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# International Report of Supportive Environment on Artificial Intelligence Courses in K-12

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# International Report of Supportive Environment on Artificial Intelligence Courses in K-12

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# Preface

With the development of big data, computing power, and machine learning algorithms, the application of AI technology is becoming more and more common in various industries and people's daily life. The integration of AI and education is becoming closer and closer. How to use AI technology to improve education quality and teaching efficiency, and how to cultivate professionals who master AI technology have become the focus of global attention. In 2019, the president of the People's Republic of China Xi Jinping to International Artificial Intelligence and Education Conference pointed out that grasp the global AI development situation, find the breakthrough and main direction, cultivate a large number of innovation ability and cooperation spirit of AI high-end talents, is the important mission of education. As an important result of the meeting, more than 100 member countries and UN institutions, AI, civil society and the private sector of about 500 representatives jointly published the BEIJING CONSENSUS — AI and education (Beijing consensus), The consensus is committed to implementing appropriate policy strategies through AI and education system, comprehensive innovation education, teaching, and learning methods. In addition, the consensus is to use AI to speed up the construction of an open and flexible education system to ensure that people enjoy fair, suitable for everyone, and high-quality lifelong learning opportunities. This will thus promote the realization of the Sustainable Development Goals and a community with a shared future for mankind. At the opening ceremony of the AI and Education International Forum, Chinese Education Minister Huai Jinpeng stressed the importance of AI in education, and mentioned that "AI will give education power, change education and innovate education, which will undoubtedly create a better future for everyone else."

To promote youth AI education and analysis of the supportive environment, the National Engineering Research Center for Cyberlearning and Intelligent Technology joined the Smart Learning Insitute of Beijing Normal University in carrying out the ***International Report of Supportive Environment on Artificial Intelligence Courses in K-12***. This report aims to, through all kinds of data collection, summary, analysis, and comparison, for academia, education, and industry to provide a comprehensive understanding of the supportive environment for AI courses in K-12. The report also discusses the key elements that affect K-12 learning in AI courses. For instance, it includes teaching techniques for K-12 students, such as assigning independent learning, analyzing possible trends for the future AI development of youth education, and providing sufficient teaching resources for teachers, scholars, or other personnel.

This report contains six chapters, briefly described as follows:

The first chapter is an overview based on clarifying the concept of AI and reviewing the development situation of AI in education. This chapter expounds on the two relationships between AI and education: AI as an auxiliary education tool and AI as learning content. The Beijing Consensus summarizes the impact of AI on education development and puts forward five critical elements of the supportive environment for AI courses in K-12.

The second to fifth chapters introduce the elements of the supportive environment in K-12 AI courses. The second chapter introduces open educational resources, the teacher's development online community, analyzes the benefits of using open education resources, introduces some AI learning platforms and online communities for educators. The third chapter summarizes the current situation of K-12 AI textbooks, presents the selection of AI textbooks for different ages, and introduces some AI teaching practices. The fourth chapter discusses the challenges and prospects of the K-12 AI algorithm. It also summarizes the datasets that may be involved in algorithm teaching. The fifth chapter presents the classification and characteristics of AI teaching laboratories and lists some examples.

Finally, chapter 6 is the conclusion and recommendation of the report, which summarizes the overall situation of the supportive environment of AI education.

Due to the vital influence of AI technology, countries invest a lot of resources in auxiliary and AI education. The application of AI in education and its education resources will be more and more. The case listed in the white paper is only part of the case collected so far and can lay a foundation for readers to understand the basic situation in the field. I believe this field will continue to grow and have a better future development.

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# International Report of Supportive Environment on Artificial Intelligence Courses in K-12

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# 1. An Overview of Artificial Intelligence and Education

Artificial intelligence (AI) is changing every aspect of our lives. Under the influence of AI, transportation, healthcare, logistics, finance, and industrial manufacturing, will develop more productive and cost advantages and, more importantly, provide better services, where education will be one of the most affected areas[1]. The use of AI in According to a Global Market Insight report, AI use in education is expected to explode to $6 billion in the next six years. It turns out that education systems and institutions need a lot of reform, and AI will take a significant role in the developing process.

## 1.1 Definition and classification of artificial intelligence

Artificial Intelligent (abbreviated as AI) is a generic term for a machine or computer program capable of performing tasks or activities (such as planning, problem-solving, identifying patterns, and logical actions) that require features of human intelligence[2]. While the term was first coined in the 1950s, AI has exploded, driven by the Internet, big data and cloud storage, and more powerful computing and algorithms. In the field of AI research, the application scope of AI is divided into three stages[3]: Artificial Narrow Intelligence (ANI), Artificial General Intelligence (AGI), and Artificial Super Intelligence (ASI). Artificial Narrow Intelligence can only complete specific tasks, not compound tasks. Artificial General Intelligence refers to the AI that can perform all human work. Artificial Super intelligence is a high degree of AI autonomy, far more than human beings.

## 1.2 The current development of global artificial intelligence in education

At present, the governments of most of the world's developed economies have determined the potential of AI as a competitive element of its future labor force and economy, all promoting the popularization of relevant education in different ways. In 2017, Information Technology Curriculum Standard for Chinese Ordinary HighSchools was released, and AI became included in the curriculum system of Chinese high school students. In May 2019, Xi Jinping, the president of the People's Republic of China, sent a congratulatory letter to the International Conference on Artificial Intelligence and Education. He pointed out that it is an important mission of education to grasp the global development trend of AI, identify the right breakthrough and main direction, and cultivate a large number of high-end AI talents with the innovative ability and cooperative spirit. In December 2021, Huai Jinpeng, Chinese Minister of Education, proposed to fully integrate AI education into education at all levels and of all types to improve students' digital skills and digital literacy. In April 2022, Information Technology Curriculum Standards for Chinese Compulsory Education were released, and AI added to the learning content of grades 7-9 of Compulsory education in China. In May 2018, the American Association for Association for the Advancement of Artificial Intelligence (AAAI) and the Association of Computer Science Teachers (Computer Science Teachers Association, CSTA) jointly formed a working group to launch the US K-12 AI Education Action[4]. Since 2016, Japan has been exploring and developing AI and programming education, proposing to help all children build the "AI thinking" needed in this era. In 2014, the Ministry of Education launched a new computer syllabus that teaches children to write simple computer programs, store and retrieve data from the age of 5, learn computer programming languages and solve computer failures from the ages of 11 to 14. Countries, including the United States, Japan, and the UK, are now beginning to explore and practice the combination of AI with K-12 education.In February 2022, UNESCO released the "K-12 Artificial Intelligence Curriculum. Officially Endorsed AI Curriculum Design Guide," which describes the scope and length of the nine categories of AI courses covered by existing K-12 AI curricula, as well as the expected learning outcomes for each category, summarizes the prerequisites needed to implement the curriculum, including teacher training, learning tools, and environments, and provides pedagogical recommendations[5].

The combination of AI and K-12 education is the trend of the Time, but how to do it is a huge challenge for educators and policy-makers who have to make today's students thrive in a very uncertain tomorrow.

## 1.3 AI as a tool and learning content

In the field of education, there are two relationships between AI and education[6]. One is the integration of AI and education, namely Artificial Intelligence in Education (AIED). The second is to cultivate AI talents that take AI as educational content.

AIED has two research objectives: one is to make a comprehensive and in-depth application of AI technology in education to promote education reform and development. The other is to use AI technology more systematic and micro, and reveal the principles and mechanisms of learning, to create conditions for learners to master certain knowledge[7] effectively. With the research and exploration of AIED, the application of AI in education is also becoming more abundant, and the main application types are shown in Table 1.

**TABLE 1: TYPES OF AI APPLICATIONS IN EDUCATION [8]**

| APPLICATION TYPE | SPECIFIC SCENARIOS, APPLICATION TECHNOLOGY |
|---|---|
| Intelligent and adaptive learning | Virtual teachers created by integrating intelligent adaptive learning technology can penetrate the whole teaching process and support personalized teaching. Each student can learn at their own pace, increasing learning efficacy and motivation. |
| Man-machine interaction | Smart Energy processing and search technology |
| Dual-teacher class | Image recognition |
| Speech evaluation | Intelligent language processing and speech recognition |
| Intelligent language processing applications | Based on language processing, some syntax framework can be established |
| Photo-based question search | Computer vision and image recognition |

As a field that all developed economies attach great importance to, AI has gotten the attention on the implementation of AI education in primary education to cultivate people those who have innovative talents in an intelligent society. The basic education stage in learning the content of AI is to let students understand the development and concept of AI and learn the implementation of typical AI algorithms. This learning process includes building a simple AI application module, experience design, and realizing the basic process and method of a simple intelligent system, enhancing intelligent technology service for developing human responsibility[9].

## 1.4 The impact of artificial intelligence on education development

In May 2019, "The Beijing Consensus on Artificial Intelligence and Education[10]" was released by UNESCO, leading the 2030 education agenda Sustainable Development Goals 4, committed to implementing appropriate policy strategies through AI and education system. This includes comprehensive innovation education, teaching and learning methods, and the use of AI to speed up the construction of open and flexible education systems. The ultimate goal is to ensure fair and suitable lifelong learning opportunities for everyone and to develop goals that can be shared with future humankind.

This report and the guidelines proposed by UNESCO have a wider audience and are closer to front-line teachers. AI has several effects on education, which are mentioned in the Beijing Consensus. This report extends a more detailed content according to the Beijing Consensus. Here are several effects of AI on education as shown in Table 2.

