2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
ASEE
Paper ID #37721

Work in Progress: A Survey of Artificial Intelligence Educational Resources for Pre-College Education

Eisa A. Khawaja, Alpharetta High School

Eisa Khawaja is currently a junior at Alpharetta High School in Alpharetta, Georgia. He plans to pursue a degree in mechanical engineering. He is also interested in Artificial Intelligence and participated in an AI Scholars summer program.

Dr. Hoda Ehsan, The Hill School

Hoda is Chair for Engineering and Computer Science Department and the Director of Quadrivium Design and Engineering at The Hill School. She holds a Ph.D in Engineering Education from Purdue University, M.S. in Childhood Education from City University of New York, and B.S. in Mechanical Engineering from Bahonar University in Iran.

Work in Progress: A Survey of Artificial Intelligence Educational Resources for Pre-College Education

Abstract
Artificial Intelligence (AI) has emerged as the next imperative topic in pre-college education. Given the rapid integration of AI in K-12 education, examining the resources and curricula currently available for teaching AI is vital. Therefore, this exploratory study conducted a literature review to survey AI resources developed for K-12 education and how the resources enabled students to explore AI ideas and practices. The preliminary findings revealed that many developed resources and curricula focused on secondary education, specifically middle school. However, recently there has been an increase in curriculum development for primary education.

Introduction

Artificial Intelligence (AI) has gained significant attention in recent years across all sectors and fields [1]. In the past, AI was traditionally limited to industry. However, the integration of engineering and computer science (CS) in pre-college education has led AI to emerge as the next imperative topic in K-12 education [1], [2], [3]. With new technologies emerging rapidly, such as Alexa and Tesla's self-driving cars, students must understand these tools and their utilization starting in lower elementary [3]. Research suggests emerging technologies have great potential to improve learning and help students develop an interest in science, technology, engineering, and mathematics (STEM) [1]. In essence, academia, non-profits, and for-profits have begun to develop AI curricula and resources for pre-college education [2]. The Massachusetts Institute of Technology (MIT) recently released 'The Middle School AI + Ethics Curriculum,' which integrates ethics in technical lessons to develop students' ethical design skills [2].

Background

Artificial Intelligence in Pre-College Education

Artificial Intelligence (AI) in literature is defined as "the science and engineering of creating intelligent machines" [4, p. 2]. AI is a branch of CS that merges machine learning, algorithmic creation, and natural language processing [5]. While CS focuses on computational competencies, AI explores how computers "sense, think, act, learn, make decisions, create, perceive, and make sense of things" [6, p. 2]. The inclusion of AI was initially in higher education, but now it is becoming an integral component of pre-college education. Hence, to expand AI in pre-college education, the Association for Advancement of Artificial Intelligence (AAAI) and the Computer Science Teacher Association (CSTA) created a working group to develop national guidelines for teaching AI in pre-college education [7], [8]. Furthermore, AI for K-12 (AI4K12) also created guidelines on what students should learn within each grade band (i.e., K-2, 3-5, and 9-12) [8]. The organization proposed the Five Big Ideas framework (See Table 1), which includes *Perception*, *Representation and Reasoning, Learning, Natural Interaction, and Societal Impact* [8]. The framework aims to provide a structure for developing AI instructional tools [8]. Additionally, MIT's Responsible AI for Social Empowerment and Education (RAISE), an MIT-wide initiative to conduct AI research, education, and outreach, developed AI materials for K-12 students and the education community [9].

Table 1: AI Five Big Ideas and Definition [8]

Five Big Ideas	Definition
Perceptions	Process of extracting meaning from sensory signals, such as "see" and "hear" for practical use.
Representation and Reasoning	Agents maintain representations of the world and use them for reasoning.
Learning	Computers can learn from data.
Natural Interaction	Intelligent agents require many types of knowledge to interact naturally with humans.
Societal Impact	Artificial intelligence can impact society in both positive and negative ways.

