	Software and intelligent agents	Mentioned
Marx E.; Leonhardt T.; Bergner N. [28]	2023	Germany	Scoping review	Secondary School	X	X	Attitude and mental models	X	Mentioned
Anabela Brandão A., Pedro L., Zagalo N. [23]	2024	Portugal	Literature review	K-12 System and Higher education	X	Knowledge of AI, process in AI and impact of AI	X	X	X