**TABLE 2: THE IMPACT OF ARTIFICIAL INTELLIGENCE ON EDUCATIONAL DEVELOPMENT**

| INFLUENCE | ACTION CONTENT |
|---|---|
| Improve education management and education governance capacity | Be cognizant of the breakthrough in the use of data in transforming evidence-based policy planning processes. Consider integrating or developing AI technologies and tools that are relevant for upgrading education management information systems (EMIS) in order to enhance data collection and processing, making education management and provision more equitable, inclusive, open and personalized.<br>— From Article 10 of the Beijing Consensus |
| Help teachers to empower teaching | Be mindful that while AI provides opportunities to support teachers in their educational and pedagogical responsibilities, human interaction and collaboration between teachers and learners must remain at the core of education. Be aware that teachers cannot be displaced by machines, and ensure that their rights and working conditions are protected.<br>— From Article 12 of the Beijing Consensus |
| Support the development of a lifelong learning system for all | Reaffirm that the guiding principle for achieving SDG 4 is lifelong learning, which encompasses formal, non-formal, and informal learning. Adopt AI platforms and data-based learning analytics as key technologies in building integrated lifelong learning systems to enable personalized learning anytime, anywhere, and potentially for anyone, with respect for learners' agency. Exploit the potential of AI to enable flexible learning pathways and the accumulation, recognition, certification, and transfer of individual learning outcomes.<br>— From Article 20 of the Beijing Consensus |
| | Be mindful of the need to give appropriate policy attention to the needs of older people, especially older women, and to engage them in developing the values and skills needed for living with AI in order to break the barriers to digital life. Plan and implement well-funded programs to equip older workers with skills and options that enable them to remain economically active for as long as they choose and to engage in their societies.<br>— From Article 21 of the Beijing Consensus |
| Realize personalized learning services | Consider also introducing new models for delivering education and training in different learning institutions and settings that can be enabled by the use of AI, in order to serve different actors such as students, teaching staff, parents, and communities.<br>— From Article 11 of the Beijing Consensus |
| Help to improve skills to precisely match employment needs | Be mindful of the systemic and long-term transformation of the labor market, including its gender dynamics, due to AI adoption. Update and develop mechanisms and tools to anticipate and identify current and future skill needs in relation to AI development, in order to ensure the relevance of curricula to changing economies, labor markets, and societies. Integrate AI-related skills into the school curricula and qualifications of technical and vocational education and training (TVET) and higher education, taking into consideration the ethical aspects and interrelated humanistic disciplines<br>— From Article 17 of the Beijing Consensus |

## 1.5 Key factors in the implementation of AI education

AI used in K-12 education can be divided into two parts. One is to use AI technology, such as intelligent perception, intelligent education evaluation, intelligent recommendation of digital education resources, and realize personalized learning, that is, the application of AI technology in various education scenarios[11]. The other is to carry out AI education, namely primary and middle school students accept artificial intelligence-related content learning, AI theory, computing thinking, programming, and other related knowledge and skills[12].

The former AI technology can be seen as a help to K-12 education, and the second is to specifically describe learning about AI technology. Therefore, based on these two relationships, the five key elements of the primary and secondary school courses are extended, which are the necessary factors to develop K-12 AI education. As shown in Figure 1:

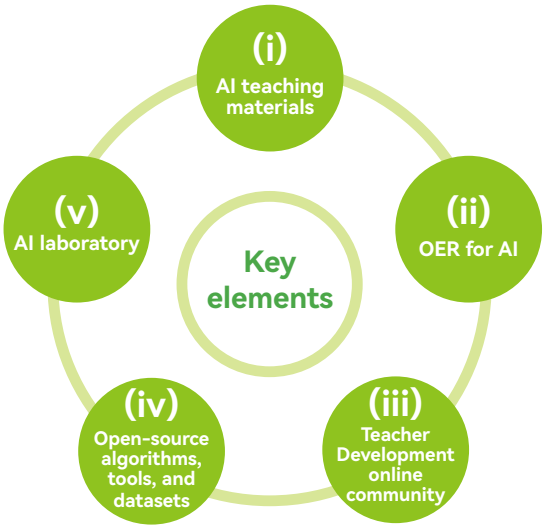


Figure 1: Key elements of AI teaching

**(i)** AI teaching materials: it refers to the textbook used for AI teaching. It is compiled according to the curriculum standards and systematically reflects the content of the subject. The textbook is the embodiment of the curriculum standards, which is different from the general books, usually divided by school year or semester, divided into units or chapters[13].

**(ii)** OER for AI: refers to all kinds of open educational resources enhanced by AI technology, using open authorized teaching materials, usually digital materials, which can be used for teaching, learning, and research[14].

**(iii)** Teacher Development Online Community: It is the online community for teacher to learn for his job. A series of activities enable teachers to reflect on practice with colleagues, share expertise in a distributed knowledge framework, and establish a common understanding of new teaching methods, standards, and curriculum[15].

**(iv)** Open-source algorithms, tools, and datasets: Algorithms are a series of clear instructions to solve problems, and algorithms represent the systematic method to describe the problem-solving policy mechanism[16]. Tools refer to AI development tools, such as TensorFlow, flying paddle (Paddle Paddle), and other AI open-source framework. Datasets refer to the sample data used for the training of the AI algorithm, such as MNIST for character recognition, ImageNet for image recognition processing, etc.

**(v)** AI Laboratory: Laboratory for K-12 learning of AI content, including equipment for personal workstations and other equipment for instructional laboratories[17].

Among them, element one and element two are necessary for the learning content in the relationship between artificial intelligence and education, while elements three, four and five cover the necessary elements of teaching tools. The subsequent sections of this report will outline the global development status and issues of these five key elements.

# 2. Open Educational Resources and Teacher Development Online Community

This chapter provides an overview of the Global K-12 AI Open Education Resource (Open educational resources, abbreviated as OER) and the Teacher Development Online Community. The OER is any type of educational material in the public domain[18]. More and more schools around the world begin to support the digital education model. Although the use of open educational resources cannot allow learners to get degrees, it is of great help to open education and distance teaching, and also helps to make the distribution of educational resources more evenly, indirectly making up for the gap in educational resources between countries[19]. At present, the teachers development online community has become an essential platform for teachers' professional development worldwide. AI professional education community began to appear in the international world; it enables teachers to collaborate in learning, share experiences, and help solve problems. More importantly, the community helps to cultivate internationally competitive and talented teachers and provides more means to increase youth information literacy.

## 2.1 Introduction of open educational resources

The term OER were initially proposed at a conference hosted by UNESCO in 2000 and were promoted in the context of providing free access to educational resources worldwide. OER use publicly authorized textbooks, usually digital materials, which can be used for teaching, learning, and research[20]. They are released as open licenses (i. e., knowledge sharing), describing how to use, reuse, adapt, share, and modify the material for specific needs. Those contents include textbooks, lecture notes, syllabuses, assignments, and exams.

OER are a critical forefront of expanding access to quality education, reducing the chance of getting overly complicated teaching materials, and encouraging teachers, students, and educational institutions to participate in creation and collaboration actively. Educational institutions and organizations, including some of the world's most prestigious universities and colleges, are working to create and disseminate this resource to support academics and students. MIT Open Course Ware has played a considerable role in promoting the development of global open educational resources. With over 2,500 online publications on MIT course materials, the site freely shares knowledge with learners and educators around the world, including information technology types of courses and lectures.

The British Open University also significantly impacts the construction of open education resources in the field of distance education, which can support more than 170,000 students. British Open universities break the constraints of time, space, teaching environment, and economic conditions through distance education and open educational resources to promote teaching equity.

OER Initiative provides open learning opportunities for high-quality education resources worldwide. From an institutional base of large or institutional-supported initiatives to many small activities, the number of programs, and programs related to OER has increased rapidly over the past few years.


Figure 2: The Typical OER Project

## 2.2 Open educational resources for AI learning

There are few platforms suitable for K-12 to learn AI. The examples collected in this report are all open, content-rich, and interesting. More importantly, K-12 can fully understand the technology of AI and learn such AI thinking. As Dale Lane on the Machine Learning for kids platform once said in a speech: It's good to introduce machine learning to teenagers now, not just to people like developers or technicians. Some of them may continue to be the inventors of the next generation of technology. They will invent the next machine learning system that can solve larger problems that we can't approach today. We need them to keep the technology forward, maybe introduce machine learning to them today to play, experience, understand, maybe it will inspire their imagination and start a lifetime of invention and creation.

Here are a few examples listed as follows.

**TABLE 3: K-12 PLATFORM FOR LEARNING AI**

| NAME | ACTION CONTENT | URL |
|---|---|---|
| **Machine Learning for kids** | It is a free online learning platform for teenagers to train computers on how to accomplish the tasks given. It guides them step by step to create machine learning models, and the types that can be identified are text, numbers, images, and sound. The user first collects the examples you want to identify, then trains the computer to identify them, and finally makes a game or app that enables the computer to recognize them. | https://machinelearningforkids.co.uk/ |
| **Code.org** | Aimed to enable every child in the world to receive computer science education. The group targets the K-12 age group and customized free courses with content such as AI, which can be used to allow children aged 4-6 and 8-12 to start learning. Each course includes video tutorials and fun hands-on exercises to help children apply what they learn while maintaining their interest in learning. | https://code.org/ |
| **Khan Academy** | The computer programming program at Khan College is completely free, which leads children and students to learn computer-based, artificial intelligence-related courses. | https://www.khanacademy.org/ |
| **Elements of AI** | The program has spread the world with graduates from more over 170 countries. Over 750,000 students were enrolled in the AI Elements course. About 40% of course participants were female, more than twice the average computer science course. The site's curriculum is divided into two categories, a simple introduction to AI and building AI applications. | https://course.elementsofai.com/ |

## 2.3 Benefits of using open educational resources

Ensuring the equality and availability of education is the fundamental value of the open education movement, and addressing these issues becomes increasingly important as we move to the future[21]. Open education addresses many issues that complicate education, including:

- **Outdated textbooks:** Traditional educational materials, such as textbooks, can only be as timely as their publication date. Unfortunately, the latest knowledge, especially in the AI technology area, will soon be obsolete. In the modern world, students and teachers who use outdated materials are in very disadvantaged positions. On the other hand, OER can be constantly updated, adjusted and improved, so that they are never obsolete.

- **Cost:** Setting up AI workstations and learning materials often have high prices, raising a painful problem for many students: having no materials or being heavily in debt to get them. Cost of education is a significant social problem. The goal of open education is to make high-quality, free online material, which is a direct answer to the question of cost.