This push for AI has led several nations, such as the United States, United Kingdom, China, South Korea, Finland, and Australia, to integrate AI into K-12 education [10]. Researchers have also called for formal pre-college education to prioritize AI literacy and teach children to interact with AI [2], [9], [8]. As AI becomes increasingly prevalent, there is a greater demand for AI-literate workers [9]. Consequently, several studies have explored the potential of incorporating AI in pre-college education through "playful experiences and approachable content to prepare children for an AI-saturated world" [10, p. 2]. Additionally, AI studies in early childhood are also emerging [6], [11], [12], [13], [14]. Given the growth of AI in K-12, it is necessary to explore AI resources developed for pre-college education. Examining the available AI resources will help understand how AI is integrated into teaching and learning in pre-college education. This will also help to identify any gaps in curriculum development. Moreover, it will offer a basic understanding of current AI technologies and their use in theories and practice [10].

Research Purpose

This exploratory study aims to conduct a literature review to survey AI resources developed for K-12 education. Through this study, we aim to address the following research questions: *1) What AI resources, specifically curricula and technological tools, are available for pre-college education? 2) How do these resources enable pre-college students to explore AI ideas and practices*?

Methods

The literature review was conducted to examine the AI resources developed for pre-college education. The literature review focused on empirical studies that identified curricula and tools designed for pre-college education and how these resources enabled students to explore AI ideas. We followed the literature review guidelines suggested by Grant et al. [15] to conduct this literature review.

Literature search

With the growing surge of AI and open-access publications, searching even with well-defined criteria is difficult. Thus, we decided to focus on research publications collected on one of the most widely used and accessible web-based databases for this study. The literature search was conducted in December 2022 by using Education Resources Information Center (ERIC). The

decision to use ERIC was because ERIC is good for locating a broad array of literature related to all aspects of education and across educational levels.

Multiple rounds of searches were conducted on the source database using different combinations of keywords and search strategies. The search criteria encompassed "AI K-12 Education", "AI K-12 Curriculum", and "AI K-12 Resources". For this review, we only considered papers published between 2010 and 2022, and no further restriction was placed on the source of publication. In addition, we strictly followed the following criteria for screening and selection purposes; AI studies conducted in pre-college education and studies that discussed AI curriculum or tools. Published research on AI in non-educational settings, such as healthcare, was excluded. Moreover, theoretical and conceptual papers were also excluded from the analysis. However, to broaden our theoretical understanding of AI in education, we did review the theoretical/conceptual papers. Lastly, articles referenced in the publications we reviewed for this study were also examined. Our literature search yielded 296 publications, most of which were fairly recent.

After reading each paper carefully, we noted the resources, the curriculum, and the grade level the studies focused on and/or discussed in their results. Using an inductive thematic analysis approach, we first organized the papers according to grade levels (elementary and secondary) [16]. Elementary comprised of studies conducted in kindergarten through fifth grade, with some including sixth grade. Secondary comprised of studies conducted in sixth through twelfth grade. This was followed by further reviewing the resources discussed in the research and labeling them as curriculum versus other resources and how they enabled the teaching and learning of AI. For this work-in-progress study, we highlighted only the most recent curricula/resources discussed in the literature and how they enabled learning due to space constraints (See Appendix for others).

Results

The preliminary finding of this literature review revealed that AI integration in pre-college education via curricula and/or tool development is rapidly growing, especially in elementary education [14], [18], [19], [21], [22], [23]. Thus, curricula have been developed to expose students to AI skills and knowledge [17], [18], [19]. However, many units created are for upper elementary and lower secondary levels. For instance, five studies focused on upper elementary and one on lower elementary [6], [26], [32]. Six studies were in the lower secondary and one in the upper secondary level [29], [33]. Most of the elementary lessons were designed to be conducted face-to-face [6], [24], [25]. While lessons created for secondary were either for in-person or remote implementation [9], [26]. The length of the curricula also differed across the studies. For instance, Dai et al. [25] developed an AI curriculum consisting of 10 modules, each approximately 40-80 minutes long. In comparison, Van Brummelen and colleagues [26] designed a five-day remote AI workshop series that was 2.5 hours long per day. The curricula discussed in the studies have also been implemented in various settings (i.e., formal, informal, workshops, and camps). For instance, Alvarez et al. [29] implemented a condensed version of their AI curriculum in a two-week summer camp. Moreover, the learning content and the assessments covered in the curricula differed across the studies. While some units incorporated formal assessments, others suggested informal assessments [6], [24], [26] (e.g., class discussion and observations).

