

What to Teach and How to Teach: Artificial Intelligence Education in Primary and Secondary Schools

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Abstract: *With the growing impact of artificial intelligence (AI) technology on human society, many countries have introduced AI education into their basic education curricula to facilitate their young generation's adaptation to future societal development. This study is a review of the current state of primary and secondary AI education from the standpoints of "what to teach" and "how to teach" and finds that AI literacy development is the paramount objective despite the differences in AI education purposes among various countries; that current AI curriculum content primarily includes basic AI knowledge and techniques, AI applications, and ethics of AI; and that a wide variety of pedagogical approaches have been adopted in AI education, including lecture, group study, project-based learning, and activity-based learning. The article also summarizes common AI teaching tools in use. Issues with current AI education are discussed as well.*

Science Insights Education Frontiers 2025; 28(1):4613-4626

DOI: 10.15354/sief.25.re523

How to Cite: Xia, X. (2025). What to teach and how to teach: Artificial intelligence education in primary and secondary schools. *Science Insights Education Frontiers*, 28(1):4613-4626.

Keywords: *Artificial Intelligence Education, Curriculum Content, Training Objective, Pedagogical Approach, Primary and Secondary School*

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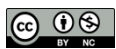
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Conflict of Interests: None

Funding: No funding sources declared.

AI Declaration: The authors affirm that artificial intelligence did not contribute to the process of preparing the work.

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Introduction

TODAY, artificial intelligence (AI) technology is advancing at an overwhelmingly rapid pace, permeating every facet of human society and profoundly transforming how people live and work. AI-informed professions are bound to proliferate, and future society will be highly digital and intelligent. Against this backdrop, cultivating in citizens the adaptability to the future intelligent era becomes a core mission of education. In recent years, governments and organizations worldwide have introduced a wide range of AI education initiatives that call for integrating AI education into primary and secondary curricula to equip the next generation with knowledge and skills required in the digital era. For instance, the *Beijing Consensus on Artificial Intelligence and Education*, released by UNESCO in 2019, highlights AI's systemic and long-term impact on the labor market and the need to incorporate AI skill training into K-12 curricula (UNESCO, 2019; Wei, 2025). In November 2024, the Ministry of Education of China issued the *Circular on Strengthening Artificial Intelligence Education in Primary and Secondary Schools*, explicitly setting the goal of universalizing primary and secondary AI education in China by 2030 (Ministry of Education of China, 2024). In the United States, the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) jointly launched the "AI4K12 Initiative" (<https://ai4k12.org/>), aiming to promote K-12 AI education by providing national guidelines, the inventory of online resources available, and the list of developer communities for AI teaching tools and materials.

Current AI education at the primary and secondary levels is in its infancy, pending further exploration. Despite governmental and non-governmental organizations having advanced policies or provided certain resources to support the development of AI curricula, many challenges remain in actual AI teaching practices, such as a lack of well-defined objectives, fragmentary instructional content, immature teaching methods, and teaching staff shortages (Lu et al., 2021). In effect, there are no conclusive interpretations of terms like "AI in education," "AI education," and "AI literacy" (Ng et al., 2024) in the education world, let alone well-developed course design and evaluation frameworks. Moreover, the continual iteration of AI technology itself poses complications to the development of professional and up-to-date AI teaching materials (Zhong & Liu, 2022). Also, there are issues of content overlapping and a lack of smooth transition in AI education between educational phases (e.g., between lower and upper primary grades, between primary and secondary levels) (Cao et al., 2025). Additionally, some of the prevailing pedagogical methods are not suitable for AI instruction, and the shortage of qualified teachers is a severe impediment to the advancement of AI education (Wang, 2024).

To enhance AI education, educators and researchers have actively explored solutions to the aforementioned issues. For instance, Chiu (2021) investigated the views and practices of 24 AI educators from 12 secondary schools in Hong Kong and advanced a comprehensive AI teaching design model, which not only includes the core content of basic AI curricula but also effective approaches to implementing the curricula. Due to socioeconomic and cultural differences, AI education programs and implementation strategies vary in different countries and territories, and their explorations have generated valuable insights into how to advance AI education. Using the method of literature review, this study seeks to encapsulate the training objectives, curriculum content, and instructional approaches in current AI education with the purpose of providing implications for further improvement in this area.

