Cultivating Tomorrow's Innovators: Navigating the Landscape of High School AI Literacy

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Erin Bosarge is a Ph.D. candidate in the Instructional Design and Development program at the University of South Alabama, focusing on integrating artificial intelligence literacy into high school curricula. As a research assistant, she has contributed to teacher training workshops and observed the implementation of AI lessons in classrooms, gaining practical insights. Her dissertation will examine student and teacher perceptions of AI and assess how the AI4K12 framework might positively influence these perceptions. Erin aims to bridge the gap between emerging technology and educational practices, emphasizing the importance of AI literacy in high school education to prepare students for the workforce.

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Abstract - With the significant rise of artificial intelligence (AI) across sectors, its integration into high school education is just starting to appear. As this new technology is becoming more prominent, educational stakeholders are beginning to plan how to equip students with the necessary skills and competencies in AI. This literature review delves into AI literacy in high school contexts. It employed Kitchenham and Charters guiding principles to plan, conduct, and report on the status of high school AI literacy research. Following an extensive search across leading academic databases simply using the terms "high school" AND "artificial intelligence," 1,943 articles were initially found. Strong inclusion and exclusion criteria were developed to ensure the selection of articles that only related to research primarily focused on high school AI literacy. After rigorous screening for relevance and availability, we selected 16 articles related to high school AI literacy.

We employed the Elo and Kyngäs inductive analysis approach, extracting data for publication year, study objectives, number of citations, authors' related publications, stakeholders addressed, stakeholder perceptions, AI4K12 content coverage, and ethical considerations. We analyzed each topic, finding commonality and uniqueness among the articles. By analyzing the objectives, we found these articles highlighted four primary themes: curriculum and program development, teaching and learning methods, student engagement and perceptions, and inclusion and diversity in education. We also found that there was a significant increase in publications of this sort published in 2022, with a decrease in publications in 2023.

Using our other extracted data, we were able to answer four research questions to help guide stakeholders: 1) To what extent do current research articles address the spectrum of AI literacy, and how thoroughly do they cover the AI4K12 concepts? 2) What ethical considerations are addressed? 3) How inclusive is the current body of research concerning all stakeholders involved in developing, implementing, conducting, and evaluating AI education? 4) What are stakeholders' perceptions toward AI?

The preference for hands-on learning in AI education suggests an impactful approach to engaging students. Integrating such methodologies into instructional design can significantly enhance student interaction and comprehension of AI concepts. For stakeholders, this implies a need to develop curricular resources that are interactive and immersive, using methods like project-based learning to thereby facilitate a deeper understanding and application of AI in real-world scenarios.

The review identifies critical gaps in comprehensive resources and the integration of ethical best practices in AI education. Future research should focus on utilizing existing frameworks, such as AI4K12, that incorporate ethics into the AI curriculum. Future research should also explore more inclusivity of stakeholders, identifying the resources necessary to support a diverse range of educational contexts.

The significance of this review lies in its spotlight on the evolving landscape of AI education in high schools. It calls for a concerted effort among educators, policymakers, and curriculum designers to develop AI education programs that are not only technologically advanced but also ethically informed and culturally sensitive. Addressing the identified gaps and advocating for research in underexplored areas will be crucial in shaping a future where all students are well-prepared for the AI-driven world.

Table of Contents

Abstract

1. Introduction

2. Background

2.1 The Emergence of AI in Education

2.2 Integration of AI Literacy

2.3 AI4K12's Five Big Ideas

3. Methods

3.1 Planning the Review

3.1.1 Identifying the Need for the Review

3.1.2 Specifying the Research Questions

3.1.3 Developing the Protocol for Review

3.2 Conducting the Review

3.2.1 Search Strategies

3.2.2 Search Keywords

3.2.3 Article Selection Measures

3.2.4 Assessment Criteria for Study Quality

3.3 Finding of Quality Assessment

3.3.1 Author Credibility Results

3.3.2 Literature Impact Results

3.3.3 Data Extraction and Analysis

4. Results

4.1 Overview of Included Articles

4.1.1 Summary of Papers Included by Publication Year

4.1.2 Articles Grouped by Theme Objectives

4.1.3 Articles Grouped by AI Technology Used

4.2 Results for RQ1: Examining AI Literacy Coverage in Current Research

4.2.1 Analysis Framework

4.2.2 Evaluation of AI4K12 Concepts in Selected Articles

4.2.3 Synthesis of Findings

4.3 Results for RQ2: Ethical Discussions

4.4 Results for RQ3: Evaluating Stakeholder Involvement

4.4.1 Analysis Framework

4.4.2 Evaluation of Stakeholder Involvement in Selected Articles

4.4.3 Synthesis of Findings

4.5 Results for RQ4: Stakeholder Perceptions

5. Discussion

6. Limitations

7. Conclusion

1. Introduction

Artificial intelligence (AI) stands at the forefront, which is a signal for considerable changes across career fields and our daily lives in the era of rapid technological evolution. As AI becomes a necessary element of the modern workforce, the imperative to teach students the foundational AI skills and competencies has never been more pressing. This need is very evident in education, where machine learning (ML) concepts are integrated into high school curricula is gaining momentum as a critical intersection between education and emergent technology.

Recent scholarly work [1] underscores the capacity of high school students to comprehend and apply foundational ML concepts effectively, especially when engaged through dynamic pedagogical approaches like problem-based learning. These findings pave the way for a broader discussion on AI literacy, which encompasses a spectrum of concepts beyond ML, presenting educators and students alike with a daunting yet exciting challenge.

To navigate the complexities of AI education, the "5 Big Ideas" framework proposed by AI4K12 has emerged as a promising tool, chunking the complex nature of AI into more manageable segments for educational purposes [2]. However, adopting this framework in educational settings remains inconsistent, with a historical preference for robotics or computational thinking as proxies for a more holistic AI literacy [3].

Addressing this gap, this systematic review aims to scrutinize the landscape of AI literacy within the high school educational context, focusing on the breadth and depth of AI topics accessible to students. By meticulously examining the extant literature, this study highlights the prevailing scope of AI education, revealing significant gaps, particularly in the content coverage of the AI4K12 framework and the inclusivity of stakeholder perspectives. The goal of this article is to offer a comprehensive synthesis of current research findings, identifying areas ripe for further inquiry and suggesting paths for future exploration.

Guiding this review are four pivotal research questions:

RQ1: To what extent do current research articles address the spectrum of AI literacy, and how thoroughly do they cover the AI4K12 concepts?

RQ2: What types of stakeholders' perceptions toward AI does current research gather?