In elementary, AI has primarily been infused into the computational thinking curricula in core subjects, such as science, technology, engineering, mathematics, and even arts (STEAM) [17]. Additionally, the curriculum is designed to teach children AI concepts, such as basic processes of AI, speech recognition, image recognition, data, and knowledge representation [6], [11], [12], [24]. For example, Yang et al. [24] developed 'AI for Kids' for kindergarten students. The curriculum highlights AI using an embodied project-based approach. The curriculum theme is "AI and Ocean Protection," which was determined based on children's interests given their location (Hong Kong). The learning activities within the curriculum integrate music, language, STEAM, and literacy. Children learned about AI by listening to stories and picture books and reviewing specific vocabulary in the stories. Children learned about AI's thinking and training principles through picture books and games with graphics cards and manual materials. In contrast, Dai and colleagues [25] curriculum development was a collaborative project initiated by six computer science teachers and an engineering professor. The curriculum aimed to develop students' basic AI concepts, processes, and problem-solving strategies, including the use of AI in everyday life.

Additionally, other resources and tools developed to teach AI to elementary students include Google's Teachable Machine [20], QuickDraw, Cognimates [21], Cosmo robot, and Calypso for Cozmo [22]. Scheidt et al. [27] developed *Any Cubes,* a prototype toy that allows children to explore machine learning. Similarly, William et al. [14] developed an AI platform*, PopBots,* for preschool children to train and interact with social robots to learn AI concepts related to knowledge-based systems, machine learning (ML), and generative AI interactions with social robots.

In secondary education, AI was initially incorporated as a relevant component of computational thinking curricula and integrated with STEM subjects [17]. For example, Akram et al. [28] designed AI modules integrated into science concepts. Each module amalgamates an AI concept and science core disciplinary area (e.g., Search & Life sci.; Knowledge-representation systems & Physical sci.; Machine Learning & Earth sci, etc.). Whereas Alvarez and colleagues [29] AI curriculum focused on natural language processing, sentiment analysis on textual data, dataset bias, computing ethics, AI connections to social media, and AI in real-world applications. The 'DAILy Curriculum' [30], also designed for middle school, comprises ten units that cover Logic systems, Machine Learning, and Generative Adversarial Networks (GANS). In each unit, students investigate the presence and causes of algorithm bias, "its societal and ethical implications and ways to mitigate bias" [30, p. 3]. Students also develop an awareness of AI careers, an understanding of the importance of technical skills development, and the "ongoing nature of change and adaptation in today's job world" [30, p. 3].

Additionally, Al in secondary also includes topics associated with morals and ethics of using AI. For instance, MIT's 'The AI + Ethics Curriculum' for middle school encompasses online and un-plugged activities [2]. The curriculum introduces students to AI's technical aspects and its social and ethical implications. Moreover, one activity engages students in machine learning by having them develop a visual classifier using Google's Teachable Machine and then experiment with bias in training. Through this activity, students learn about bias and the ethical implications of technologies [2].

Similar to elementary, tools have been developed for secondary education that enable students to interact with AI, such as Google's Teachable Machine and Cognimates [20], [22], [23]. These tools can be utilized by both elementary and secondary students. Medium [23] developed '*TensorFlow Playground,'* a graphical application that allows high school and undergraduate students to experiment with neural networks and backpropagation learning.