What to Teach: AI Training Objectives and Curriculum Content

Training Objectives

Objectives of AI education set by different countries and research programs vary due to their distinct focuses. According to China's *Primary and Secondary Artificial Intelligence Curriculum Guidelines* (Primary and Secondary AI Curriculum Research Group & Jiang, 2023), basic AI education is aimed at (i) cultivating future citizens for the development of intelligent society; (ii) supporting the development of core AI competences in students; (iii) meeting students' interest in learning about AI technology; and (iv) promoting education innovation in the era of intelligence. The guidelines serve as policy orientation for AI education in China with overarching goals, since they are formulated in response to the state's strategic document *China's Educational Modernization 2035*, aiming to provide direction for the development of AI curricula in primary and secondary schools nationwide. On the other hand, some AI education programs implemented on a smaller scale have more specific objectives. For instance, the AI curriculum designed by Chiu et al. (2021) and Chiu (2021) has the following aims: (1) inspiring interest in AI: piquing students' interest in studying AI technology and encouraging devotion to AI development in them as future academic or career pursuit; (2) developing AI competencies: equipping students with AI knowledge, skills, and ethical awareness, enabling them to become qualified AI users, developers, researchers, and ethical norm designers.

Educators and researchers have also proposed to set varying AI training objectives for distinct education phases. For example, Cao et al.

(2025) argue that the chief objective of elementary AI education is to give the pupils the “preliminary AI experiences, helping them acquire perceptual understanding of AI technology and its basic features through simple, engaging interactive activities; that for junior secondary students, the main objective is to “lay an AI foundation,” enabling the students to progressively build the AI knowledge structure, including core concepts and basic programming skills; and that at the senior secondary level, the primary objective is to “reinforce the AI foundation,” further expanding the students’ horizons of AI knowledge, updating them on cutting-edge developments and applications of AI, and encouraging creation of AI projects in them, to lay a robust groundwork for their future specialized AI studies in universities. Furthermore, certain studies find that AI training objectives for specific education levels may be more sophisticated than generally perceived. For instance, Su et al. (2024), after reviewing 21 studies on AI curriculum development, discovered that in a portion of elementary schools, the pupils, in addition to learning basic AI concepts, were also expected to use machine learning knowledge to train, code, and test intelligent programs, as well as apply the knowledge to construct machine learning models. In some secondary schools, AI education objectives could be very challenging, involving the design and development of machine learning applications and comprehension of advanced machine learning concepts such as linear classification, machine learning algorithms, and natural language processing.

Despite there being different training objectives for AI education, fostering students’ AI literacy is the common goal shared by the AI education community, even though there are differential ways of interpreting AI literacy. “Digital Promise” defines AI literacy as the essential body of knowledge and skills that enable people to critically comprehend, evaluate, and use AI systems and tools to safely and effectively engage in an increasingly digital world (as cited by Lan et al., 2025). China’s *Primary and Secondary Artificial Intelligence Curriculum Guidelines* (Primary and Secondary AI Curriculum Research Group & Jiang, 2023) emphasize that AI literacy should cover four basic dimensions: (i) AI awareness—reaction, understanding, and value judgment on AI; (ii) AI thinking—the intellectual ability to formulate solutions to problems using AI methodologies; (iii) AI application and innovation—the ability to critically assess AI tools and resources and select appropriate ones based on practical needs; (iv) AI social responsibility—personal duties in an AI-driven society regarding privacy protection, ethical norms, and self-discipline.

“Five Big Ideas in Artificial Intelligence,” advanced by AI4K12 (<https://ai4k12.org/>), has been adopted by many researchers as a reference framework for developing AI literacy training programs (Touretzky et al., 2019; Li, 2022). The Five Big Ideas include perception (computers perceive the world using sensors); representation & reasoning (agents maintain

representations of the world and use them for reasoning); learning (computers can learn from data); natural interaction (intelligent agents require many kinds of knowledge to interact naturally with humans); and societal impact (AI can impact society in both positive and negative ways). These five core ideas provide a valuable framework for K-12 AI literacy training, guiding the teachers to develop proper course content and teaching activities for different age groups.