RQ3: How inclusive is the current body of research concerning all stakeholders involved in the development, implementation, conduction, and evaluation of AI education?

RQ4: What ethical issues does current research address related to high school AI literacy?

We structured this article to first review the background of AI integration, setting the stage for understanding the critical role of AI in shaping future learning. Following this, the methodology section outlines the criteria for article selection and the analytical frameworks employed. The results section then synthesizes the key findings, shedding light on their implications for AI education, especially concerning curriculum development and stakeholder engagement.

2. Background

2.1 The Emergence of AI in Education

Integrating AI into educational settings mirrors its broader societal adoption, signifying a pivotal shift towards incorporating AI literacy in K-12 education. This shift goes beyond merely acquainting students with AI technologies; it encompasses a holistic educational paradigm that emphasizes the development of technical proficiencies and a deep understanding of AI's ethical and societal ramifications. A multidisciplinary approach is essential for effective AI education, whereby AI concepts are woven through various subjects, enabling students to cultivate a well-rounded comprehension of AI's potential and pitfalls [2, 4].

Recognizing the multifaceted nature of AI, it becomes evident that its integration into education demands a structured yet flexible framework that can accommodate the diverse aspects of AI literacy while catering to the evolving educational landscape.

2.2 Integration of AI Literacy

The comprehensive integration of AI literacy within K-12 education necessitates a deliberate and nuanced approach. Embedding AI literacy seamlessly into existing curricula requires an interdisciplinary strategy that covers technological competencies and delves into AI's ethical and societal implications [4]. This approach underscores the critical role of educators, who must receive robust professional development in AI to guide their students effectively. Furthermore, collaborative curriculum development emerges as a critical theme, advocating for a participatory process involving educators, policymakers, and AI experts. This collaborative effort aims to co-design AI educational programs that are both relevant and forward-looking, preparing students for a future where AI is an integral part of various sectors.

To have the participation of the stakeholders—teachers, students, curriculum developers, and AI experts—we need to adhere to a structured approach to AI literacy, which leads us to the AI4K12 initiative, which sought to reveal AI's complexities for educational purposes through its "5 Big Ideas in AI."

2.3 AI4K12's Five Big Ideas

The "5 Big Ideas in AI" framework, proposed by the AI4K12 initiative, serves as a foundational guide to distill the core concepts of AI into teachable and understandable segments. This framework facilitates a more accessible understanding of AI for students and educators, addressing the critical need for comprehensive AI literacy beyond mere technical knowledge [2]. The AI4K12 framework encompass the following AI concepts:

1. **Perception**: How AI systems interpret the world through data, like human senses but within a digital realm, using algorithms to process images, sounds, and text.

2. **Representation and Reasoning**: The ability to organize and use information for decision-making, problem-solving, and prediction, imitating human cognitive processes.

3. **Learning**: The adaptive nature of AI systems, which evolve and enhance their capabilities through experience, leveraging techniques like ML.

4. **Natural Interaction**: The development of AI that communicates with humans intuitively, employing technologies that aid natural language and speech interactions.

5. **Societal Impact**: Examination of AI's broader implications on society, including ethical considerations, bias mitigation, privacy concerns, and changing work and social norms.

By exploring the arrival of AI in education, the strategies for integrating AI literacy, and the structured approach offered by AI4K12's "5 Big Ideas," this sets the stage, revealing a need for our systematic review. It underscores the importance of not only understanding the technical parts of AI but also addressing the ethical and societal aspects as well. This broad look into AI education helps address our review's aims: to evaluate the breadth and depth of AI literacy in current research and to assess the inclusivity of stakeholder perspectives in shaping AI education.

3. Method

This systematic review aims to synthesize and analyze existing literature and research on AI literacy in high school education. We explore how researchers have explored high school AI literacy in their research and identify areas requiring further investigation. Kitchenham and Charters guiding principles [5] shown in Fig. 1, including phases for planning, conducting, and reporting, are what we used to develop this systematic literature review.

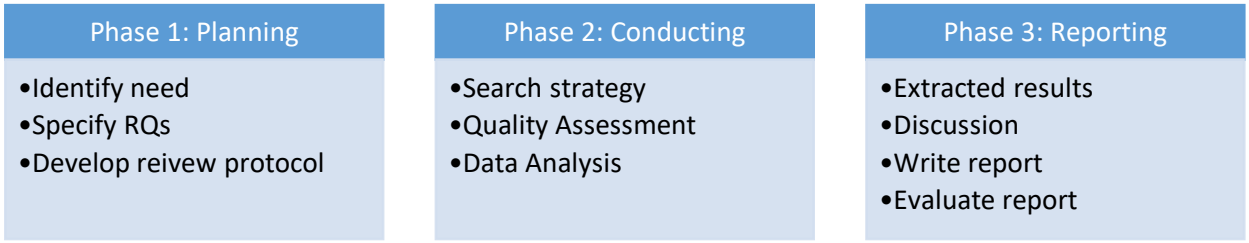

Fig. 1 Systematic literature review process [5]

Retrieving articles from multiple sources was important since one source does not find all relevant articles. It also helps to avoid database bias to have more than one source, and for that purpose, we chose to conduct our research by selecting articles retrieved from five different databases, as seen in Table 1. The selected publication databases each contain relevant articles that focus on educational research. The results from each database were downloaded into a RiS file that was then uploaded to Zotero.

3.1 Planning the Review

3.1.1 Identifying the Need for the Review

While following the above procedure, the first step of this review was to make a solid plan for the review conditions. The main aim of this review is to explore what articles specifically focused on high school AI literacy rather than the broader available research of K12. This review

would reveal what areas of high school AI literacy have been represented in current research and shed light on those areas needing more research.

3.1.2 Specifying the Research Questions

This paper focused on existing research on high school representation in AI literacy. We framed the research questions below to reveal the high school AI literacy curriculum research status.

RQ1: To what extent do current research articles address the spectrum of AI literacy, and how thoroughly do they cover the AI4K12 concepts?

RQ2: What types of stakeholders' perceptions toward AI does current research gather?

RQ3: How inclusive is the current body of research concerning all stakeholders involved in the development, implementation, conduction, and evaluation of AI education?

RQ4: What ethical issues does current research address related to high school AI literacy?

3.1.3 Developing the Protocol for Review

The foundation of this systematic review was the carefully designed protocol that guided our methodology, ensuring a structured approach. To create this protocol, we combined both informal and formal search strategies to comprehensively identify the research objectives and amass the essential data pertinent to our study's scope. The preliminary findings, derived from these initial searches, were instrumental in shaping the research questions that directed the entire review process. We detailed these findings in the background section, providing a contextual framework that informed the subsequent stages of the review. This protocol aided a systematic approach to data collection and analysis but also ensured that the review process was aligned with the established research questions, thereby enhancing the coherence and focus of the study.

