National Engineering Laboratory for Cyberlearning and Intelligent Technology

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Smart Learning Institute of Beijing Normal University

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Citation (English Version)

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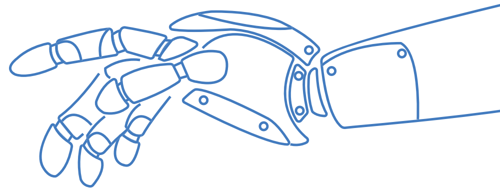
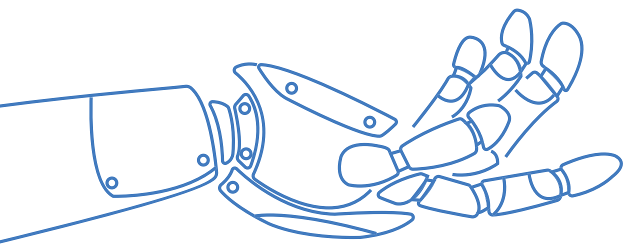
Citation (Chinese Version)

刘德建，黄荣怀，Kinshuk,Jonathan Michael Spector,Carolyn Penstein Rose，李艳燕，林琳，杨俊锋，张定文，Gerald Knezek，江师雁，王欢欢，包昊罡，尹霞雨． 智能技术变革教育：中美比较研究（2019）[R]． 北京：北京师范大学智慧学习研究院，2019．



Motivation and Methodology



1.1 Motivation

The past few years have seen a surge of interest in intelligent technologies, involving Artificial Intelligence (AI) and emerging advanced technologies empowered by AI, such as Internet of Things (IoT), Virtual Reality (VR)/ Augmented Reality (AR) enhanced by AI, and intelligent terminal devices. The proliferation of intelligent technologies has dramatically altered the landscape of global businesses and communication[1]. As described by Bughin and colleagues[2], 70% of the companies are expected to adopt intelligent technologies by 2030.

Many fields are already vigorously moving ahead with the adoption of intelligent technologies. Recently, Wealthfront added AI capacities to understand how customers spend, invest, and make financial decisions and provide customized advice to customers[3]. Intelligent technologies have exerted significant impact on healthcare and medicine, such as allowing early detection of cancer[4]. Another example of the application of intelligent technologies is in journalism, where Reuters News Tracer can filter fake news in social media with machine learning algorithms for detecting breaking news[5]. Intelligent technologies, are also changing the face of the education sector by making teaching and learning innovative. The broad applications of intelligent technologies have the potential of boosting efficiency through automation and establishing a better society.

Accordingly, many countries have proposed policies to support the use of intelligent technologies in different fields. The U.S. published the National Artificial Intelligence Research and Development Strategic Plan[6] in 2016. The plan illustrates the importance of AI technologies in the future and advocates that all stakeholders should prioritize AI. The plan also provides a vision for maintaining the leadership of the U.S. in using AI for promoting economic prosperity, expanding educational opportunity, and protecting national security. Subsequently, several policies, such as Preparing for the Future of Artificial Intelligence[7] (2016) and Summary of the 2018 White House Summit on Artificial Intelligence for American Industry[8], have been proposed to further encourage the adoption of AI technologies. Furthermore, the 2019 budget in the U.S. was approved emphasizing on intelligent technologies. The U.S. also released National AI R&D Strategic Plan: 2019 Update[9].

Meanwhile, the European Union (EU) member states started the Human Brain Project in 2013 with the aim to simulate the complete human brain on supercomputers. The project involved 24 countries and 112 enterprises. The EU also put forward a new report in 2018, The Age of Artificial Intelligence: Towards a European Strategy for Human-Centric Machines[10]. This report points out the ethical and privacy problems in developing intelligent technologies. Besides, Policy and Investment Recommendations for Trustworthy AI[11] was put forward by the High-Level Expert Group on AI (AI HLEG).

Moreover, the United Kingdom (UK) has stated its aim to lead in the field of AI ethics.