Curriculum Content

Primary and secondary AI curricula may involve diverse subjects but primarily consist of areas as follows:

- *Foundational AI Knowledge*: It refers to declarative knowledge about AI, including the definition of AI, basic AI concepts (e.g., the intelligent agent, machine learning, deep learning, robotics, natural language processing, etc.), the history of AI, the latest developments, major application areas (e.g., healthcare, education, transportation, etc.), and the limitations of AI applications.
- *AI Techniques*: The students need to acquire basic programming and algorithm design skills, develop an understanding of the principles behind AI data processing, and learn how to design sensor control for simple intelligent systems and use relevant tools and platforms to develop basic AI programs. Some schools or training institutions may offer preparatory courses on programming and robotics before introducing AI courses (Zhong & Liu, 2022) in a bid to increase AI education outcomes.
- *Application and Practice*: This part of AI training typically uses specific application scenarios (e.g., the smart home system, intelligent traffic surveillance, medical image diagnosis) to deepen students' understanding of AI's roles in different fields. For example, using deep learning algorithms to assist doctors in disease diagnosis is an important application of AI in healthcare. Alternatively, the students may be engaged in interactive learning through online AI experimentation platforms (e.g., TensorFlow Playground, Machine Learning for Kids) to develop knowledge on the training and optimization of AI models.
- *Ethics and Societal Impact of AI*: The importance of raising students' awareness of AI's ethical challenges and societal implications has been underscored by many AI curricula (Lee & Kwon, 2024; Yue et al., 2022). In this area of AI education, the students explore ethical issues with AI such as algorithmic bias (e.g., gender or racial bias in facial recognition technology), privacy protection (e.g., the legitimacy of data collection and usage), and data security (e.g., the

possibilities of data breaches and hacking). They also investigate AI's societal impacts, including changing the employment structure (e.g., the effect of automation on employment), exacerbating social inequality (e.g., disparities in AI penetration across regions and demographics), and transforming working patterns (e.g., the rise of remote work and virtual collaboration).

The significance of AI technology and its impact on future society are undeniable. Nevertheless, not every student is interested in delving deeply into the subject or pursuing AI as a career path. In effect, most students primarily need a basic understanding of AI and its applications. Hence, certain researchers suggest differentiating AI education for students (Steinbauer et al., 2021). For example, the EDLRIS protocol offers both basic and advanced AI courses. The basic course is designed for all students, aiming to provide foundational AI knowledge and encourage reflection and discussion on AI's implications. The advanced course, on the other hand, targets high-potential students or those with special AI backgrounds, offering in-depth AI education to prepare them for tertiary AI programs or future AI-related careers.

How to Teach: AI Teaching Approaches and Tools

Pedagogical Approaches

The literature shows that a variety of teaching approaches have been experimented with for AI curriculum implementation. The *UNESCO's K-12 AI Curricula: A Mapping of Government-Endorsed AI Curricula* report four commonly used pedagogical approaches: lecture or instruction, group work, project-based learning, and activity-based learning (Lou et al., 2022; UNESCO, 2022). With lecture or instruction, information is delivered verbally, in print, or through a combination of media by a teacher, facilitator, or expert. In some studies, this approach is dubbed "direct instruction." The report claims that 89% of AI curricula surveyed adopt lecture or instruction. As the most traditional pedagogical approach, it is effective in teaching basic AI concepts and applications and explaining how AI models work, helping students with no prior AI knowledge develop a preliminary understanding of AI technology (Lee & Kwon, 2024). Group work involves learners collaborating to complete one or more tasks. The report states that about 50% of AI curricula use this approach. Oyelere et al.'s (2022) systematic review also suggests that group work is one of the common AI teaching approaches in African schools. Through group work, the students can more effectively comprehend and apply AI technologies, collaborate to complete AI projects, and, in the meantime, develop their teamwork and communication skills (Ng et al., 2024). Also, the intergroup competition can substantially boost their