3.2 Conducting the Review

The first of the three Kitchenham and Charters guiding principles [5] is to conduct the review. We describe how we searched for articles, including which databases we used. Then, we explain the specific words we chose to find articles about AI in high schools. We also explain the selection measures used to choose which articles to include, ensuring they are relevant and of excellent quality. Lastly, we checked the quality of the articles we chose using a set of criteria.

3.2.1 Search Strategies

We developed a comprehensive search strategy to identify relevant articles for inclusion in this study. We carefully executed this search across five major academic databases: Education Search Complete, ERIC, APA Psych, Academic Search Complete, and Scopus. This approach was chosen to ensure the thorough exploration of the available literature, aligning with the principles of systematic and exhaustive research advocated by Kitchenham and Charters. By searching in education-specific and multidisciplinary databases, we aimed to minimize the risk of overlooking pivotal studies, thus enhancing the comprehensiveness of our review.

3.2.2 Search Keywords

A standardized set of keywords was used across all databases to capture articles related to AI literacy in the high school educational setting. The keywords were selected to gather studies about AI literacy and high school education. Trial and error proved that this was the best combination to retrieve an adequate number of relevant articles. No existing keyword-search approaches were referenced in this search. The keywords used in the search included "artificial intelligence" and "high school." The search strategy aimed to capture a comprehensive and representative body of literature that explored AI literacy in high school education within the broader context of K-12 settings.

Academic Databases	Search Date	Protocol
Education Research Complete ERIC APA Psych Info Academic Search Complete Scopus	10/11/2023	(ALL TEXT (“artificial intelligence” and “high school”

Table 1 The specific protocol executed in each database.

As depicted in Table 1, the search design for each database was the same, where “ALL” fields would be included. We searched for the keywords in the title, abstract, keyword, and full text. This design was chosen as some articles have a title of K12, but the method used high school students. Based on this, we would get returns for any article that mentioned high school AND AI anywhere in the article. We intended to have many articles to sift through individually with exclusion criteria.

3.2.3 Article Selection Measures

Our systematic review adopts a meticulous approach to selecting articles that align with our objective of exploring AI literacy within high school education. This procedure ensures the inclusion of literature that directly contributes to a comprehensive understanding of how AI literacy is integrated into high school curricula.

Inclusion Criteria: We focused on English-language, peer-reviewed articles published from January 2000 to October 2023. Only articles that specifically address AI literacy in the context of high school education were considered. This approach allowed for a focused yet extensive collection of literature pertinent to our research goals. Articles covering broader educational levels were included if they provided significant insights into high school AI literacy. We included only original research articles.

Exclusion Criteria: We excluded articles published outside our specified timeframe and those from non-peer-reviewed sources. We also excluded secondary sources and other systematic reviews. Articles that broadly covered K12 education without a clear focus on high school or that did not involve high school participants were also excluded. Attempts were made to access paid publications; however, not all were accessible within our time constraints.

Search Strategy and Database Selection: We conducted an extensive search across multiple academic databases, including Scopus and EBSCOhost Search (which encompasses Academic Search Complete, ERIC, Education Research Complete, and APA PsycInfo). Our search, focusing on literature published since 2000, utilized primary keywords such as "artificial intelligence" and "high school" and was restricted to articles in English.

Initial Retrieval and Screening: The initial search yielded a significant number of articles: 1,208 from Scopus, 221 from EBSCOhost, 273 from ERIC, 118 from Education Research Complete, and 162 from APA PsycInfo. After merging and removing duplicates using Zotero, we were left with 670 unique articles.

Further Screening: Articles not centrally focused on AI literacy were removed, including those that treated AI as a general educational tool or were not explicitly about AI literacy in the context of education. This refinement process excluded several articles, narrowing down the selection to 38. Three systematic reviews were excluded from the analysis because they were not original works [6-8]. A detailed examination of the remaining 35 articles identified 15 focused on grade levels other than high school were excluded.

Final Selection: We identified 19 research articles that were specifically relevant to AI literacy at the high school level. Three articles [9-11] were excluded because access was not granted, leaving our final selection with 16 articles.

This final set of 16 articles, which underwent a rigorous screening process for relevance and specificity to our criteria, forms the foundation for the analysis and discussions in the following sections of our review.

3.2.4 Assessment Criteria for Study Quality

We employed evaluation standards to determine their quality in selecting 16 pertinent articles based on predefined inclusion and exclusion criteria. Given the scarcity of literature about AI literacy in high schools, we struck a balance between methodological rigor and feasibility in our evaluation approach:

1. **Participant Count:** We considered studies with any number of participants above zero. Those with 'large' participant pools (over 100 individuals) were deemed more suitable for generalization. In contrast, studies with 'small' participant counts (less than 30 individuals) were recognized for their potential to provide detailed insights.

2. **Research Methodology:** Our inclusion spanned various research methodologies, including experimental, observational, and qualitative studies. Given the emergent nature of this field, we acknowledged the potential limitation in the variety of methodologies but assessed each study's effectiveness in addressing the research objectives.

3. **Author Credibility:** The academic contributions of the authors in the realm of high school AI literacy were scrutinized, focusing on their publications within the field to affirm their authority and credibility.

4. **Literature Impact:** The frequency with which each article was cited in subsequent works was reviewed, indicating its influence and the degree of recognition it has received within the academic community.

3.3 Finding of Quality Assessment

The assessment criteria mentioned above were used to assess the quality of the articles considered for inclusion in this systematic review. There were 16 articles identified as having a sample size greater than zero, allowing us to consider them as part of this systematic review. Each of these articles also included varying degrees of study design and methodology. To further refine our quality assessment, we also reviewed the author credibility and the literature's impact within the academic community.

3.3.1 Author Credibility Results

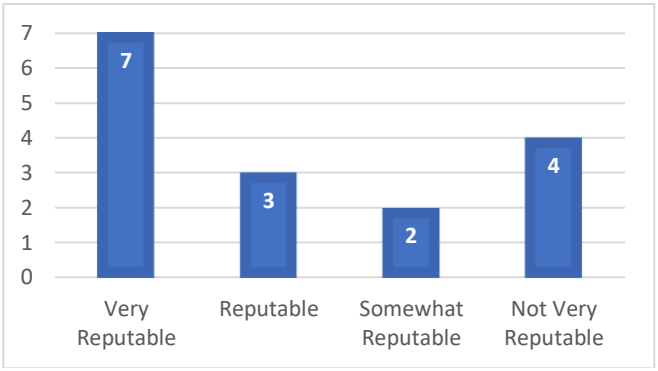

Figure 1 Author Credibility

To analyze the expertise and credibility of authors in our study, we defined evaluation criteria based on their publication records, mainly focusing on their contributions to AI education at the high school level and their broader engagement with STEM subjects. Those authors with more than three articles focused on high school AI literacy were considered highly reputable, while authors with more than one but less than three were labeled as just reputable. Authors with only one high school AI literacy article, but other publications in education or AI were ranked as somewhat reputable, and those authors with only one high school AI literacy article were labeled as not very reputable. Despite these rankings, all articles were included equally, due to limited findings.