In Asia, Japan proposed the Japan Revitalization Strategy 2016[12] with an emphasis on the revitalization of Robot technologies. In 2017, the Japan government published the Artificial

Intelligence Technology Strategy: Report of Strategic Council of Artificial Intelligence Technology[13]. This report defines what AI technologies are and provides a technical framework for AI development. Also, China is making huge strides to become a global leader in intelligent technology. In 2017, Chinese State Council promulgated The New Generation of Artificial Intelligence Initiatives[14]. Based on this planning, many organizations, enterprises, and provinces have proposed specific guidelines for the development of intelligent technologies in different fields. In 2018, the Chinese Ministry of Education published action planning for adopting intelligent technologies in higher education. Many universities have established AI academy for talent training. What we can learn from the policies as mentioned above in different countries is that intelligent technologies are quite crucial for the future, and countries have started to take significant advantages of intelligent technology innovations.

In recent years, with the rapid development of Internet and online services, there is a massive amount of data accumulated. Researchers have the opportunity to extract valuable information from an unprecedented amount of data, which will help us better understand the intricate patterns of human behaviors that were not available in the past. Intelligent technologies could build new models about human behavior and facilitate making data-driven decisions. Meanwhile, recent advances in AI acceleration (e.g., GPU), deep learning, meta-learning, and reinforcement learning techniques are delivering significant changes in the accuracy of predictions. Moreover, all these technologies mentioned above could support the construction of a more efficient and productive society as well as education.

The application of intelligent technology in education has been in existence for a long time. In the 1950s, the computer was used as a tutoring tool. It was the prototype of technology applied in education. Intelligent Tutoring System (ITS) is the new development of computer-aided tutoring under the promotion of intelligent technology, and it is one of the typical applications of intelligent technology in education[15]. The development of intelligent technology, especially the rapid development of image recognition, voice recognition, natural language processing, and the gradual maturity of relevant educational products, provides more possibilities for educational reform and intelligent tutoring. It also provides strong support for education and tutoring in environmental construction, decision support, talent training, emotional companionship, precise services, tutoring support, and intelligent evaluation.

China and the U.S. are the two major powers in the development of global intelligent technology. China, as a representative of developing countries, is ambitious in pushing the advances of intelligent technology. The U.S., as a representative of developed countries, leads the race to supply intelligent technology. Both China and the U.S. are making substantial investments to transform education through intelligent technology. Although intelligent technology has brought many obvious changes to education, the complexity and seriousness of education has led to many debates about how intelligent technology can be effectively and efficiently infused into education. In order to compare the current application of intelligent technology in education between China and the U.S., and to further explore how to use intelligent technology in education, this report begins with the intelligent technology itself, from the aspects of academic research, talent training, industry scale and national strategy to oversee the development of intelligent technology. Furthermore, the report analyzes factors of infusing Information and Communications Technology (ICT) into education in both China and the U.S., laying a solid foundation for analyzing the application of intelligent technology in education. Finally, the report lists typical scenarios, key products and technology, and typical cases of intelligent technology in education, showing the panorama of current development of China and the U.S.

1.2 Methodology

There are three aims of this report:

- To depict the landscape of intelligent technology for education.
- To identify factors of infusing ICT into education in both China and the U.S.
- To recognize the differences between China and the U.S. on transforming education through intelligent technology.

In order to achieve the three research objectives, we firstly organized the research team to execute the whole research process. Specific methods used in this study included the desk research, the case study, the expert interview and the comparing inquiry. It is worthwhile to note that CIPP (Context, Input, Process, Product) model[16] was also used to help us think about how intelligent technology can be used in education during the process of desk research and case study. For the expert interview and the subsequent comparing inquiry, we applied an Iterative Comparison Framework with Deep Inquiry (ICFDI) to the study, thus assisting us to deepen the understanding of experts' opinions and compare the opinions between China and the U.S.

In the process of the desk research and the case study, we analyzed more than 200 AI reports and policies from various sources of China and U.S., and collected more than 100 cases about infusing intelligent technology into education in China and U.S. We especially introduced the CIPP model to the desk research and the case study. Specifically, concerning the "Context", ICT background and AI trends in China and the U.S. were explored to have a brief view of the history and the state-of-the-art. In terms of the "Input", national policies and funds, talent training situations of China and the U.S. were listed to understand the current state of the intelligent technology. With regards to the "Process", procedures for promoting learning and teaching were collected to compare the effectiveness of intelligent technology in education between China and the U.S. For "Product," the representative cases of infusing intelligent technology into education between China and the U.S. could be helpful to understand the education systematic change.