- **Access and Equality:** Cost, geographical and structural inequalities in society often lead to educational opportunities and equity. Through open education, high-quality materials are available at minimum (or no) costs, and with minimal access barriers, providing a level playing field for students to prepare for future life.

## 2.4 Teacher Development Online Community

The professional development of teachers is seen as standard-guided and rooted in teacher work. It focuses on students' learning, and is suitable for the lifelong and situational form of teachers' career development, the purpose is to develop, implement and share theknowledge between teachers, practice, and measure the online and offline activities of all students[22].

**TABLE 4: THE TEACHER ONLINE DEVELOPMENT WEBSITE**

| NAME | INTRODUCE | URL |
|---|---|---|
| **Youth Artificial Intelligence Innovation Initiatives (Yuanzhuo Plan)** | The aim is to explore the linkage mechanism between the government, universities, and enterprises, integrate various forces and resources of the society, stimulate the interest of teenagers in using original AI algorithms to solve real and complex problems, serve the country, guide teachers, and cultivate students through public welfare. | https://yuanzhuo.bnu.edu.cn/ |
| **ISTE** | The website supports and improves K-12 education and teaching, science and technology, and management. It also provides a free and practical guide for students to participate in AI creation for free. ISTE and GM's Classroom Practice AI Program Guide provide computer science teachers with innovative curriculum resources regarding AI in different grades and subject areas. | https://www.iste.org/areas-of-focus/AI-in-education |
| **KQED Teach** | Offers a range of free-practice professional learning opportunities focused on digital media. Educators can develop skills in digital narrative, data visualization, and key media use to support all curriculum areas, especially AI-related courses. These skills enable teachers to facilitate a learning environment, where students can create digital content, develop their communication and technical skills, and participate in encouraging deeper learning of critical thinking. There are analysis and evaluation classes, teacher video production, podcasts, and audio production for teachers to learn. | https://teach.kqed.org/ |
| **AI for Teachers** | It is a website dedicated to supporting the integration of AI knowledge throughout K-12 learning, providing educators with quality planning resources to address the challenges of integrating AI into existing courses. | https://aiforteachers.org/ |

# 3. K-12 AI Textbook and Teaching Methodology

This chapter explores the educational materials and teaching methodologies used in K-12, presenting a number of countries around the world on AI educational materials and extracurricular books, categorizing them by age group. Adolescents are the new generation living in an intelligent environment, their lives are closely related to AI, and children are eager to learn about AI. Therefore, it is important to popularize computational thinking and AI thinking methods among teenagers, and to cultivate their strong interest in AI research and problem solving using AI, in the hope that they will be able to innovate technology in the future[23].

## 3.1 Current status of K-12 AI textbooks

A comprehensive survey on various kinds of complicated books on AI at home and abroad has found that with the popularization of AI, several AI books suitable for teenagers have appeared. However, there are so few countries that add AI courses to the basic education system as independent courses, there are so few AI textbooks applied to classroom teaching.

In terms of content, kindergarten and primary school textbooks focus on practical life, and experience abstract concepts through cases to help students perceive AI; junior high school AI textbooks focus on programming teaching, programming as a link, experience, develop and understanding AI; high school textbooks go deep into programming and robot education, reflecting the idea of multidisciplinary integration[24]. At the level of teaching methods, each textbook emphasizes experience perception and the integration between disciplines.

Because AI is a subject with strong manual practice, AI learning needs the corresponding practice environment. This has led to some textbooks relying on specific hardware and software platforms, and their universality needs to be improved. In addition, most of the AI textbooks are relatively difficult, and they lack of pilot data and effect evaluation.

## 3.2 K-12 textbook selection

AI children's books, including fun books, novels, activity manuals, and useful tutorials, guides, all help children prepare for their future life and develop their interest in AI technology[25]. This report believes that the AI reader suitable for K-12 students has five-article standards:

i. Cultivate children with good morality
ii. Inspire AI thinking and creativity
iii. Adapt to the children's age, development, and understanding
iv. Provide useful information under the current trends
v. Suitable for repeated reading

Figure 3: Selection Principles of AI Textbook

The following are the results obtained after the research group screened the globally retrieved teaching books according to the above selection principles, as shown in Table 5.

**TABLE 5: K-12 TEXTBOOK SELECTION**

| TYPE | AGE GROUP | CHARACTERISTICS | NAME | AUTHOR | PUBLISHER | CONTENT INTRODUCTION |
|---|---|---|---|---|---|---|
| **Popularize cognition** | Early children, primary school students age group | Concrete abstract concepts through cases, and help children perceive and understand AI. | AI+ME | ReadyAI | ReadyAI Independent Publishing (July 22,2020) | The picture book for K-2 students respectively introduces the five concepts of AI perception, representation and reasoning, machine learning, the interaction between people and AI, and social impact. The book is suitable for being a popular science book for children's AI knowledge. |
| | Junior high school stage | Special attention is paid to the cultivation of AI thinking, to experience, develop and understand AI. | Artificial Intelligence: 101 Things you have to know today about the future | Lasse Rouhiainen | CreateSpace Independent Publishing Platform (January 29,2018) | It covers many interesting and time-effective topics related to AI, including self-driving cars, robots, chatbots, and how AI affects the job market, corporate business processes, and content across the industry. Suitable for serving as a junior high school popular science books. |
| | Senior school education | The concept of AI has been thoroughly understood, and it focuses more on how to achieve the actual goals. | Artificial Intelligence (High School Edition) | Tsinghua University | Tsinghua University Press (September 2020) | In the book, the eight core basic modules of AI are fully sorted out, which can be used as high school AI curriculum textbooks, or as popular science books. The book is also equipped with exclusive website resources, providing programming help and advanced content to help people interested in AI learn further. |
| **Thinking training** | Early children, primary school stage | It is mainly the popularization of five concepts of AI, so that young children can also understand the concept of AI. | How To Train Your Robot | Ken Goldberg et al | (Supported by the NSF and the UC Berkeley Lawrence Science Institute). Free to download (November 2019) | The book is a children's book for K-8, written by Bluma Goldberg in 2019, and is available for free download from online. The book introduces readers to cutting-edge robotics and AI in a highly accessible way and mimics real engineering practices such as repeated design, testing, and pass failure learning. |
| | Junior high school stage | Let students understand the characteristics and scope of AI technology, the design process that engineers develop new devices, and how technology affects humans and society | Artificial Intelligence (Junior Edition) | Fan Lei et al | Tsinghua University Press (August 2020) | The book gives a preliminary explanation of AI from the development and application of AI, data, algorithm, supervision and learning and other aspects. Junior high school students can understand the knowledge and technologies related to AI and stimulate their interest in AI. The book is suitable for junior high school students, and can be used as an AI entry textbook for junior high school students. |

**CONTINUED FROM TABLE 5: K-12 TEXTBOOK SELECTION**

| TYPE | AGE GROUP | CHARACTERISTICS | NAME | AUTHOR | PUBLISHER | CONTENT INTRODUCTION |
|---|---|---|---|---|---|---|
| **Thinking training** | Senior school education | Emphasize the cultivation of ability and thinking, and understand, apply and innovate AI in a practical way. | What to Think About Machines That Think | John Brockman | Harper Perennial Press (October 2015) | Nearly 200 short papers, written by renowned scientists, philosophers, and futurists, explore the question of human and machine intelligence and consciousness. The book is written for educated non-computer professionals, and a wide variety of views may cause high school students to think about other issues on AI, so it is suitable for high school students and above. |
| **Technical ability learning** | elementary school stage | Through simple practical cases, the abstract concept is clearly described, and then draw inferences from one example, to practice the knowledge just learned. | AI future intelligent maker: artificial intelligence boutique course series in primary and secondary schools | Wang Jiqing et al | East China Normal University Press (October 2018) | This set of books allows students to perceive, recognize and apply the connotation and extension of AI, thus becoming interested in AI technology. Each book is aimed at a special topic, and each special topic contains 16-18 theme content and 2-4 activity courses. The knowledge of AI advances layer by layer, and students can form a systematic knowledge framework of AI. |
| | Junior high school stage | Pay attention to the cultivation of AI technology and engineering thinking, junior high school, the final thing is the cultivation of thinking. | How Smart Machines Think | Sean Gerrish | MIT Press (October 2018) | Offering a fresh and modern vision of AI, machine learning, and deep learning about Jeopardy video game shows, Netflix, Starcraft, board games (e. g., Go, chess, Sudoku), and self-driving cars. Great entry for engineers interested in putting the AI in context. |
| | Senior school education | In the critical period of cultivating AI technology ability, the high school textbooks are in-depth programming and robot education, which reflects the thought of multidisciplinary integration. | Fundamentals of Artificial Intelligence | Dr.Nisha Talagala et al | AIClub | The book covers the basics of AI, and its mathematical and coding levels match the capabilities of middle and high school. Each chapter is equipped with exercises to help improve students' practical operation ability. |

## 3.3 Teaching practice of artificial intelligence

> **Support school-wide pilot tests on the use of AI to facilitate innovation in teaching and learning, drawing lessons from successful cases and scaling up evidence-based practices.**
>
> **—From Article 15 of the Beijing Consensus**

In the future, the deep integration of AI and education will force teachers to face and deal with enormous challenges. The role of the teacher will also undergo a significant transformation teaching knowledge to guiding the overall development of students' moral, intellectual and physical development, and acting as a mentor and counselor[26]. Teachers under AI should also become the realizer of personalized education. Teachers should learn to use the student learning data provided by AI and analyze it accordingly to accurately obtain personalized data of students in the learning process and implement personalized teaching and targeted teaching. Teachers' information technology capabilities should also be accelerated, and through the construction of smart education systems and teaching platforms, teachers should realize accurate teaching, screen high-quality teaching resources and teaching materials and upload them to the platform to provide optional teaching content and information for students.