Highly Reputable: Authors with many publications in this area have significantly contributed to high school AI literacy. As shown in Fig. 1, there were 7 authors rated as highly reputable, with Bellas [12] publishing at least six high school AI related articles, Chui [13] with at least ten publications, Von Wagenheim [14] with three, Jiang [15] with five publications, Leitner [16] with at least four publications, Sanusi [17] with numerous publications in AI literacy for K-12, and Xia [18] with four publications.

Reputable: Authors with a modest number of publications specifically focused on high school AI literacy or those who have demonstrated engagement with AI in educational contexts alongside other academic contributions in STEM. This group includes Tsai [19, 20] with two high school AI articles, and Zhan [21] with two high school AI articles and additional STEM publications.

Somewhat Reputable: Authors with a limited but notable presence in high school AI literacy, often with a single publication in the field supplemented by other scholarly works in broader STEM disciplines. Asunda [22] fall into this category, with one AI publication among many others mentioning STEM, and Lin [23], with two publications from the same study on high school AI.

Not Very Reputable: Authors with minimal contributions to high school AI literacy, often represented by a single publication in the field without further related scholarly works. This category includes Bochniarz [24], with only one relevant article and two in psychology and neuroscience. Lu and Fan [25], where this is the only publication for both authors. Oskotsky [26], with one relevant publication among others in biomedicine, and Tena-Meza [27] with just one publication.

This classification refines our understanding of each author's depth of contribution to high school AI literacy, highlighting the range of expertise within the academic community from those with extensive, focused research in the field to those with emerging or tangential contributions.

3.3.2 Literature Impact Results

To accurately convey the impact and reception of the articles within the research community, it was imperative to evaluate their scholarly influence by examining citation frequencies. This assessment was conducted using ResearchGate.net, a decision influenced by a comparative analysis of citation tracking methodologies across various publication hosting platforms. ResearchGate was selected for its ability to accommodate discrepancies in citation protocols among these platforms. All 16 articles under review were included in this evaluation. Our analysis categorized the articles into three citation frequency tiers: those with no citations, those cited fewer than ten times, and those cited more than ten times.

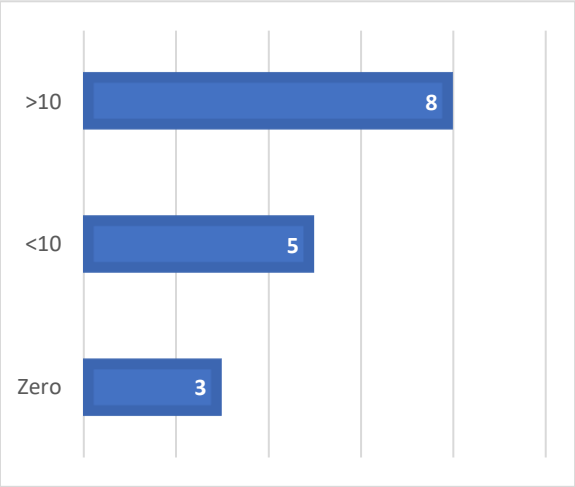

Figure 2 Literature Impact

More than 10 citations: As seen in Fig. 2, a substantial portion of eight journals [12-14, 17-19, 21, 25] were recognized for being cited more than ten times in other scholarly publications.

Less than 10 citations: A further five articles [15, 16, 23, 26, 27] were found to have garnered attention, albeit to a lesser extent, being cited fewer than ten times, but more than once, in the academic literature.

No citations: In contrast, a minority within the collection, some journals [20, 22, 25] were observed to have not been cited by any other academic publications, highlighting a range of engagement and recognition among the articles examined. However, it is important to note that those articles that have received the most citations are also considerably older publications.

3.3.3 Data Extraction and Analysis

We took a detailed approach to gather and analyze information from chosen articles, starting with key data extraction organized in an Excel sheet, including details like publication year, study goals, citations, and author publications. This provided a complete overview, facilitating trends, impact, and theme analysis in the field. We also included points directly related to our research questions, including AI4K12 content and stakeholder representation.

We used the Elo and Kyngäs inductive content analysis [28] for a grounded data exploration, developing categories and themes that aligned with our research questions through a coding process. We also created a ranking system for AI4K12 content and stakeholder representation, using rubrics to classify coverage and involvement levels. This allowed for a comparative and quantitative analysis of how articles and stakeholders addressed AI literacy concepts.

4. Results

4.1 Overview of Included Articles

In our comprehensive systematic review, we meticulously analyzed 16 peer-reviewed journal articles that shed light about high school AI literacy. These articles were carefully chosen based on their relevance, rigor, and contribution to the field, providing a rich tapestry of insights and findings. This section not only catalogs these selected studies by their publication year and primary research focus but also sets the stage for a deeper exploration of the evolving discourse on AI education at the high school level.

4.1.1 Papers Included by Publication Year

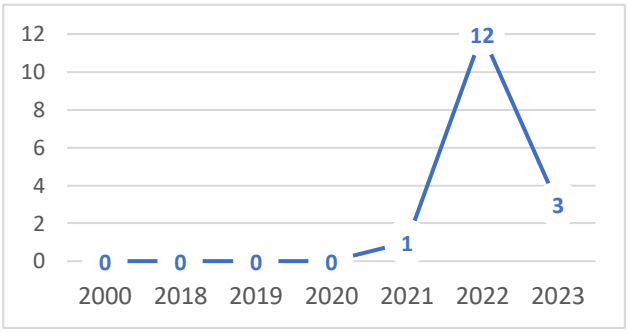

Figure 3 Publications by year

Our search revealed that the academic focus on this topic commenced in 2021, marked by a pioneering study [19]. As you can see in Fig. 3, the momentum significantly accelerated in 2022, evidenced by the publication of 12 articles that satisfied our selection criteria, [12-15, 17, 18, 20, 21, 23, 24, 26, 27]. However, the trend did not sustain into 2023, as we identified only three relevant publications for that year [16, 22, 25]. The pronounced increase in publications during 2022 highlights a burgeoning interest in high school AI literacy, paralleling the rapid advancements in AI technology. The same significant upward trend in publications in 2022 followed by a downturn in 2023 was evident in a similar systematic literature review [6].