interest and motivation for AI learning. In project-based learning (PBL), the learners, under the guidance of the teacher, leverage their knowledge and skills to tackle a real-world challenge over an extended period of time. According to the UNESCO's report, approximately 70% of curricula surveyed use this approach. In some studies, it is combined with collaborative learning to enable the students to solve practical problems or complete projects in groups, developing both problem-solving and teamwork skills (Deng et al., 2021; Ng et al., 2024). For instance, in Toivonen et al.'s (2020) study, elementary school students worked in groups for their AI projects, using Google's Teachable Machine (a web-based machine learning tool) to collect data and train models to address real-world problems identified. However, there exist challenges in adopting PBL for AI curriculum implementation despite its popularity. According to Zhong & Liu (2021), a full cycle of PBL requires an extended period, and its outcomes are often less ideal than expected in AI education, given the limited class hours allocated to AI curricula in many schools. Activity-based learning usually takes place in classrooms and is designed to foster independence, exploration, and experimentation in students. Student active engagement and collaboration in the classroom are its key elements (Anwer, 2019). The UNESCO survey reveals that around 52% of AI curricula adopt this approach. In enacting the AI curriculum developed by Jiang et al. (2022), the students worked in pairs to classify positive and negative comments on the service of their school dining hall via manual and StoryQ platform-based manipulation, respectively. Through this activity, the students grasped basic concepts of machine learning, learned to model unstructured-text data, and increased their understanding of the mechanisms of AI technologies.

Aside from the four approaches outlined in the UNESCO's report, other teaching methods often mentioned in the AI education literature include: interactive learning, where the students complete tasks and gain hands-on experience by engaging with robots or platform tools (Yue et al., 2022); game-based learning, which uses games or competitions to make learning enjoyable and engaging (Lee & Kwon, 2024; Su et al., 2024); and design-based learning or design-oriented learning, where students learn AI applications and problem-solving by designing and developing their own AI projects (Li, 2022).

Additionally, further possibilities of pedagogical approaches to AI education have been extensively explored. Xia et al. (2022) integrate self-determination theory (SDT) into AI instruction to enhance learning outcomes. SDT, a motivation theory, emphasizes the impact of three basic psychological needs on the individual's motivation and behavior: autonomy (freedom and control in decision-making), competence (capability and self-efficacy perceived in task completion), and relatedness (emotional connections with others elicited in the learning process) (Ryan & Deci,

2020). Drawing on this theory, Xia et al. (2022) argue that the teacher can increase students' autonomy by allowing them the choice of topics and tools for AI projects and encouraging independent design of solutions, boost their senses of competence by helping them build AI knowledge and skills with clear objectives and step-by-step guidance, and heighten interaction and relatedness in students through group work and regular teacher-student meetings. Another example is Eguchi et al.'s (2021) trial to apply "culturally responsive approaches" to AI education for Japanese students. The culturally responsive approach is student-centered with a heavy emphasis on tailoring curriculum content and implementation strategies to the cultural backgrounds of the learners (Gay, 2002). It prioritizes the use of cultural elements familiar to the students to assist with their understanding and application of new knowledge (Papert, 1993). Eguchi et al.'s (2021) AI curriculum program is an adaptation of Blakeley H. Payne's "AI Ethics Curriculum for Middle School Students" based on the Japanese context, using Japan's AI tools and devices (e.g., Sharp's smart microwaves and SoftBank's Pepper robot) as replacements. The research findings reveal that the culturally responsive approach is highly effective in increasing the applicability of the curriculum as well as student engagement.

Teaching Tools

AI education is a highly practical subject while also involving many abstract concepts that challenge the cognitive capacity of primary and secondary school students. Hence, using intelligent tools is essential for the enactment of AI instructional activities. Based on their purposes, these tools can be classified into the following categories:

- *Tools facilitating programming in novice learners.* For example, visual programming languages (such as Scratch and MIT App Inventor) provide AI-related extension modules (e.g., speech recognition and image recognition) to help beginners get started quickly. Scratch's AI extensions allow students to create simple AI programs by dragging and dropping code blocks. No-code tools can go even further, enabling users to configure and train AI models without programming (Steinbauer et al., 2021). Illustrative is Google's Teachable Machine, a web-based tool that enables users to train basic machine learning models by simply uploading data and visualizing the training results.
- *Tools for visualizing conceptual demonstration to support student intuitive understanding of fundamental AI concepts and theories.* For example, TensorFlow Neural Network Playground, an interactive tool, can help the students adjust neural network parameters and observe outcomes through a visual interface,

assisting with their comprehension of how neural networks work (Druga et al., 2022). Another example is the Reinforcement Learning VR framework, a virtual reality-based tool for teaching reinforcement learning concepts through maze navigation or treasure-hunting games.