The following are specific examples of the AI teaching practice:

### (i) Project-based Learning

Project-based learning (PBL) is a teaching methodology that reintegrates interconnected knowledge points into several relatively independent teaching programs, and organically combines theory and practice to mobilize learners with the help of teaching programs[27]. Project teaching comes from Dewey Do middle school (learn by doing) and Cooper's experiential learning theory (experimental learning), etc,. The core idea is group cooperation to build physical orientation through real problems in the real world to capture students' interest, guide students to analyze problems, find resources to design clear solutions in the process to stimulate students' deep thinking and learning, realize the understanding and internalization of knowledge. This methodology has changed the traditional teacher-centered education concept of teaching, emphasizing student-centered learning, and truly makes students become active builders of knowledge. The project points to students' high-order thinking ability, which mainly solves the problem of bad structure, so that students can perceive and understand knowledge in the process of project practice, and realize the improvement of problem analysis, logical reasoning, collaborative communication and other abilities.

**Case: Artificial intelligence robot Cozmo programming thinking and interactive application[28]**

**Introduction:** The project is an AI experience summer camp designed by the founder of the Cozmo Robot Programming Language.

Cozmo is an AI toy, the first smart toy robot to have visual, auditory, vocal, and programmable instructions and interaction with people. The program is based on CMU's Calypso (Ocean Fairy, a rule-based programming language).

**Target Students:** The high school students.

**Course content:** Programmable instructions and interactive experiments for intelligent toy Cozmo. Students learn the reasoning framework of different programs, predict the robot's behavior to the program, and writes calibration programing when the program has mistakes; by writing Calypso programming language, making the robot complete specific actions and events, simulating real situations.

**Teaching Procedure:** The course is about three weeks. Prior to the formal start of the course, training on basic knowledge, including basic knowledge of Calypso programming language, project design thinking, and project planning training is provided. In the first week, students independently design the robot project theme, implementation plan and conception; the second week is R & D and experiments, with practical programming training and simulation experiments around the project topics, independently designed by students. The theme of the third week is summary & refining. Based on the previous simulation experiment, summarize the project results, design the defense mode, and record the defense video.

### (ii) Problem-based learning

Problem-based learning (PBL) is a contextual-based, student-centered teaching methodology that anchors learning into complex and interesting problems, usually group cooperation[29]. PBL will ask students to solve real-life problems, learn the scientific knowledge behind the problem, and form problem-solving skills. The role of teachers is to provide ways to obtain learning resources and appropriate guidance on learning methods. Unlike the traditional classrooms where teachers use a problem to lead students to the lesson topic and discard it right after or after completing the lesson and use problems to test students, in PBL, all learning activities build upon the initial problem. The
acquisition of personal knowledge is implicit in the process of problem-solving. Subject knowledge is the assistant serving problem-solving. Therefore, as the starting point of learning, the problem is whether problem-based learning can be effectively implemented.

**Case: Qingdao Artificial Intelligence Class[30]**

**Introduction:** The course is an open AI class in Laoshan District, Qingdao, China, in 2020. The speaker is Guo Chunlei, an information technology teacher from Laoshan District No.2 Experimental Primary School in Qingdao.

**Target Students:** grade 4 students.

**Course content:** Basic principles of AI machine recognition — facial recognition.

**Teaching Procedure:** "Students, can you help me quickly find all the photos of Liu Yankai from these images within 1 minute?" This is the question the lecturer asked to the students in the beginning.

The whole classroom is divided into three main parts. The first part of the class served as a guide, and the teacher assigned two small activities to the students. The first activity is finding a student's photos in the computer photo album, and the second is finding the target object in 12 images. The former is a task that a human cannot complete within a specified time; hence, it leads to the second part, explaining and discussing the knowledge of "face clustering" and "face recognition." The third part is experimental exploration. The teacher let students, according to specific steps in the SenseStudy AI experiment platform with Python programming experiment, experimental record data, through practical experience how is about three weeks. use face clustering, and after the end of the experiment, to search engines and logistics robots as an example, about real-life application of is about three weeks.. Different from the traditional introduction with problems into the class, they are discarded when their functions are completed, or after completing knowledge learning, teachers ask carefully designed questions to guide student discussion. In problem-based learning, all learning activities are developed around the initial problem. The acquisition of individual knowledge is implicit in the process of problem solving. Subject knowledge is the assistant serving problem-solving. Therefore, the problem, as the starting point of learning, is related to whether the problem-based learning can be effectively implemented.


Figure 4: Screenshot of the teaching process of the facial recognition course

### (iii) Experiential teaching

Experiential teaching is a teaching methodology that senses, understands, and verifies the teaching content through personal experience[31]. It contains several basic characteristics:

- Experience learning is a learning process.
- Experience learning is a continuous process based on experience.
- Experience learning is the process of conflict resolution in dialectical confrontation.

This teaching methodology is also in line with the constructivist concept of learning, that is, learning is the process of active construction of the subject. In experiential teaching, individual cognition, emotion, and behavior of learners can correspond to four stages of development: in cognitive aspects, individuals experience goal orientation, knowledge acceptance, knowledge internalization, and knowledge transference. In emotional aspects, individuals experience emotional expectation, emotional emotion, emotional resonance, and emotional sublimation. In behavior, individuals will experience preview perception, activity, introspection communication, and integration[32].

**Case: Zhorai[33] [34]**

**Introduction:** Zhorai is a session agent developed by a team at the Mit Media Lab to teach machine learning concepts to primary school children.

**Teaching object:** grade 3-5 students.

**Course content:** Students talk to AI dialogue agents on this platform to understand the natural interaction with machines, how machines learn, knowledge and reasoning of how machines represent information, and the social impact of such agents. Students teach agents about animals, and agents use prior knowledge to guess which ecosystem the animal cbelongs to. In the process, students learn machine perception and reasoning, as well as AI ethics.

### (iv) Individualized earning

Education, under the influence of AI technology, will surely change. Personalized learning is a broad term, and online learning field expert Mike Sharps defines "individualized learning" as a combination of learning that combines learners' needs, interests, and abilities[35]. Individualized learning has been the educational goal of the United States for the past 40 years, and strives to provide learning resources and activities designed to suit the needs and abilities of learners.

Nowadays, mobile technology and is about three weeks. technology can provide a physical and social environment for individualized learning, and the application of technology in education is technology-enhanced learning. With the rapid development of technology andthe continuous enrichment of information resources, learners can continue to learn and gain experience outside the classroom. Machine learning technology can be used to analyze the data generated by learners, provide teaching processes that match their learning

performance, and push different learning content according to different situations.

In individualized learning, adaptive systems are widely used. They can adapt to students' behavior and inferred knowledge through machine learning and deep learning technologies, intervene in learning at an appropriate time, and give effective tips and support. And the adaptive system was designed not to replace teachers but to improve teaching. Since the 1860s, most schools in the United States began using personal learning. Amazon in the United States has deep learning-based image recognition, mobile technology, and AI technology that can support students' individualized learning in face recognition and emotion analysis; intelligent voice and chatbots can answer difficult questions. Tencent in China also has several achievements in the field of AI. For instance, Tencent has now set up an AI lab; it also has a cloud's big data processing capabilities, which can perform intelligent grading, homework intelligent correction technology, voice recognition technology, and face recognition check-in. In China, schools should be better able to support personalized learning if they can work with companies and establish good partnerships.

### (v) Dual-Teacher class

The most primitive form of dual-teacher classroom is to organize excellent teachers to record teaching resource discs, distribute them to rural primary and secondary schools, and partially replace the teaching tasks of on-site teachers. With the improvements in science and technology, the current dual-teacher classroom refers to a new classroom model in which the AI education robot and teachers jointly undertake the teaching work in the classroom. Under this teaching style, the AI education robot undertakes part of teachers' teaching tasks and provides personalized learning services.

The lesson objective of a middle school math class is to help students understand the concept of unary quadratic and can skillfully turn the equation into general forms. When analyzing the learners, the teachers provide an overall understanding of the students in the class according to the learning data provided by the AI education robot and classify the data systematically.

By using the knowledge graph technology, the knowledge points related to the unary quadratic equation are presented. In terms of presenting the learning content, teachers choose to import the equation into a scene and control the AI education robot through voice to project the video. The mobile terminal lets students transmit their questions to the AI education robot. Then, the robot will choose different ways to answer the students, and for the questions that cannot be answered, the robot will send the questions back to the teachers. At the end of the class, the AI education robot will provide an evaluation report for each student in the class, helping teachers understand each learner's learning progress[36].

Figure 5: Double-teacher class in a middle school

### (vi) Intelligent classs

The value of using AI in primary and secondary education technology is reflected more centralized in the deep integration with big data technology. Relevant organizations in various regions focus on building basic education databases and trying to build the analysis and application model of education data. The application scenarios of education data are mainly reflected in two dimensions of teaching and learning. Based on data, students' learning status can be recorded entirely, learning platforms can pus customized content, and teachers can then teach in a more targeted manner.

A third-grade classroom at the Hai Bin Primary School in Chengdu, China, utilized the iFlytek English Listening and Speaking Quality Testing System. The English listening ability assessment is divided into two types of questions: single sentence reading aloud and statement reading aloud, and students wear headphones to answer the questions. Teachers can monitor each computer in real time in the background to understand the students' answering status and ensure fair testing. At the end of the assessment, the system automatically generates class reports and individual student reports, and teachers as well as students can view their individual results and the overall class situation on the platform, introducing automatic computer scoring into the assessment.

At Hai Bin Primary School, the intelligent voice evaluation system helps English listening and speaking exams and plays an auxiliary role in daily teaching. For instance, if the teacher organizes English speaking activities in the classroom, the system can help evaluate students' oral English in real time, diagnoses speech problems, and has a one-click dictation function set up to reduce the teacher's burden. The generated evaluation report can pinpoint students' weak points and utilize better materials to help students learn.