4.1.2 Articles Grouped by Theme Objectives

Article themes were divided into four main areas: Curriculum and Program Development, Teaching and Learning Methods, Student Engagement and Perceptions, and Inclusion and Diversity in Education. Shown in Fig. 4, you can see six articles [12-14, 19, 20, 22] mainly focused on Curriculum and Program Development. Teaching and Learning Methods were covered in four articles [16, 21, 23, 25]. Another four articles [15, 17, 24, 27] delved into Student Engagement and Perceptions. The theme of Inclusion and Diversity in Education was the least represented, with two relevant articles [18, 26].

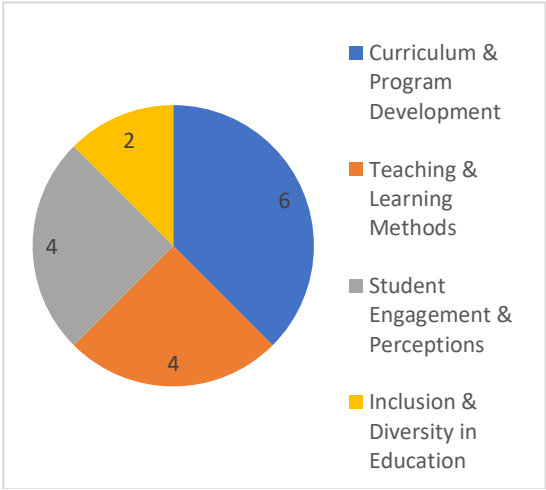

Figure 4 Theme Objectives

4.1.3 Articles Grouped by AI Technology Used

After a thorough review of the different technology used to teach AI in each of these 16 articles, we have defined six different categories: Programming and Software Tools, Robotics and Hardware Integration, Data Analysis and Modeling, Coding and Foundational Skills Programs, Game-Based Learning and Unspecified Technologies, and Computational Thinking and Conceptual Focus.

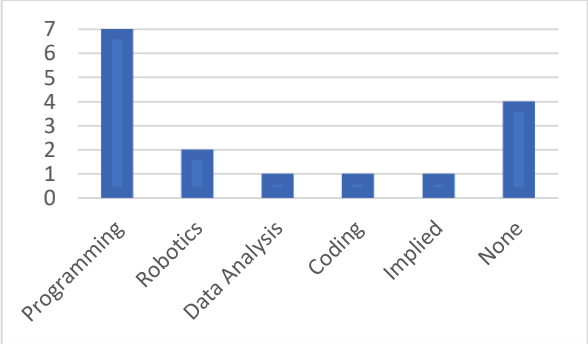

Figure 5 AI Technology Used

Shown in Fig. 5, you can see that there are seven articles [12-14, 19, 20, 25, 26] that fall into the Programming and Software Tools category, with four [19, 20, 25, 26] mentioning Python, two [12, 14] using Google's Teachable Machine, and another two (from the same study) both using SPOC and Turtle Graphics [19, 20]. Beyond this, these articles also explored unique methods for teaching AI literacy, which included technology such as the use of smartphones and MIT App Inventor to implement embedded intelligence solutions and app development which in turn increased student engagement and accessibility to AI concepts [12], Jupyter Notebooks, Blockly, WebAPPs, and CUHK iCar for interactive learning, practical AI projects, and enhancing programming skills which improved understanding and practical skills in AI [13], Arduino, Pandas AI, and Scikit-Learn to create a weather prediction project for data analysis and ML application which fostered data analysis and ML application skills [25], Google CoLab Notebooks and iPython Notebooks for programming and collaborative projects in biomedicine AI which enhanced programming and collaborative skills [26].

There were two articles [21, 23] that explored that use of Robotics and Hardware Integration. One study [21] used Xiaofie Robots for theoretical and practical AI learning which supported collaborative problem-solving and hands-on experience, while the other article [23] used Arduino Nano robots, Servo Motors, IMU, and sensors in a project for hands-on experience in robotics and AI which enhanced technical and problem-solving skills.

The remaining sections that included some sort of technology include Data Analysis and Modeling, Coding and Foundational Skills Programs, and Game-Based Learning and Unspecified Technologies. Each of these categories contain only one article. For Data Analysis and Modeling, students' used StoryQ Platform to support text mining and classification activities to enhance their data analysis skills [15]. The category of Coding and Foundational Skills Programs was fit with one article [27] that used CoderDojo, Kode with Klossy, and AI4ALL to provided foundational coding and specialized AI learning experiences. One article was included in the Game-Based Learning category for its use of a Game-Based Learning Environment where the use of AI technology was implied but not specifically detailed [16]. This Game-Based Leaning was found to have increased student engagement and motivation in AI learning, though specific technologies are not detailed.

The final category includes those articles [17, 18, 22, 24] that did not explicitly include or need to rely on technology as a form of lesson delivery. These articles focus on investigating current competencies of AI [17], self-determination theory [18], computational thinking [22], and highschooler's attitudes toward AI technology [24].

4.2 Results for RQ1: Examining AI Literacy Coverage in Current Research

4.2.1 Analysis Framework

To assess the coverage of AI literacy in the selected articles, we developed an evaluative rubric categorizing the AI4K12 concepts—Perception, Representation and reasoning, Learning, Natural Interaction, and Societal Impact—into three levels of coverage: high, medium, and low. These levels were scored to assess the overall concept coverage, as shown in Fig. 6. High coverage (2) indicates a primary focus on the concept with detailed explanations and practical examples. Medium coverage (1) denotes a general discussion with some practical applications, and low coverage (0) reflects minimal or no mention and engagement with the concept. As part of this analysis, the data were extracted and organized using a spread sheet. Then using our scale, we scored each article based on its level of representation. The scores for each article were then added together to obtain the total representation.