The findings illustrate that interest in the development of AI resources for pre-college education has grown tremendously [1], [6], [7], [24, [32]. Moreover, the increasing number of relevant articles suggests that researchers are critically investigating AI in K-12 education. Although, in this paper, most of the curricula highlighted were situated in the United States [2], [9], [14]. Nonetheless, this trend of AI in K-12 education is not limited to the United States [6], [24], [25], Thus, future research needs to incorporate findings from empirical studies conducted worldwide.

Limitation

We recognize that many resources available for pre-college education are not research-based and have yet to be published in a research database. Many curricula are developed and marketed to schools at expensive fees, and the content is not freely available. Therefore, our paper lacks to include those curricula. For this study, we only used the ERIC database to conduct the literature search focusing on empirical studies in pre-college education, specifically studies that discussed AI curricula or tools. Published research on AI in non-educational settings, such as healthcare, was excluded. Thus, this review is limited in its scope. Future studies need to expand the research scope to include other reputable databases and specialized journals. A future search may also incorporate non-empirical resources, such as reports. Additionally, keywords such as "Machine learning," "AI tools," and "AI Informal learning" may retrieve more publications. The current search only reviewed studies between 2010 and 2022. Future inquiries need to expand the search time to include studies published in 2023. This study presents a preliminary literature review conducted to survey AI resources developed for K-12 education. The finding highlight resources developed more recently but maybe be limited in scope.

Conclusion

As interest in artificial intelligence grows in pre-college education, exploring what currently exists for AI K-12 education, including resources and curricula, was necessary. The findings of this study identify the resources and curricula developed for pre-college education. Furthermore, the results of this study highlight for the broader engineering education community the importance of AI education. It is indeed encouraging to see AI curricula designed for children in elementary grades. Given technology's important role in the 21st century, fostering technologically literate children is essential. AI has been primarily introduced to children through problem-solving and decision-making approaches. The curricula mainly focus on technical aspects of AI, like coding and how it can be used by and for machines. However, some curricula emphasized more broadly how AI can help humans solve everyday problems within different subjects such as earth sciences and nature [24]. Most importantly, not only are pre-college-aged children learning about AI, but they are also learning about the morals and ethics of using AI. At least five curricula focused on AI, Ethics, and biases and flaws of these systems.

In this paper, we only presented the preliminary findings of this review. To complete this effort, we plan to conduct a more in-depth comparison of the curricula content and a comprehensive

evaluation of what engineering educators and engineering education researchers can use in future research and practice. In future literature, we also plan to identify the pedagogical approaches employed to teach Al in pre-college education.

Acknowledgment
We would like to acknowledge our colleagues and mentors for their support.

References

[1] D. Touretzky, C. Gardner-McCune, C. Breazeal, F. Martin, F., and D. Seehorn, "A year in K-12 AI education," *AI Magazine*, vol. 40, no. 4, pp. 88-90, 2019.

[2] B. H. Payne, "AI+Ethics Curriculum for Middle School," Cambridge, MA: MIT Media Lab., 2019.

[3] D. S. Touretzky, C. Gardner-McCune, F. L. Martin, and D. Seehorn, "Envisioning AI for K-12: What Should Every Child Know about AI?," I*n Proceedings of the Thirty-Third AAAI Conference on Artificial Intelligence*, Palo Alto, CA: AAAI Press, 2019.

[4] J. McCarthy, "From here to human-level AI," *Artificial Intelligence*, vol. 171, no. 18, pp. 1174–1182, 2017.

[5] S. Akgun, and C. Greenhow, "Artificial intelligence in education: Addressing ethical challenges in K-12 settings, *AI and Ethics*, pp. 1-10, 2021.

[6] J. Su, and Y. Zhong, "Artificial Intelligence (AI) in early childhood education: Curriculum design and future directions," *Computers and Education: Artificial Intelligence*, vol. 3, 2022.

[7] H. Roberts, J. Cowls, E. Hine, F. Mazzi, A. Tsamados, M. Taddeo, and L. Floridi "Achieving a 'Good AI Society': Comparing the aims and progress of the EU and the US. Science and engineering ethics,", vol. 27, pp. 1-25, 2021. [change 6 to 7]

[8] AI4K12. "Grand band progression charts", 2020, https://ai4k12.org/gradeband-progressio n-charts/.