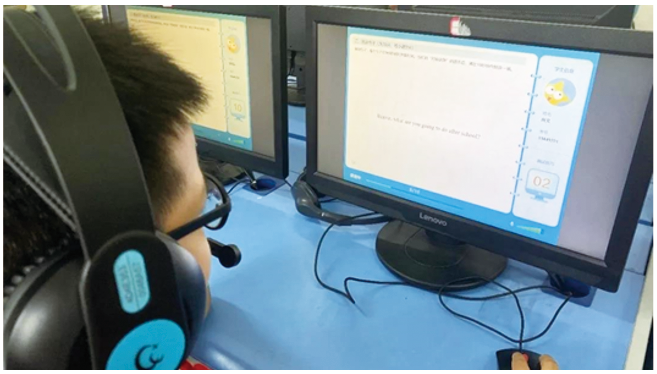

Figure 6: Students use the intelligent language evaluation system

# 4. K-12 AI Algorithms and Algorithm and Dataset

This chapter provides a brief description of the algorithms for core AI technologies, and screens the open datasets currently suitable for K-12, recommending some datasets.

## 4.1 An AI algorithm suitable for K-12

Algorithm, originally "algorism", means Arabic numbers, while the English name Algorithm, from the 9th-century Persian mathematician al-Khwarizmi, evolved into "algorithm" in the 18th century. The Euclidean algorithm is considered as the first algorithm in history. The base layer of AI can be divided again according to the algorithm, computing power and data[37]. The algorithm level includes supervised learning, unsupervised learning, reinforcement learning, transfer learning, and deep learning[38]. The computing power level includes AI chip and AI computing architecture; the data level includes data processing, data storage, data mining, etc.

The application layer can be divided into computer vision, voice processing and natural language processing according to the algorithm use. Computer vision includes image recognition, visual recognition, and video recognition. Voice processing includes speech synthesis, speech recognition and voiceprint Recognition. Natural language processing includes semantic recognition, text proofreading, machine translation, natural language generation, etc.

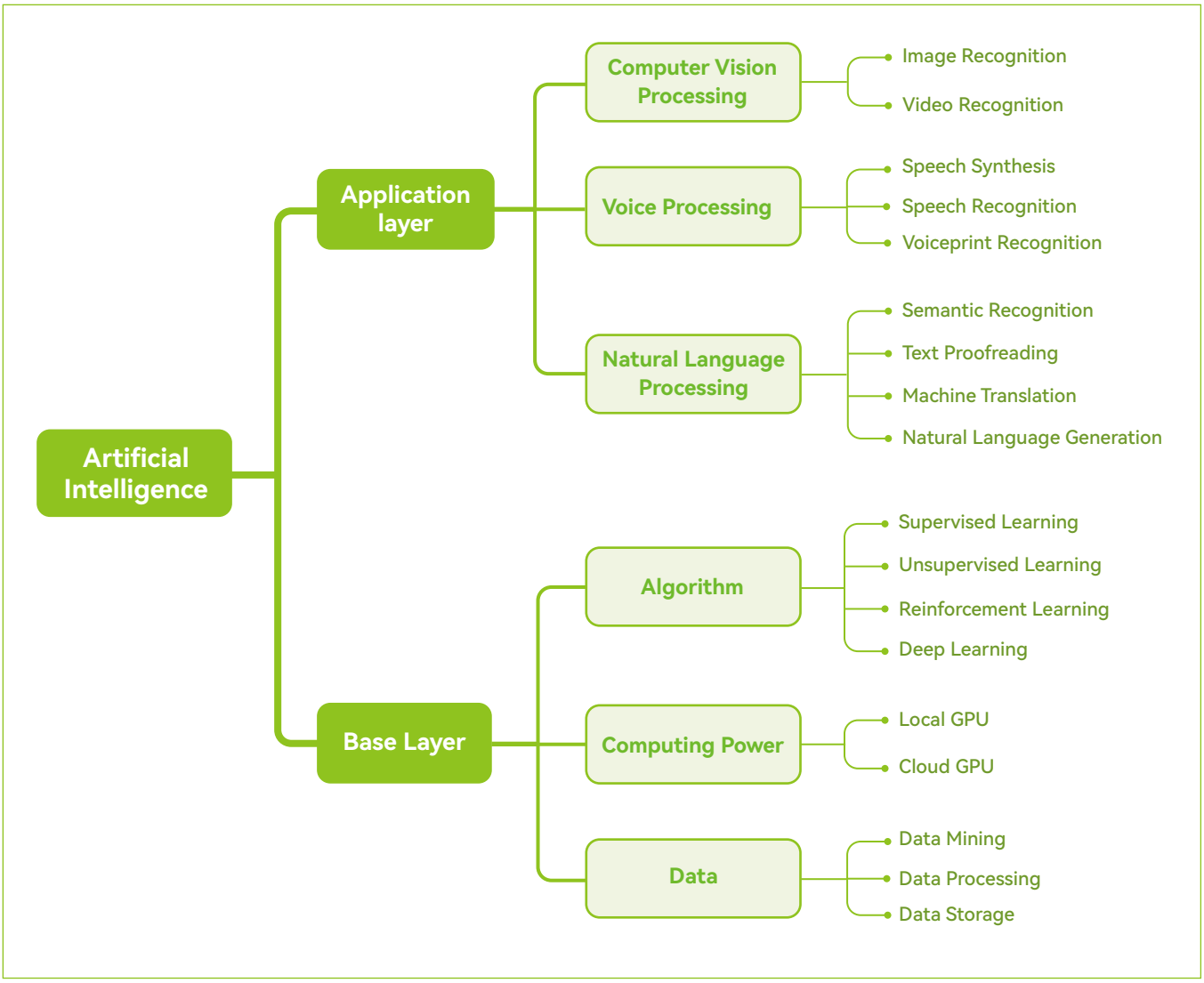


Figure 7: Core technologies of artificial intelligence

## Example of the K-12 AI algorithm

Each AI technology is complex and, for example, "machine learning" involves both mathematical foundations like "statistics," "information theory," and "cybernetic theory," and other non-mathematical knowledge. These technologies are very professional. For K-12 students, they do not need to master a certain complex algorithm in detail, but only need to understand the basic principles, application areas, use methods, etc. Therefore, we selected two typical AI algorithms as the examples.

### FACIAL RECOGNITION TECHNOLOGY

#### (i) What is facical recognition?

Facial recognition is a technique used to verify or identify individuals by processing a video frame or a digital image of a visible individual's face. Since computerized facial recognition involves measuring the physiological features of humans, facial recognition systems are classified as biometric[39]. Facial recognition techniques have several different approaches, but they often compare facial features in images to those included in the database[40]. Facial recognition systems have been more widely used in smartphones and other forms of technologies (such as robots). For example, police officers can use this technology to identify a criminal suspect; or some of its applications include automatic image index, video surveillance, human-computer interaction, etc.

#### (ii) What algorithm does facial recognition use?

Facial recognition algorithms are an essential component of any facial detection and recognition system or software. Experts divide these algorithms into two central approaches[41]: the first geometric approach focuses on distinguishing features. The regional feature analysis algorithm is widely used in facial recognition technology, which integrates computer image processing technology and biostatistics principle, uses computer image processing technology to extract portrait feature points from video, and uses the principle of biostatistics to analyze and establish mathematical models, namely face feature template.Another photographic statistics was used to extract values from images and then compared to the template to eliminate variance.In the general direction, the algorithm can also be divided into two more general categories, namely, partial and overall models. The former focuses on facial features and analyzes its spatial parameters and correlations with other features, while the holistic approach treats the face as the entire unit. The algorithms involved in facial recognition are convolutional neural network (CNN), EIGENFACES, FISHERFACES, PCA, SVM, etc.

#### (iii) Use facial recognition technology in schools

Facial recognition technology is now being introduced in all aspects of public life. This includes the rapid integration of facial recognition and facial testing into K-12 education to address issues such as campus security, automatic registration, and student emotion testing[42]. In this controversial context, we need to consider applying this technology to a specific educational context.

A prominent educational application of facial recognition technology is campus security. In addition to identifying unauthorized intruders, systems were developed to detect video objects carrying dangerous items into school[43]. Another application of facial recognition in schools is attendance monitoring, which avoids the time waste or omission caused by the teacher's roll call in class. In addition, research and development reports in the field say that detecting short "facial movements" (i. e., emotional test) can prove whether students are interested in the course, in order to achieve personalized teaching, detect their emotions in real-time, respond in time, and encourage students to listen to classes or interact actively. These systems can all help teachers with their teaching activities.

### DECISION TREE ALGORITHM

#### (i) What is a decision tree algorithm?

Decision tree is one of the most widely used and most practical machine learning algorithms, which involves little mathematics and is very easy to use and interpret[44]. Decision tree algorithms belong to a family of supervised learning algorithms. Unlike other supervised learning algorithms, the decision tree algorithms can also be used to solve regression and classification problems. The goal of using a decision tree is to create a training model that can predict the level or value of the target variable, by learning simple decision rules inferred from previous data (training data).

#### (ii) Application of the decision tree algorithm in schools

The planning and design of the student course selection system is particularly complex and involves a variety of algorithms[45].At the same time, whether the course selection system is reasonable and science directly affects the teaching quality of the whole course selection and students' enthusiasm for elective courses. Decision tree algorithm and other techniques are used to uniformly classify student information and comprehensively analyze students' hobbies and needs to achieve target data mining. In addition to playing a role in the student course selection system, it can also be used in the administration of university educational affairs[46]. At present, the number of colleges and higher learning is increasing. In order to promote the reasonable and scientific development of schools, the classification rules can provide some help for academic administrators, so the decision tree algorithm plays a certain role in these two aspects.

### Algorithmic tools and framework

At present, the basic algorithm of AI has been relatively mature, and major enterprises have made great efforts to build an algorithm model tool library, and encapsulate it as a software framework for developers to use. It can be said that the software framework is the engineering implementation of the algorithm. The software framework of an enterprise is implemented in two forms: closed source and open source. The following listed programming tools and frameworks are all open source projects and can be free to use.