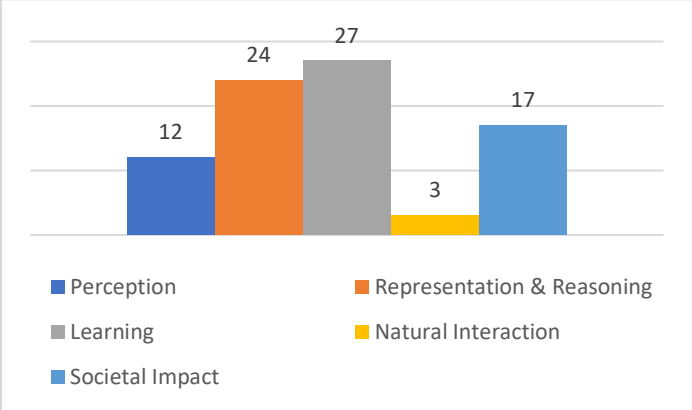

Figure 6 AI4K12 Coverage

4.2.2 Evaluation of AI4K12 Concepts in Selected Articles

The analysis revealed varied levels of engagement with the AI4K12 concepts across the articles:

Perception: Two articles [12, 23] provide comprehensive coverage on AI perception, integrating detailed exploration of sensors and computer vision within their curriculums. Another two articles [13, 16] offer high to medium coverage, with one [13] incorporating perceptual machine intelligence and the other [16] involving data interpretation through game mechanics. Some articles [14, 15, 18-20, 25-27] provide lower emphasis on direct sensory perception, focusing more on data interpretation or biomedical applications. While the three remaining articles [17, 22, 21, 24] do not directly address perception, indicating a notable absence of this concept.

Representation and Reasoning: Three articles [12, 13, 15] are at the forefront of exploring AI cognitive processes, with high coverage of how AI systems process and reason information. **C**ontributing to this concept to lesser degrees, another eight articles [16-20, 25-27] focus on problem-solving, data analysis, and using AI for prediction and decision-making. In contrast, the remaining 5 articles [14, 21-24] had low coverage, not directly addressing the concept.

Learning: There were three articles [12-14] that focus on ML principles and applications, offering high coverage on the learning aspect of AI. Nine other articles [15-20, 25-27] also engage with this concept, showcasing a range of applications from text classification to predictive analytics in environmental science. One article [23] provides medium coverage, touching upon AI principles in the context of robotic sailboat control. Two articles [22, 24] indirectly address learning, while the final article [21] focusing on group dynamics, had low coverage, not directly addressing the concept.

Natural Interaction: Two articles [16, 23] touch upon natural interaction, though their focus on game mechanics and control systems do not extensively cover human-AI communicative aspects. Several other articles [13, 18, 25] provide some coverage through language technologies, hands-on applications, and educational approaches. The remaining articles [12, 14, 15, 17, 19-22, 24, 26, 27] show low to minimal focus on this AI4K12 concept, suggesting a research opportunity in the Natural Interaction area.

Societal Impact: Two articles [24, 26] delve into the societal implications of AI, with discussions on ethics and public perception, providing insights into the broader impact of AI technologies. Another seven articles [12, 13, 17-20, 27] similarly consider the societal aspects, whether through the lens of ethics and sustainability, self-learning competencies, or inclusivity and diversity in AI education. The remaining seven articles [14-16, 21-23, 25] offer varying degrees of coverage, from medium to low, on the societal impact, highlighting areas such as ethical considerations, cultural knowledge, and the implications of AI technology on future-readiness and vocational education.

4.2.3 Synthesis of Findings

The current research articles exhibit broad coverage concerning AI literacy, strongly emphasizing the AI4K12 concepts of Perception, Representation and Reasoning, and Learning. Some articles [12-14] demonstrate high engagement with these concepts, incorporating detailed curriculum development and practical ML applications to enhance students' AI literacy.

However, the focus on Natural Interaction and Societal Impact is less prevalent, indicating a potential gap in the literature. While some articles [17, 26] begin to broach these topics, often through the lens of diversity and ethical considerations, there is an evident need for a more comprehensive integration of these concepts. Furthermore, a small portion of the research [22, 24] does not extensively address these AI4K12 concepts, suggesting room for growth in covering the full breadth of AI literacy within educational research.

4.3 Results for RQ2: Ethical Discussions

Investigating Research Question 4, which focuses on AI ethics discussions, we developed a detailed evaluative rubric. This rubric categorizes the articles into three themes: Ethics in Curriculum for ethics within educational frameworks, Ethics as a Need where advocated for need of AI ethics, and No Ethics for those articles where ethical considerations were notably absent. By applying this framework, we were able to systematically assess the focus of each article regarding AI ethics, whether through their integration into educational programs or as a crucial educational requirement. The findings of this analysis can be seen in Fig. 7.

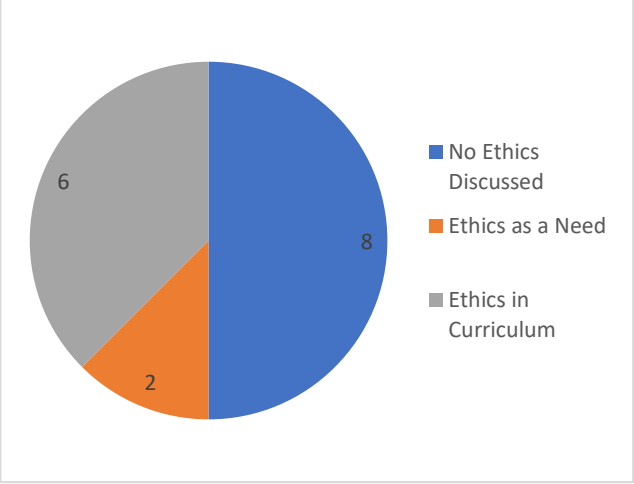

Figure 7 Ethical Discussions

Ethics included: There were 8 of the 16 articles engaged with the theme of AI ethics. Within this subset, two articles [17, 18] argued for the necessity of embedding ethics in the education of high school students, pointing to a recognition of the importance of introducing ethical considerations early in the educational journey. Additionally, six articles [12, 13, 15, 25-27] detailed various approaches to incorporating ethics into AI curricula, offering insights into the practical application of ethical education within the field. This variation in approach indicates an emerging, though still developing, acknowledgment of the critical role ethics plays in AI education.

No ethics discussed: Conversely, the remaining eight articles [14, 16, 22-24, 19-21] did not address AI ethics, highlighting a significant gap in the literature. This absence of ethical discourse in a substantial portion of the literature reviewed suggests a potential oversight or undervaluation of ethical considerations in the realm of AI education and research. Such a gap is not merely academic but poses a potential risk for the ethical development of AI technologies, given the complex and far-reaching implications of AI on privacy, bias, accountability, and societal impact.

This divergence between articles that address ethics and those that do not call for a deeper examination of the integration of ethics in AI education. It raises pertinent questions about the obstacles to embedding ethical considerations in AI curricula and the potential repercussions of this omission for future technologists and the wider society. This identified gap underlines the pressing need for subsequent research to investigate the causes behind this disparity and to devise methodologies and frameworks that ensure ethical considerations are integrally and seamlessly incorporated into AI education and research, cultivating a generation of technologists who are as ethically conscious as they are technically proficient.