[9] R. Williams, S. Ali, N. Devasia, D. DiPaola, J. Hong, S. P. Kaputsos, and C. Breazeal, "AI+ ethics curricula for middle school youth: Lessons learned from three project-based curricula," *International Journal of Artificial Intelligence in Education*, pp. 1-59, 2022.

[10] M. Yue, M. S. Y. Jong, and Y. Dai, "Pedagogical Design of K-12 Artificial Intelligence Education: A Systematic Review," *Sustainability,* vol. 14, no. 23, 2022.

[11] S. Kewalramani, G. Kidman, and I. Palaiologou, "Using artificial intelligence (AI)-interfaced robotic toys in early childhood settings: A case for children's inquiry literacy," *European Early Childhood Education Research Journal*, vol. 29, no. 5, pp. 652–668, 2021.

[12] J. Prentzas, J. (2013). "Artificial intelligence methods in early childhood education. In *Artificial Intelligence, evolutionary computing and metaheuristic*," Berlin, Heidelberg: Springer, pp. 169–199, 2013.

[13] J. Su, and W. Yang, "Artificial intelligence in early childhood education: A scoping review," *Computers and Education: Artificial Intelligence*, 2022.

[14] R. Williams, H. Park, L. Oh, and C. Breazeal, C. (2019a). Popbots: Designing an artificial intelligence curriculum for early childhood education. *In Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 33 pp. 9729–9736, 2019a.

[15] M. J. Grant, and A. Booth, "A typology of reviews: an analysis of 14 review types and associated methodologies," *Health information & libraries Journal*, vol. 26, no. 2, pp. 91-108, 2009.
[16] J. W. Creswell, "Mapping the field of mixed methods research," *Journal of Mixed Methods Research*, vol. 3, no. 2, 95-108, 2009.
[17] H., J. Hernalesteen, A. S. Collard, "Teaching artificial intelligence to K-12 through a role-playing game questioning the intelligence concept, *KI-Künstliche Intell*, vol. 35, pp. 171-179, 2021.
[18] G. I. Melsión, I. Torre, E. Vidal, and I. Leite, "Using explainability to help children understand gender bias in ai. *In Proceedings of the Interaction Design and Children*, Athens, Greece, 24–30 June 2021, pp. 87–99, 2021.
[19] S. Srikant, V. Aggarwal, "Introducing Data Science to School Kids," *In Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, Seattle, WA, USA, 8–11 March 2017; pp. 561–566. 2017.
[20] H. Vartiainen, M. Tedre, and T. Valtonen, "Learning machine learning with very young children: Who is teaching whom?" *Int. J. Child-Comput. Interact*. 2020.
[21] S. Druga, "Growing up with AI: Cognimates: From coding to teaching machine," Doctoral Dissertation, Massachusetts Institute of Technology, Cambridge, MA, USA, 2018.
[22] D. S. Touretzky, "Computational thinking and mental models: From Kodu to Calypso, *In 2017 IEEE blocks and beyond workshop (B&B),"* pp. 71-78, IEEE, 2017.
[23] Medium. "Understanding deep learning with TensorFlow playground", 2022, https://medium.com/@andrewt3000/understanding-tensorflowplayground-c20cdb7a250b.
[24] W. Yang, "Artificial Intelligence education for young children: Why, what, and how in curriculum design and implementation," *Computers and Education: Artificial Intelligence*, 3, 2022.
[25] Y. Dai, A. Liu, J. Qin, Y. Guo, M. S. Y. Jong, C.S. Chai, and Z. Lin, "Collaborative construction of artificial intelligence curriculum in primary schools", *Journal of Engineering Education*, vol. 112, no. 1, pp. 23-42, 2023.
[26] J. Van Brummelen, T. Heng, and V. Tabunshchyk, "Teaching tech to talk: K-12 conversational artificial intelligence literacy curriculum and development tools," *In Proceedings of the AAAI Conference on Artificial Intelligence*, Vol. 35, No. 17, pp. 15655-15663, 2021, May.
[27] A. Scheidt, and T. Pulver, "Any-cubes: A children's toy for learning ai: Enhanced play with deep learning and mqtt," *In Proceedings of Mensch und Computer 2019*, pp. 893-895, 2019.
[28] B. Akram, S. Yoder, C. Tatar, S. Boorugu, I. Aderemi, and S. Jiang, "Towards an AI-infused interdisciplinary curriculum for middle-grade classrooms," *In Proceedings of the AAAI Conference on Artificial Intelligence*, Vol. 36, No. 11, pp. 12681-12688, 2022.
[29] L. Alvarez, I. Gransbury, V. Cateté, T. Barnes, Á. Ledéczi, and S. Grover, "A socially relevant focused AI curriculum designed for female high School students," In *Proceedings of the AAAI Conference on Artificial Intelligence,* Vol. 36, No. 11, pp. 12698-12705, 2022.
[30] I. Lee, S. Ali, H. Zhang, D. DiPaola, and C. Breazeal, "Developing middle school students' AI literacy," *In Proceedings of the 52nd ACM technical symposium on computer science education*, pp. 191-197, 2021.