**TABLE 6: THE AI PROGRAMMING TOOL**

| NAME | INTRODUCTION | URL |
|---|---|---|
| **Scratch** | Scratch is a free program developed by the MIT Media Lab Lifetime Kindergarten Group, designed mainly for children aged 8 to 16, but people of all age groups can use Scratch to create and share. Younger children can try ScratchJr, a simplified version of Scratch for children ages 5 to 7. | https://appinventor.mit.edu/ |
| **App Inventor** | App Inventor is a fully online developed Android programming environment, discarding the complex program code and using the building block stacking method to complete the Android programs. It supports Lego NXT robot, suitable for Android beginners or robot primary development. | https://www.python.org/ |
| **Python** | Python is one of the most widely used programming languages in the AI space, and can be used seamlessly with data structures and other commonly used AI algorithms. Python has a large library of tools, making others have great advantages in AI programming. | https://www.python.org/ |

**TABLE 7: THE ARTIFICIAL INTELLIGENCE DEVELOPMENT FRAMEWORK**

| NAME | INTRODUCTION | URL |
|---|---|---|
| **Tensor Flow** | TensorFlow is an open source framework based on data flow programming developed by Google and is widely used for the implementation of various types of AI algorithms. TensorFlow supports multiple programming languages like C, Python, and Java, allowing computing on any CPU or GPU, whether it be a desktop, server, or mobile device. | https://tensorflow.google.cn/ |
| **Microsoft Cognitive Toolkit (CNTK)** | CNTK is a free, open-source business-level AI development tool framework developed by Microsoft, Inc. It has a variety of AI classical algorithms that can quickly build and train some popular deep learning systems. CNTK was developed using C + +, but is often called using the Python program. | https://docs.microsoft.com/en-us/cognitive-toolkit/ |
| **Pytorch** | PyTorch is an open-source Python machine learning library developed by the Facebook Artificial Intelligence Research Institute, providing powerful tensor computation based on GPU acceleration, while supporting dynamic neural networks. | https://pytorch.org/ |
| **Flying Paddle (PaddlePaddle)** | Based on Baidu's deep learning technology research and business application. It integrates deep learning core training and reasoning framework, basic model library, end-to-end development suite and rich tool components. Airpaddle helps developers quickly realize AI ideas and quickly launch AI business. Helps more and more industries to complete AI empowerment and realize industrial intelligent upgrading. | https://www.paddlepaddle.org.cn/ |
| **Keras** | Keras is an open source artificial neural network library written in Python that can be used as a high-level API for Tensorflow, Microsoft-CNTK, and Theano for deep learning model design, debugging, evaluation, application, and visualization. | https://keras.io/ |

## 4.2 Challenges faced in the teaching of K-12 AI algorithm

By summarizing the existing standards, books and platform of algorithm teaching in K-12 AI education, the challenges facing algorithm teaching are:

**(i)** Teaching standards have yet to be harmonized across countries.

**(ii)** Difficulty in quantifying and assessing the sequence and algorithmic difficulty of the teaching content.

**(iii)** There is room for improvement in the Internet platform learning environment.

**(iv)** There are no guidelines or examples of the fit between the teaching of algorithms and the teaching of basic subjects.

At the same time, there are still unsolved risks in the development of intelligent education: intelligent education governance risk, intelligent education technology risk, intelligent education ethics risk, and teacher career substitution risk[47]. There are also many challenges in the teaching of AI, such as lack of understanding of curriculum value and positioning, limited school hours, lack of relevant teachers and training strength, and inadequate software and hardware environment needed to carry out AI teaching. In addition, most teachers are at a loss for the students with great differences in knowledge reserves.

## 4.3 The Outlook on Algorithm Teaching in K-12 AI Education

With the release of a series of AI standards (e. g., AI4K12[48], Chinese primary and secondary school AI curriculum development standards[49], etc.), it can be seen that countries are to launch an AI education aimed at developing national guidelines for teaching AI content at the K-12 level, providing a resource catalog for teachers, and establishing a K-12 AI resource development community. As for the teaching of algorithms for them, the learning of basic principles should be the focus of teaching, and the learning of algorithms needs the support of mathematics, information technology and other disciplines. Therefore, the future for the teaching of algorithms in K-12 AI should be extended from the basic disciplines, and the learning of algorithms should correspond to the learning of basic disciplines, so that they can support each other more
easily and better.

For the teaching of algorithms in AI, an AI experience course can be conducted to familiarize primary and secondary school students with AI technologies and product applications from a basic perception level. At the same time, at the primary and secondary education level, teachers are allowed to infuse design thinking into their teaching as a way to cultivate students' innovative thinking and creative awareness, thus helping them to meet the challenges of the future AI era. A dedicated AI application course will allow students to apply AI in project-based and inquiry-based learning. The AI application course can inspire students and prepare them to enter the AI workplace in the future. By focusing on the overall project development process, an AI R&D course is set up to analyze real-world problems, to promote algorithmic learning[50].

AI has now become the integration of the current information revolution, and the algorithm realization of AI needs people, and its purpose is also to seek welfare for human beings. School education committed to talent training will only become more and more important in the future, which requires us to focus on the future and think deeply about what the mission of school education is and what the focus is. Predictably, AI education should not be the application of AI technology only, is not a simple superposition of technology and education, but should scope beyond AI, it should return to the basics — that is to say, education should return to the essential relationship between people and professional education and social functions, not blindly worship information technology, and the goal of people's happiness as the pursuit of education[51].

## 4.4 Dataset suitable for K-12 AI education

AI data plays an irreplaceable role in the commercialization of AI. When an algorithm model is designed, a large amount of annotated data is needed to train the machine, thus making the machine more "intelligent" so it can be used in actual application scenarios. If the algorithm is expected to further improve the performance, more refined data needs to be trained and constantly iterated.

> **Test and adopt emerging AI technologies and tools for ensuring teachers' and learners' data privacy protection and data security. Support robust and long-term study of deeper issues of ethics in AI, ensuring AI is used for good and preventing its harmful applications. Develop comprehensive data protection laws and regulatory frameworks to guarantee the ethical, non-discriminatory, equitable, transparent and auditable use and reuse of learners' data.**
>
> **— from Article 29 of the Beijing Consensus**

### The datasets of the representative AI technical field

The following datasets are some of the typical datasets commonly used for different AI technology fields in youth AI teaching.

**TABLE 8: DATASETS OF THE REPRESENTATIVE AI TECHNICAL FIELDS**

| APPLICATION FIELD | NAME | INTRODUCTION | URL |
|---|---|---|---|
| **Handwritten recognition** | **MNIST** | MNIST is a picture dataset of handwritten figures, with a total of 250 handwritten figures from different people. MNIST is divided into two parts: training set and test set, in which the training set contains 60,000 images and labels, while the test set contains 10,000 images and labels. | http://yann.lecun.com/exdb/mnist/ |
| **Image recognition** | **ImageNet** | The Imagenet dataset is used in the deep learning image field, which can be used for image classification, positioning, detection and other research work. The dataset has more than 14 million images covering more than 20,000 categories, with more than a million images with explicit category annotation and the location of objects in the image. | https://image-net.org/ |
| **Image recognition** | **CIFAR-10** | The CIFAR-10 contains 10 categories, 60,000 training images, and the color image size: 32x32, 10,000 test images. The CIFAR-100 contains 100 classes with 600 images, 500 for training and 100 for testing; the 100 classes form 20 superclasses. Image categories are all clearly marked. CIFAR is a very good small and medium-scale dataset for image classification algorithm testing. | http://www.cs.toronto.edu/~kriz/cifar.html |
| **Speech recognition** | **CHIME** | CHIME is a dataset for Speech Recognition Challenge (CHiME Speech Separation and Recognition Challenge). The dataset contains three parts: training set, developer machine, and test set, and each copy includes data from multiple speakers in different noise environments. | http://spandh.dcs.shef.ac.uk/chime_challenge/index.html |
| **Natural language processing** | **SQuAD** | The Stanford Q & A Answer Dataset (SQuAD) is a new reading comprehension dataset consisting of questions extracted from Wikipedia, and each answer is a piece of text in the corresponding paragraph. Over 100,000 Q & A pairs in over 500 articles. | https://rajpurkar.github.io/SQuAD-explorer/ |

### Representative professional AI dataset

For different application fields, this report collects some relatively representative and typical datasets for your reference in conducting research or teaching in the corresponding fields.

**TABLE 9: DATASETS OF THE REPRESENTATIVE SPECIALTIES**

| APPLICATION FIELD | NAME | INTRODUCTION | URL |
|---|---|---|---|
| **Agriculture** | **lemon** | The lemon data contains 2,690 annotated lemon images (1,056 x 1056 pixels) containing three subsets of training, validation, and testing. Each lemon image was taken at different angles and taken multiple times under different lighting conditions. An individual fruit has generated approximately 100 images. | https://github.com/softwaremill/lemon-dataset |
| **Biology** | **The Cancer Cell Line Encyclopedia Dataset CCLE** | CCLE covers more than 1,000 human cancer cell lines covering over thirty tissue sources for large-scale deep sequencing, integrating genetic information such as DNA mutations, gene expression, and chromosomal copy number. This database has become one of the standard reference databases for cancer genomics. | https://sites.broadinstitute.org/ccle |
| **Climate** | **The Dutch weather data platform, KNMI** | The Dutch Weather Data Platform (KNMI) has about 247 datasets containing 71 climate datasets, 78 precipitation datasets, 7 seismic and acoustic datasets, 13 sunlight and radiation datasets, 33 temperature datasets, 7 weather forecast datasets, and 38 wind datasets. | https://dataplatform.knmi.nl/ |
| **Complex network** | **Stanford GraphBase** | The Stanford GraphBase is a collection of programs and datasets that generate and manipulate graphics and networks. This package is the work of Donald Knuth at Stanford University, and the latest version of this software is always provided by an anonymous ftp from the Stanford Department of Computer Science. | https://www3.cs.stonybrook.edu/algorith/implement/graphbase/implement.shtml |
| **Machine learning** | **UCI machine learning library** | The UCI machine learning library contains 588 machine learning-related datasets of various types, of which there are classical ones like Iris, and it also contains new added datasets such as air quality and GPS trajectories. | https://archive.ics.uci.edu/ml/index.php |
| **Computer network** | **CAIDA data set** | CAIDA collects network data from dimensions such as geography and network topology and provides this data to the research community as much as possible. This dataset can analyze two categories of network data collected and being collected. | https://www.caida.org/catalog/datasets/overview/ |
| **Network security** | **CCCS-CIC-AndMal-2020** | CCCS-CIC-AndMal-2020 is a new comprehensive and massive robotic malware dataset consisting of 20 0,000 benign and 20 0,000 malware samples that total 40 0,000 Android applications, containing 14 prominent malware categories and 191 prominent malware. | https://www.unb.ca/cic/datasets/andmal2020.html |
| **Geo-information system** | **World continental, national, and city datasets** | The data contains all 7 continents, 250 countries / regions, 4k subdivisions (provinces, states, etc.), and over 127,000 cities. It shows all the languages used in each country / region, and the geographical shape of each country. All data are provided in the JSON format and can be retrieved and managed through the API. | https://www.back4app.com/database/back4app/list-of-all-continents-countries-cities |
| **Geoscience** | **AQUASTAT** | QUASTAT collects, analyzes, and disseminates data and information on water, water and agricultural water management by country, with a focus on irrigation agriculture in Africa, Asia, Latin America and the Caribbean. | http://www.fao.org/aquastat/statistics/query/index.html;jsessionid=84948F118DA73E55A555F8AF0642005F |