4.4 Results for RQ3: Evaluating Stakeholder Involvement

4.4.1 Analysis Framework

To assess the stakeholder representation in the selected articles, we developed an evaluative rubric categorizing each possible stakeholder—teachers, students, educational administrators, curriculum developers, and AI specialists—into three levels of representation: high, medium, and low. These levels were scored to assess the overall concept coverage. High coverage (2) indicates a primary focus on the stakeholder with detailed explanations and practical examples. Medium coverage (1) denotes a general discussion or implied focus, and low coverage (0) reflects minimal or no mention and representation of the stakeholder. For this analysis, we used the same system of extracting data, scoring the articles individually, and then adding together to obtain the total representation score that you see in Fig. 8.

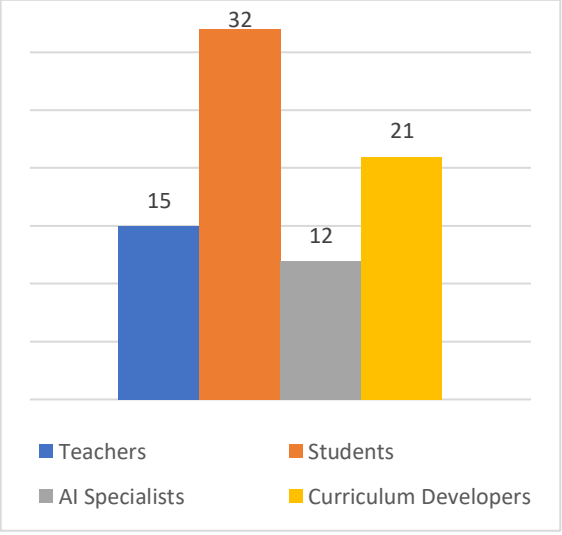

Figure 8 Stakeholder Representation

4.4.2 Evaluation of Stakeholder Involvement in Selected Articles

The analysis revealed varied levels of representation of stakeholders across the articles:

Student Focus: All articles except for one study [21] focus highly on students, either by evaluating their learning experiences, developing curricula to enhance their AI understanding, or through project-based learning initiatives. The article implies a focus on students through group learning dynamics but does not make them the central subject. Despite this, students are the largest represented stakeholder of all of those included in this literature review.

Teacher Involvement: Ten articles [12-15, 19, 20, 22, 23, 25, 27] provide medium to high coverage on teacher involvement, highlighting their roles in implementing AI curricula and facilitating student learning. Three additional articles [16, 17, 21] suggest some degree of teacher involvement in educational activities, though not as the primary focus. One article [18] provides medium coverage, emphasizing the role of teachers in supporting students through self-determination theory-based practices. There were two articles that did not address teachers as a stakeholder, with one [26] not mentioning teacher roles but implies their contribution to the program's development, and another [24] not addressing teacher perspectives, focusing instead on students' attitudes toward AI.

Curriculum Developers: High coverage is observed in six articles [12-14, 16, 19, 20] where the development of AI curricula or specific AI educational content is a central theme. Medium coverage is noted in eight other articles [15, 17, 18, 22-26] where curriculum design is discussed, though not always as the primary focus. Two additional articles [21, 27] provide low or medium coverage, focusing on specific projects or the impact of group learning rather than broad curriculum development.

AI Specialist Contribution: Medium coverage is provided nine articles [12-14, 16, 19, 20, 23, 25, 27] suggesting some involvement of AI specialists in curriculum development or educational programs. There were four articles [17, 18, 21, 26] that hint at the involvement of AI expertise by focusing on AI competencies and content, though not explicitly mentioned. The remaining three articles [15, 22, 24] give low or no coverage of AI specialists.

4.3.3 Synthesis of Findings

The inclusiveness of stakeholder engagement in AI education research varies across the literature, as seen in Fig. 7. Curriculum developers and student involvement are consistently well-represented in the studies, focusing on curricula directly impacting their roles in AI education. Some articles [12, 13] underscore some teacher engagement in curriculum co-creation and implementation while placing students at the center of learning and assessment processes. Conversely, while there was engagement of AI specialists' contributions mentioned regarding curriculum advice or content development in some instances, it was not as prevalent as other stakeholders.

This suggests that while the body of research includes various stakeholders, it still lacks a holistic approach encompassing the full range of contributors to AI education, from development to implementation and evaluation.

4.5 Results for RQ4: Stakeholder Perceptions of AI

Our study synthesized findings from various research efforts examining the stakeholders' perceptions and attitudes toward AI education through diverse methodologies, including surveys, questionnaires, and participatory action research. The only stakeholders represented as far as perceptions were students, reflecting on AI in general or the curriculum they participated in.

One study [24] developed a tool to measure cynical hostility towards AI, uncovering nuanced student perceptions and the need for educational interventions. Another article [15] explores work with AI text modeling practices enhanced students' understanding and application of AI, leading to a more positive outlook. Another article shared results of a survey [23] after project-based learning activities in AI and marine disciplines showed increased engagement and interest, indicating improved perceptions. Another study [25] demonstrated a significant positive shift in AI learning attitudes using the Artificial Intelligence Learning Attitude Scale (AILAS), with students showing increased confidence and reduced anxiety post-course. One study [17] used a survey to assess AI competencies and ethical considerations, revealing higher competence and ethical awareness post-experimental teaching. Two additional studies [19, 20] highlighted the positive effects of participatory action research and an AIoT course on students' satisfaction and learning outcomes, self-efficacy, and reduced learning anxiety. A pre and post-program questionnaire used in another study [18] showed significant improvements in AI readiness, confidence, and attitudes, indicating the effectiveness of a Self-Determination Theory (SDT)-based program. A final article [21] suggested that smaller groups in AI education led to better motivation, lower cognitive load, and higher-quality collaborative problem-solving. These studies detail the evolving student attitudes toward AI, stressing the importance of tailored educational approaches to foster positive perceptions and competencies in AI technologies.

The collective results reveal a significant positive shift in students' attitudes towards AI post-intervention, with enhanced confidence, reduced anxiety, and heightened interest in AI applications. Project-based and experiential learning approaches effectively engaged students and fostered a more nuanced understanding and ethical consideration of AI technologies.

However, a notable gap exists in exploring AI perceptions among critical stakeholders beyond students, such as teachers, curriculum developers, policymakers, and AI specialists. Despite these groups' critical role in shaping and implementing AI education, their perspectives and attitudes towards AI integration in educational settings remain underexamined. This oversight suggests an opportunity for future research to delve into these stakeholders' views to provide a more holistic understanding of the challenges and opportunities in AI education.