[31] G. V. Wangenheim, J. C. Hauck, F. S. Pacheco, and M. F. Bertonceli Bueno, “Visual tools for teaching machine learning in K-12: A ten-year systematic mapping. *Educ. Inf. Technol*, vol. 26, pp. 5733–5778, 2021.

[32] S. Lee, B. Mott, A. Ottenbreit-Leftwich, A. Scribner, S. Taylor, K. Park, J. Rowe, K. Glazewski, C. E. Hmelo-Silver, J. Lester, “AI-Infused collaborative inquiry in upper elementary school: A game-based learning approach,” *In Proceedings of the AAAI Conference on Artificial Intelligence,* Vol. 35, pp. 15591–15599, 2021.

[33] F. Bellas, S. Guerreiro-Santalla, M. Naya, *et al.*, “AI curriculum for European high schools: An embedded intelligence approach”, *Int J Artif Intell Educ*, 2022.

[34] P. Lin, J. Van Brummelen, G. Lukin, R. Williams, and C. Breazeal, “Zhorai: designing a conversational agent for children to explore machine learning concepts”, *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 34, no. 09, 2020.

[35] S. Kim, Y. Jang, W. Kim, S. Choi, H. Jung, S. Kim, and H. Kim, “Why and what to teach: AI Curriculum for elementary school,” Proceedings of the AAAI Conference on Artificial Intelligence, vol. 35, no. 17, pp. 15569-15576, 2021.

[36] A. Sabuncuoglu, “Designing one-year curriculum to teach artificial intelligence for Middle School, pp. 96-102, 2020.

APPENDIX A

Author and Year	Age Level	Curriculum/Tool	Content/Topics	Assessments
Sue & Zhong, 2022	Primary (Kinder)	AI Curriculum	Introduction to AI; Machine Learning; Speech Recognition; Flaws and Biases of AI	Observations & Interviews; Pre/Post assessments (create on your own); Self-assessment questionnaire
Yang, 2022	Primary	AI for Kids	**AI+ Ocean Protection**: Basic principle of data processing of AI; Understand and apply the basic principle, and process of making judgments of AI; Understand the concept of prejudice and recognize that AI also has prejudices and errors.	Possible assessments discussed: Timely feedback; Authentic assessment tasks; Portfolios; student artifacts; and Self-assessment
Dai et al., 2022	Primary	AI Curriculum	Intro to AI and AI in our everyday life; Data and knowledge representation; Machine perception; Machine reasoning; Machine cognition	No curriculum assessment discussed.
Lin et al., 2020	Primary	Zhorai platform and curriculum	What does Zhorai know; Teaching Zhorai; Witnessing Machine Learning; AI & Ethics	Five-item open question assessment; Self-evaluation questionnaire
William et al., 2019a	Primary	*PopBots* platform	Knowledge-Based Systems; Supervised Machine Learning; and Generative AI.	Observations & Interviews
Lee et al. (2021)	Primary	PRIMARYAI (game-based learning)	Image Recognition; Machine learning; planning; automated decision making	Pre/post assessment of AI concepts, ethics, life science
Su & Zhong, 2022	Primary/ Secondary	Teachable Learning Tool	***Teachable Machine***: a web tool to explore machine learning by training a computer to recognize your images, sounds, & poses,	
Druga et al., 2018	Primary/ Secondary	Tool	***Cognimates*** - Scratch add-on that offers users access to APIs for voice production, speech recognition, text classification, object identification, and robot control	