- *Tools providing opportunities for practical manipulation and project-based work in AI learning.* For instance, Cognimates provides a platform where the children build interactive games through training models; Machine Learning for Kids offers interactive tutorials and projects, allowing the students to understand basic machine learning concepts through hands-on practice.
- *Tools supporting online collaborative learning.* For example, Wekinator provides a platform where the students can collaborate to train and test machine learning models in groups. The students can also use online document tools to plan their project, organize, and share learning materials.

Discussions

In summary, the objectives and content of current basic AI curricula underscore the education of both AI knowledge and techniques and AI ethics and societal implications. Yet, when it comes to the specific AI subjects the students need to learn, prior studies tend to prioritize specialist AI knowledge, such as algorithmic principles, data processing, and data analysis, aimed at training developers of AI technologies, with less attention paid to the education on practical and legitimate AI use. The truth is that it necessitates solid expertise in advanced mathematics and programming to become a professional AI developer, which is beyond the competence of most students. Moreover, not every student is interested in AI technology or computer science. The majority of them need only to become successful AI users who can leverage AI to assist learning, harness the benefits of AI in day-to-day lives, select the most appropriate tools from multifarious AI applications, and become honest AI users with the awareness of the detriments of AI misuse, such as cheating on homework or exams. Additionally, due to the possibility of AI “hallucinations,” it is important to teach the students to evaluate the accuracy of AI-generated content. Essential skills like these, however, are rarely discussed in the AI education literature. This oversight may result from the overemphasis of AI talent cultivation as part of the national AI development strategy. Nevertheless, cultivating high-end AI talent is primarily the responsibility of higher education. Primary and secondary AI education should prioritize fostering students’ basic understanding of AI and their capacity to use it in a legitimate manner,

facilitating their adaptation to the AI era. Research in this area remains insufficient.

Furthermore, the content of some AI courses overlaps with that of those more established subjects such as programming, robotics, and STEM education. This overlapping may cause some of the teachers to misuse relevant concepts in delivering AI instruction (Zhong & Liu, 2022), compromising the implementation outcomes of AI curricula with prescribed objectives. More studies are needed to clarify concepts from different fields.

Also, competent AI teaching staffs are crucial for successful AI education. Many studies have discussed issues like the AI teacher shortages and inadequate qualifications of AI educators and the significance of strengthening AI teacher training. Yet, few of them delve into the specifics of current teacher training programs and their criteria for AI teachers' competence. Insufficient research on AI teacher training may result in a dearth of practical support needed by the AI educators, weakening the results of AI curricula at the basic education level.

It is noteworthy that advanced educational resources and supportive environments are the prerequisites of successful implementation of AI education, which poses additional requirements for the schools. Due to unbalanced economic development, there are disparities in access to and utilization of AI-related education resources between schools. More privileged schools can equip themselves with advanced hardware and professional software tools, providing a top-notch AI learning environment to the students. On the other hand, those in underserved regions may face shortages of AI education facilities and teaching materials. This imbalance in resource accessibility can exacerbate educational inequity. The research community and educational authorities need to pay more attention to this issue.

Conclusion

The study reviews the literature on primary and secondary AI education from the standpoints of “what to teach” and “how to teach.” In the dimension of “what to teach,” AI education in different countries may vary in objectives but places comparable emphasis on AI literacy development in the students; current curriculum content primarily focuses on four areas: basic AI knowledge, AI techniques, AI application and practice, and ethics and social impact of AI. In the dimension of “how to teach,” diverse pedagogical approaches have been discussed, such as direct instruction, group work, project-based learning, and activity-based learning, and the value of AI teaching tools analyzed.

Despite being a relatively comprehensive review of the current state and practices of AI education at the basic education level, the study is not

without limitations. Its research results may not be able to adequately mirror the issues with current AI education due to its adoption of literature review rather than empirical investigation as its research method. In addition, the study excludes the evaluation and assessment of AI education, which is also crucial to its implementation. This will be addressed in future research.

Based on the results of the review, we make the following suggestions: (i) Differentiate AI training objectives, aligning them with the various developmental levels in the students; (ii) strengthen education on the legitimate use of AI, aside from the delivery of AI technology-related knowledge and skills; (iii) encourage interdisciplinary learning in AI education, integrating AI with other subjects like mathematics and science education; (iv) diversify teaching approaches to serve varied needs of different students; (v) provide professional training with explicit objectives and up-to-date content for the AI teaching staff to increase their expertise in AI education.

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Received: December 27, 2025

Revised: February 05, 2025

Accepted: April 16, 2025