**CONTINUED FROMTABLE 9: DATASETS OF THE REPRESENTATIVE SPECIALTIES**

| APPLICATION FIELD | NAME | INTRODUCTION | URL |
|---|---|---|---|
| **Economics** | **Economic data from all countries around the world** | Economic data from the American Economic Society collects American macroeconomic data, as well as economic data from other countries. It can provide a growing variety of economic data for students, teachers, and professionals. | https://www.aeaweb.org/resources/data |
| **Education** | **The New York State Education dataset** | The New York State Education Dataset collected New York State education data from 1999 to 2016, containing a transcript database, enrollment database, graduation rate database, etc. | https://data.nysed.gov/downloads.php |
| **Finance** | **The FAANG stock dataset** | The FAANG stock dataset contains stock data when FAANG Corporation began trading. These data includes data on the opening price, closing price, sales of these stocks. | https://www.kaggle.com/aayushmishra1512/faang-complete-stock-data |
| **Physics** | **Crystallography Open dataset COD** | COD is an open access database that collects crystal structures of organic, inorganic, metal organic compounds and minerals, but not biopolymers. The COD database currently has more than 480,000 pieces of data. | http://www.crystallography.net/cod/ |
| **Physical culture** | **The CRICSHEET Cricket Dataset** | The CRICSHEET Cricket Data provides structured score data for more than 10,000 cricket games. | https://cricsheet.org/ |
| **Traffic** | **The Freight Analysis Framework, FAF** | The Freight Analysis Framework (FAF) integrates data from a variety of sources to provide a comprehensive understanding of freight flow through various means of transportation between US states and major metropolitan areas. The FAF included data from agriculture, mining, utilities, construction, services, and other sectors. | https://ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm |

# 5. AI Laboratory for K-12

This chapter briefly describes the AI experimental environment, which is divided into three types: economy type, standard type, and advanced type. Different types of experimental environments correspond to different learning groups, and you can choose the most suitable learning (teaching) platform. Experimental environment is necessary for learning AI, through which learners can practice the theoretical knowledge learned. Many students cannot innovate in the laboratory if they have not practiced in the laboratory. AI teaching laboratory is an important infrastructure for developing AI education.

The AI labs focus on learning and using new technologies to solve real-life problems.AI labs can inspire students to prepare for the fourth industrial revolution in AI, robotics, and automation technologies.

On the basis of fully considering the school economic situation and teaching positioning differences, the research group proposed the classification of AI education laboratory as shown in Figure 8.

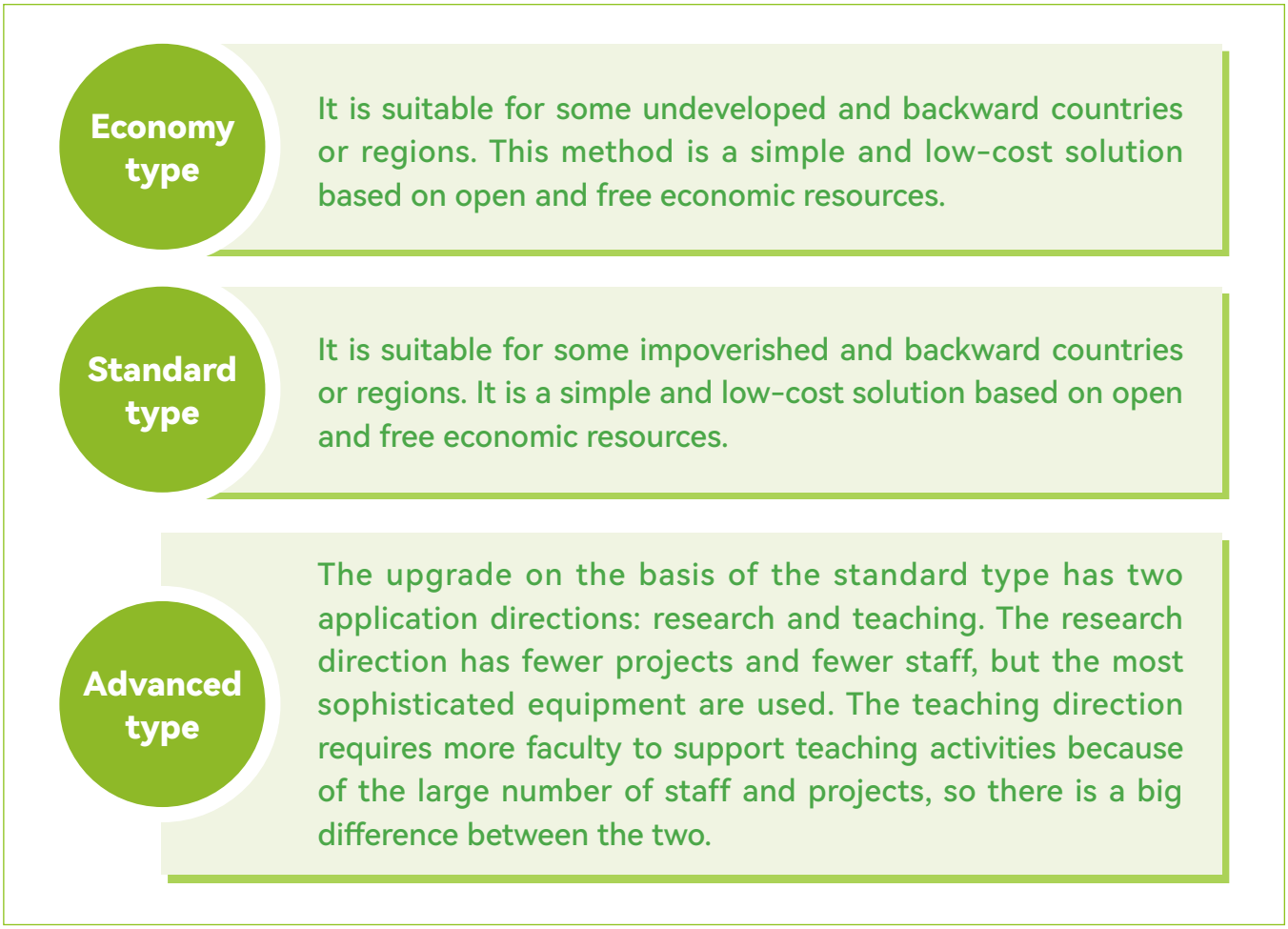


Figure 8: The AI Laboratory Classification

## 5.1 Classification and characteristics of AI laboratories

Different types of experimental environments correspond to different learning groups of learners, one can choose the learning (teaching) platform that best suits their needs. An experimental environment is a necessary condition for learning AI, through which learners can put the theoretical knowledge they have learned into practice[52]. Because many students have not practiced in a lab, it is difficult to gain new technological innovations from theoretical courses. With an environment for learning AI, the number of AI talents will continue to grow in the future.

**(i) Economy type of AI lab**

In 2018, Africa, a "most dedicated teacher" on the Internet fire, because of poverty, the computer in their side is almost an inaccessible thing, then their students how to take computer classes? The teacher had a brainstorm, he took chalk hand-drawn computer page on the blackboard, so as to teach the students.

Many schools do not have robust lab facilities and rely mainly on boring textbooks to teach AI, which can make learning much less effective. Most of the economical labs currently existed are free and open, which include providing a free programming platform, GPU computing power and some courses that all people can use or teach for free. The characteristics of this kind of lab are: anytime, anywhere, flexible, open, and able to accommodate all people who want to learn AI technology. Some platforms are free to use, which is more suitable for those who are living in poverty.

Economical labs log in to AI cloud services via the school's computer room WEB and conduct experimental teaching using the free AI computing power and services provided by these cloud services. Currently, such cloud services are provided by Baidu, Ali, Google and other companies.

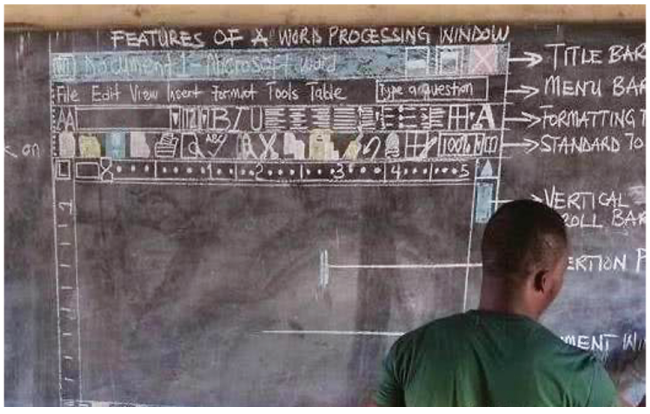


Figure 9: Hand-painted computer by African teachers

**(ii) Standard type of AI lab**

At present, there are six major research directions in AI technology, among which computer vision, natural language processing, robotics and machine learning are relatively popular, and more and more products are being applied in related fields. Standard laboratory characteristics: enough to support the personal workstation equipment, can be equipped with their own equipment according to different project needs, set up suitable for their own workstation. This laboratory does not cost too much and is suitable for an individual laboratory.