Touretzky, 2017	Primary	Tool	***Calypso for Cozmo:*** rule-based visual programming language for Cozmo that includes speech recognition, landmark-based navigation, a visible global map, and state machine programming capabilities.	
Scheidt & Pulver, 2019	Primary	Tool	***Any Cubes:*** a prototype toy that allows children to explore machine learning.	
Dale, 2020	Primary	Tool	***Machine Learning for Kids:*** A tool to teach kids about machine learning, by allowing them to train a computer to recognize sounds, text, numbers, and pictures.	
Kim et al, 2019	Primary	Al Curriculum	Introduction to AI; Traditional approaches to AI-search & reasoning; face detection; speech recognition; machine translator; image & text classification; self-driving cars.	Self-assessment; Peer assessment; Small group discussion; Five-point Likert scale to assess AI Knowledge, Skills, & Attitudes
Medium, 2022	Secondary	Tool	***TensorFlow Playground***: Graphical application that allows high school and undergraduate students to experiment with neural networks and backpropagation learning	
Lee et al., 2021	Secondary	DAILy Curriculum	Introduction to AI; Logic Systems; Supervised learning with Teachable Machine; Neutral Networks through a participatory simulation game, & Generative Adversarial Networks (GANSs)	AI Concept Inventory; Attitudes toward AI; AI careers survey; Observations
Sabuncuoglu, 2020	Secondary	AI Curriculum	Introduction to AI; Developing intelligent interfaces to communicate with human users; Computer vision systems to see the environment; Speech and audio systems to hear the environment	In-class evaluation forms; Kahoot quizzes

Van Brummelen et al., 2021	Secondary	AI Curriculum for remote workshop	Addressed AI competencies: Recognizing AI; Understanding Intelligence; Interdisciplinarity; General vs. Narrow; AI Strengths & Weaknesses; Imagine Future AI; Representations; Decision-Making; ML Steps; Human Role in AI; Data Literacy; Learning from Data; Critically Interpreting Data; Action & Reaction; Sensors; Ethics; Programmability	Questionnaire, Student artifacts, Student observations
Williams et al., 2022	Secondary	Three curricula: *Creative AI, Dancing with AI; How to Train Your Robot*	**AI + Ethics Education**: Technical AI knowledge; Thinking critically about the implications of AI; Application of AI knowledge	Pre-Post Questionnaire; Activities context specific assessments; Rubrics
Akram et al., 2022	Secondary	AI Curriculum for Science Classrooms	Search & Life Sciences; Knowledge-representation systems & Physical sciences; Machine Learning & Earth sciences; Natural Language Processing & Engineering Technology and Application of Science	Teaching "breadth first Search" as part of the search curricular module
Alvarez et al., 2022	Secondary	CS Frontiers (CSF) curriculum	Natural language processing, sentiment analysis on textual data, bias in datasets, computing ethics, AI connections to social media, and AI in real world applications.	Pre/Post surveys that also includes items on curriculum content knowledge.
Bellas, et al., 2022	Secondary	AI Curriculum	Web search and investigation; Intelligent apps; Basic robotics; Intermediate robotics, IOT.	Final test of theoretical concepts; Final test of the program; Individual rubrics

Note: 'Al Curriculum' is entitled for curricula that didn't specify a title in the study. Also, we only included assessments for studies that discussed assessments.