5. Discussion

The examination of high school AI literacy highlights key areas where current research is strong and where gaps remain. The literature shows a significant focus on developing AI-related curricula and teaching methods, which suggests that the educational community is actively working to integrate AI into high school learning environments. The increased publication activity in 2022 indicates a growing recognition of the importance of AI education. The drop in publications in 2023 could perhaps suggest a shift towards deeper, more qualitative studies that take longer to complete and publish.

The thematic analysis of the included articles reveals a strong emphasis on curriculum and program development. This focus is essential for laying the foundation of AI literacy but also points to the need for more research on the effectiveness of these curricula in enhancing students' understanding and application of AI. The themes of student engagement and perceptions are well-covered, showing that hands-on, project-based learning methods are effective in increasing student interest and confidence in AI topics. However, the theme of inclusion and diversity in education is less represented, indicating a significant gap in literature. This gap suggests that future research should explore how AI education can be made accessible and relevant to a wider range of students, considering various backgrounds, learning styles, and needs.

The technology used in the reviewed articles is diverse, ranging from programming tools to robotics, which reflects the multidisciplinary nature of AI education. However, the reliance on specific tools and platforms may also highlight a potential barrier to access, as not all schools may have the resources to provide such technology.

A notable strength across the selected articles is the comprehensive coverage of the AI4K12 concepts (RQ1), particularly in Perception, Representation and Reasoning, and Learning. This indicates a robust engagement with the technical and cognitive aspects of AI, as evidenced by detailed curriculum development and machine learning applications. Such focus is essential for fostering a deep understanding of AI technologies among students, preparing them for a future where AI plays a significant role. However, the review also uncovers critical gaps in the literature, particularly concerning the concepts of Natural Interaction and Societal Impact. The lesser emphasis on these areas suggests a potential oversight of the broader implications of AI technologies, including ethical considerations, societal ramifications, and the importance of human-AI interaction. This gap points to a need for more holistic AI literacy frameworks that encompass not only the technical aspects but also the social and ethical dimensions of AI.

Ethical considerations in AI education (RQ2) were addressed in half of the selected articles, indicating a growing awareness but also revealing that ethical discussions are not universally integrated into AI literacy curricula. This emphasizes the need for embedding ethical content into all aspects of AI education to prepare students for responsible AI use and development.

Stakeholder involvement (RQ3) received varied levels of representation across different groups. The consistent focus on teachers and students underscores their central role in the educational process. However, the lesser emphasis on educational administrators and AI specialists highlights a disconnect between curriculum development and broader educational policy and implementation. This gap suggests a need for more inclusive and collaborative approaches to AI education that engage all stakeholders, ensuring that AI curricula are not only technically sound but also practically implementable and aligned with broader educational goals.

The exploration of stakeholder perceptions (RQ4) reveals a positive shift in attitudes towards AI post-intervention. This underscores the potential of tailored educational approaches, such as project-based and experiential learning, to enhance students' understanding and appreciation of AI. However, the limited focus on other stakeholders' perceptions points to a significant research gap, suggesting that future studies should explore the attitudes and needs of a broader range of stakeholders to develop more effective and inclusive AI education strategies.

6. Limitations

This literature review, while extensive, encounters inherent limitations reflective of the dynamic and multifaceted domain of AI literacy in high school education. The scope of literature, constrained by the databases and search terms employed, may not encapsulate the entirety of global research, potentially omitting studies pivotal to understanding diverse educational contexts. It is suggested to refer to the literature reviews identified through this review [8, 9] to follow their search terms as a template. The database selection was also minimal compared to similar literature reviews, so referring to the databases these authors used would also be beneficial for future research.

The rapid pace of technological advancements in AI presents another significant limitation. The evolving nature of AI technologies and their applications in various sectors can outpace the curriculum developments discussed in the reviewed literature. This misalignment raises concerns about the relevance and currency of educational content, potentially limiting the applicability of our findings over time. The literature may not sufficiently address the continuous need for curriculum updates to incorporate the latest AI advancements, which is crucial for maintaining the efficacy and relevance of AI education in high schools.

Furthermore, our review highlights a critical gap in addressing the ethical considerations and broader societal impacts of AI within the educational context. While ethical issues are mentioned, there is a need for a deeper exploration of how these considerations are integrated into AI curricula and the extent to which students grasp and engage with these complex topics. This includes discussions around privacy, bias, and the ethical use of AI technologies, which are paramount for developing responsible AI practitioners and informed citizens.

Lastly, the limited focus on the preparedness and professional development of educators to teach AI effectively is a notable limitation. The assumption that teachers possess the requisite AI literacy or have access to adequate professional development opportunities may not hold true across different educational contexts. This gap points to the crucial role of teacher training and support in the successful implementation of AI education, underscoring the need for comprehensive professional development programs that equip educators with the necessary knowledge and skills.

7. Conclusion

The exploration of AI literacy within high school education, as revealed through this literature review, marks a critical juncture in preparing students for an AI-integrated future. The substantial increase in relevant research in 2022 underscores a burgeoning interest in this field, yet the decline in 2023 suggests a potential pivot towards more in-depth, qualitative investigations.

Our review has identified four principal themes: the development of AI-centric curricula, the adoption of interactive teaching methodologies, the analysis of student engagement and perceptions, and the crucial yet underexplored domain of inclusivity and diversity within AI education. The evident preference for hands-on, experiential learning highlights its efficacy in

not only engaging students but also in fostering a deeper understanding of AI concepts, advocating for its broader implementation in educational strategies.

Despite these positive strides, our review also uncovers significant gaps. There is a notable scarcity of comprehensive AI educational resources and a lack of ethical considerations within existing curricula, pointing towards essential areas for future development. Moreover, the literature reveals a conspicuous absence of insights into teachers' perceptions of AI. Given their pivotal role in the educational ecosystem, understanding their perspectives is paramount for crafting AI education programs that are both effective and resonate with educators' needs and aspirations.

In light of these findings, we advocate for a concerted effort among educators, policymakers, and curriculum designers to develop inclusive, ethically informed, and culturally sensitive AI education programs. Such initiatives should not only equip students with necessary technical skills but also instill an ethical and responsible approach to AI utilization. Addressing the identified gaps, particularly the need for more inclusive research on stakeholder perspectives, including teachers, will be crucial in evolving AI literacy programs that are comprehensive and universally applicable.

As we forge ahead, it is imperative that the AI education community collaborates to fill these gaps, ensuring that the future of AI literacy in high schools is not only technologically robust but also ethically grounded and inclusively designed.

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