In relation to the expert interview, 21 experts from the fields of AI, education and educational technology took part in it. Forms of interviews included group interviews (normally lasted for 90 minutes) and personal interviews (30 minutes to 45 minutes). Ways of interviews consisted of online (webinar, email, Skype, etc.) and offline (seminar, exclusive interview, etc.). The topic of interview is relating to "Transforming Education through Intelligent Technology", adopting the semi-structured interview. Through rounds of interviews, we generally achieved the three research objectives, i.e., the general use of intelligent technology in education, the factors of infusing ICT into Education in both China and the U.S., and the trends and challenges of AI in education were briefly understood. The use of the ICFDI helped us iterate opinions from experts round by round. Specifically, only after collecing experts' opinions meeting the four standards at the same time, i.e., problem clarity, system comparability, conclusion exploration, evidence sufficiency, could we continue the following research steps.

Concerning the comparing inquiry, we introduced the ICFDI to explore the topic of transforming education through intelligent technology between China and the U.S. The ICFDI consists of six main phases proceeding in an interactive way, including conceptualization, contextualization, comparison, explanation, reconceptualization and application. The aim is to increase the depth and width of comparative study findings in order to generate more meaningful educational insights. The process is shown in the Figure 1-1.

The six phases are:

- "Conceptualization" refers to putting forward research topics, finding research gaps, and then refining research topics into specific research questions, or research objectives.
- "Contextualization" is mainly about collecting literature on comparative equivalence, analyzing the comparative equivalence, and ensuring comparative variables from the perspective of educational system and comparative standards.
- "Comparison" is expected to figure out and compare the similarities and differences of each variable.
- "Explanation" means that researchers are supposed to find out reasons resulting in the similarities and differences.
- "Reconceptualization" is to clarify the iteration details of this research which is to reconsider the original research questions/objectives and put specific research conclusions into the original comparative framework to comprehensively consider the appropriateness of the conclusions.
- "Application" is to apply the specific conclusions of this study to other educational situations, and demonstrate the impact and significance of research findings.

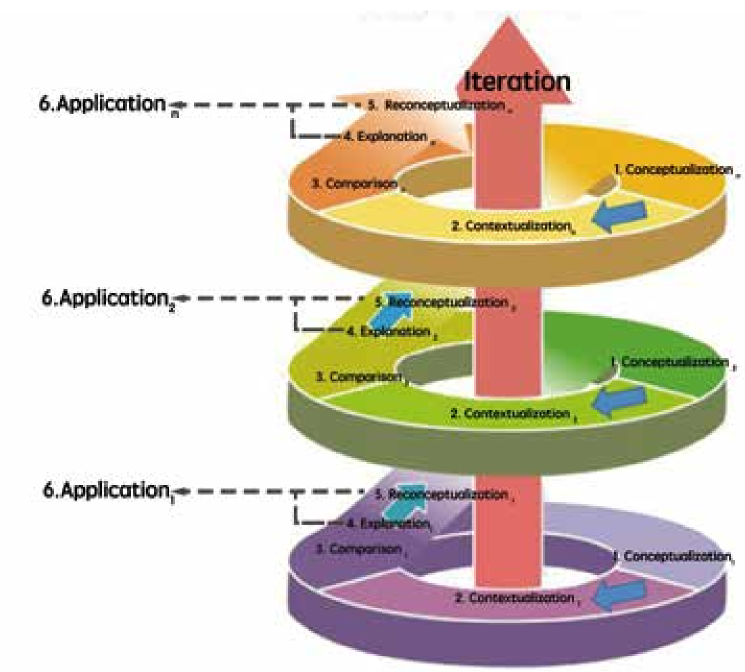


Figure 1-1. Iterative Comparison Framework with Deep Inquiry (ICFDI)

The Landscape of Intelligent Technology for Education

2.1 Overview of Intelligent Technology

The birth of intelligent technology is accompanied with the field of AI in the 1950s through the work of pioneers such as Marvin Minsky, Herbert Simon, and Allen Newell. Its foundations grow out of a confluence between psychology and computer science, with a foundational goal of modeling human decision-making and problem-solving. Early efforts aiming at intelligent technology were housed in the field of Cognitive Science. Its leading research society, the Cognitive Science Society was founded by leading researchers including Roger Schank, Allan Collins, and Donald Norman in the late 1970s. In the same year, the American Association for Artificial Intelligence, now called the Association for the Advancement of Artificial Intelligence, was born, with early society presidents including both Allen Newell and Marvin Minsky. With the focus on human learning, decision-making, and problem-solving, a connection with education was natural. While the field of Educational Technology grew out of the field of Education, the field of ITS grew more from Cognitive Science and AI roots. Moreover, finally, in the 1990s the field of AI in Education grew up, eventually formalized in the society that bears the same name.