**(iii) Advanced type of AI lab**

AI is the most important development field of the future, and the demand for students or users is growing. And many students who have not practiced in the lab and have only taken theoretical courses alone will have a hard time using those theories to innovate technologically in the workplace. Creating an AI lab is a huge challenge for schools because it is not clear what equipment is needed for each area of AI[53]. And thus, we need to analyze the different areas of AI and then make a professional recommendation for schools. The features of the advanced type of AI lab include the unified of the school, the equipment required for professional and comprehensive, allowing students to thoroughly learn professional knowledge and cutting-edge AI technology. However, the cost for this kind of lab is the most expensive among the three other labs, so it is more suitable for large institutions, such as schools, to build.

## 5.2 K-12 AI lab example

### The Artificial Intelligence Education Laboratory in the Xiongan New Area

The laboratory is established by Baidu Education, Smart Learning Insiture of Beijing Normal University and Baiyangdian senior high school. This lab could support the learning parctice of AI, robot, big data, internet of thing and brain interaction, which is smart learning solution integrating curriculum resource, teaching platform, practical teaching and virtual experience. This lab will serve the AI teaching, STEM education and teacher training at shcool.

The AI curriculum is divided into three main categories according to the K-12 age group. The elementary school level focuses on computational thinking development, aided by the perception and experience of artificial ntelligence. The middle school level focuses on advanced computational thinking development, aided by an initial understanding of the AI implementation knowledge system. The high school level focuses on thematic AI technical understanding, aided by the frontiers of AI educational development and application. The learning focus and specific measures for these three stages are introduced in detail, and the three stages comprehensively cover basic education. Solutions are also proposed for the training of K-12 teachers through online and in-person training. In this way, teachers can understand the history, current situation, methods, and significance of AI technology and understand the teaching. methods and outcome evaluation criteria of AI courses. Teacher training ensures that students can master the cognition of AI technology, understand the definition of AI sub-disciplines, and grasp the principles of AI technology through practical activities. Educators are required to pass training assessments before starting teaching.

Figure 10: Xiongan AI Education Laboratory of Xiongan New Area

### IN-MaC Design and Innovation Studio[54]

On March 13, 2020, the Indiana Next Generation Manufacturing Competitiveness Center (IN-MaC) and Honda Manufacturing Indiana LLC (HMIN) debuted the latest IN-MaC Design and Innovation Studio.

Located at the HMIN facility in Greensboro, this lab offers hands-on experience with modules such as additive printers, robotics design and AI coding, as well as engineering and science learning. In addition, it includes virtual reality experience stations and equipment for STEM education. With the goal of enhancing middle and high school students' exploration of design thinking, problem solving, technology and innovation skills, the lab enables students from southeastern Indiana, USA to discover and explore the next generation of manufacturing.

The strength of this lab is that, on the one hand, it allows students to put into practice the theoretical knowledge learned in STEM courses and develop their problem-solving skills and interest; on the other hand, it brings a real work environment into the school learning environment, providing a unique way of bridging the gap between industry and education. In this way, students are provided with relevant experiences that help develop their IT skills, employability skills, form career concepts and develop new ways of thinking.

Figure 11: The I N-MaC Design and Innovation Studio

### "Cloud for Youth" Digital Learning Space for Rural Students

"Cloud for Youth" is a new initiative aimed at building a new learning space for rural students. The initiative is founded with participation from governments, companies, and civil societies to lead the betterment of digital education for rural students. Leveraging cloud technologies, the initiative provides a virtual "personal desktop", which integrates classroom management capabilities and provides digital capabilities including resource storage and digital laboratory. This is expected to create a conducive learning environment for the IT education of primary and secondary students, providing students with access to AI-powered experiments and after-school learning programs. As the provider of cloud-based services and hardware for the initiative, Alibaba Cloud will provide 5 years' worth of free deployment and technical services.

The learning space is equipped with 40–50 all-in-one lightweight devices that provide access to the virtual CPUs, GPUs, memory, and disks deployed on Alibaba Cloud. This initiative solves long-standing issues where rural schools lack access to modern computing technology and staff to manage and maintain IT equipment. Through this initiative, rural students are provided with equal access to digital learning and experiment spaces as students in urban schools. "Cloud for Youth" promotes equitable access to technology for students in rural areas.

Teaching resources and tools will be deployed on the cloud and every teacher and student will be able to log on to their own personal desktops and access their resources at anytime, anywhere, and on any device. Teachers and students no longer have to be bound by the confines of the school and can continue their education from the comfort of their own homes. The learning space also creates a contextualized teaching environment for AI-powered classes. Through cloud networking, dynamic distribution, and peer-to-peer management, students can collaborate with each other in learning and can interact with the teacher during classes. This way, students can gain a better understanding of the importance of digital technologies and cultivate creative thinking through collaboration and interaction.

Figure 12: “Cloud for Youth” Digital Learning Space

# 6. Conclusion and Recommendation

AI is increasingly adding its important application value in many fields with the advent of the intelligent era. However, AI education still faces many practical problems in basic education, such as fuzzy curriculum orientation, differentiated teaching content, and complex curriculum system and resources. Looking forward, we will find that the development of K-12 AI education will still go through a long stage of development.

## 6.1 The Conclusion on K-12 AI Education

- **The development on AI open education resources will lead to a fair educational resource distribution**

The AI OER is the teaching, learning, and research material for any media (digital or other media) located in the public domain or issued with open licenses. The license allows free access, use, adaptation, and redistribution without user restrictions. Although the current OER granted by some institutions or famous universities may help to create fair educational resource distribution, which still lacks suitability among the users.

- **Teaching materials and methodologies are indispensable for developing AI in K-12**

Textbook and teaching methodologies are regarded as complementary to each other. Textbooks are the main carrier of teaching content, in they serve as a guide to help learners meet their education goals. AI textbooks for kindergarten and primary school centralize the popularization of AI knowledge and the cultivation of student skills. In the meantime, AI textbooks for junior high school focus on the cultivation of AI techniques and engineering thinking. For high school students, AI textbooks emphasize fostering students' ability and mindset through hands-on practice to understand and apply AI. This teaching type through practice in AI education has appeared to be successful.

- **Algorithmic literacy is an essential ability for K-12 educators**

Three elements of AI are calculating skills, algorithms, and data. Although these skills are required and essential in AI education, many K-12 educators lack algorithmic literacy. Even if they possess the skill of algorithmic literacy, it is often included in the curriculum of computer science instead of AI education. To help develop students' algorithmic literacy55, we should first put attention to the educators' own algorithmic literacy[55] . It is recommended to first ensuring that AI educators' possess sufficient algorithmic literacy skills , then utilize project-based or case-based learning to teach K-12 students.

- **The AI laboratory for education is a key factor in the development of K-12 AI teaching**

Suppose we separate the AI teaching laboratory into three scenarios. In that case, the economy type is to provide free resources in less developed countries like Paddle OCR by Baidu, which gives free online coding environment, GPU algorithm, and algorithm and open data. The second scenario is the standard type, suitable for setting up personal AI workstations; it allows the learners to open up deeper learning, data science, reinforcement learning, and AI all-in-one personal workstations. The third scenario is the advancement type. This third type of scenario is suitable when school builds their laboratory for learning. This lab can accommodate more students to do activities, present models, corroborate, and be creative in this environment. This laboratory will provide students an opportunity to participate in practical learning activities in AI professionals'working environment.

- **The educational policy for AI needs to be future improved to achieve SDG.**

Referring to the Beijing Consensus, when developing AI education, we should recognize the multidisciplinary nature of AI, ensuring the coordination between educational AI and public policy, plan and govern educational AI policies through all government participation, cross-departmental integration, and multiple collaboration. Identify strategic priority areas of policy based on local challenges in achieving SDG and its specific goals and other SDG efforts. From the perspective of lifelong learning, to complete and improve AI education, we should plan and formulate the whole system with AI educational strategy by integrating education policies.

- **The AI policy and safety are critical for owners to avoid legal and ethical issues.**

When governments and education departments support AI development, AI applications may have different types of biases. These biases are inherited in the input and output of AI data or the algorithms used in the system. We should recognize the dilemma between open access and privacy protection on data, the legal issues and ethical risks associated with data ownership, data privacy, and the availability of data serving increases the public interest. In addition, we should adopt principles of ethics and privacy and utilize design to ensure security when building AI.

## 6.2 K-12 AI Education Recommendation

With significant progress over the past decade and during the COVID-19 pandemic, AI adoption has accelerated worldwide and across different sectors. The global AI market is expected to reach a staggering $312.4 billion by 2027. Therefore, governments worldwide have prioritized AI, launching national strategies, encouraging research and development, promoting regulatory reform, and increasing the talent pool. The talent shortage has been highlighted as a vital issue in AI policy. Major decision-makers in government, academia, and private enterprise sectors operate by initiating and increasing support for AI education and esearch, particularly during the educational phase of K-12, as they view AI as primarily an investment in economic competitiveness.

However, there is a general lack of information about implementing AI into K-12 education curricula. Some countries include AI education in national-level plans to introduce AI education systematically, while others still rely on nitiatives from local or university organizations. This divergence suggests that creating opportunities for international discussions on K-12 AI education is crucial, sharing each other's good practices and identifying solutions to common challenges.

According to the research and analysis of this support report, the author team provides the following suggestions for government, private sector and civil society: governments must invest in K-12 AI education, provide equal access to basic knowledge and skills, and encourage private sector and private society participation, but the government should ensure the quality and consistency of AI education. Finally, educators should be encouraged to seek breakthroughs in education. AI should not  be the only tool for professional computer teachers. Any subject can seek the assistance of AIED.

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