Some of the early work in intelligent technology focused on frameworks for separating representation of knowledge from models of reasoning. Models of reasoning were formalized as symbolic systems, like formal logics that ran within theorem provers. The separation was meant to enable characterization of reasoning and problem solving as general skills that could apply to any area depending on the specific knowledge base that was used. This approach to intelligent was known as the typical approach. From another side, grounded in statistics, Calculus, and Algebra, a sister approach referred alternately as the statistical approach, the machine learning approach, or the purely empirical approach posed a competing vision for progress towards the goal of modeling human intelligence. While the history of technology and its waves at a very coarse-grained level were discussed above, drilling down from technology at large, to computer science, and then even more specifically to intelligence, we see the same pattern of waves, in this case beginning with periods of optimism, followed by disappointment and subsequent lessening of focus, and then renewal.

The earliest work on intelligent technology was focusing on symbolic methods and formal reasoning systems with roots in logic and philosophy. However, from the beginning, there have sometimes been more complementary and sometimes more adversarial efforts growing out of statistics and mathematical modeling. Thirty years ago, as significant advances in processor speed accompanied by massive decreases in the cost of hardware, the field of intelligent technology in general and Machine Learning more specifically had the opportunity to blossom under an abundance of processor speed and memory capacity. With time and space constraints on computational complexity being lifted, or at least massively reduced, simple computational paradigms that were born in the 80s were able to be applied to much bigger and more complex problems.

As an example, longtime members of the computational linguistics community have observed the paradigm shift that took place after the middle of the 1990s. Although initially approaches that combined symbolic and statistical methods were of interest, with the focus on huge corpora and leveraging of new frameworks for large scale statistical modeling, symbolic and knowledge-driven methods for natural language processing were largely left by the wayside. Along with older symbolic methods that required carefully crafted grammars and lexicons, the concept of knowledge source became strongly associated with the notion of theory, which is consistent with the philosophical notion of linguistic theory advocated by Chomskyan linguistics and other theories of formal linguistics. As knowledge-based methods were replaced by statistical models, a grounding in linguistic theory grew more and more devalued, and instead, a desire to replace theory with empiricism became the zeitgeist that drove progress within the field.

Beyond increases in processor speed and memory, another ingredient that fueled faith in machine learning as the hope of reaching the holy grail of human-level learning and problem solving is the massive growth in available data that came with the internet.

Twenty years later, as faith in probabilistic graphical models began to waver, another surge of growth in processing power was born within the field of video games: The GPU was born. Moreover, with the birth of GPUs came the rise of Deep Learning, which initially grew not out of formal statistical modeling, but from the area of Neural Networks. While probabilistic graphical models offered the opportunity to specify models that embody knowledge in informally satisfying ways, even with large scale computing capacity, models became big and unwieldy very quickly, and work using them turned away from a focus on the specification and on to the problem of parallelization and factorization in order to scale models back to meet practical constraints. Deep learning offered the advantage of using data to make the reduction. Moreover, paired with the added capacity offered by GPUs, the field of Deep learning was able to revive simple paradigms that showed promise in the 1980s but were not able to achieve their full potential due to constraints on processor speed and memory.

Several classic definitions provided from different perspectives on AI:

- McCarthy, Minsky, Rochester, and Shannon (1995) firstly defined AI as "the science and engineering of making intelligent machines, especially intelligent computer programs[17]."
- Zhong (2006) defined AI is "a branch of modern science and technology aiming at the exploration of the secrets of human intelligence on the one hand and the transplantation of human intelligence to machines as much as possible on the other hand so that machines would be able to perform functions as intelligently as they can[18]."
- ITU (2008) defines AI as "a set of associated technologies and techniques that can be used to complement traditional approaches, human intelligence and analytics, and other techniques."

In this report, intelligent technologies best understood as a set of disciplines, methods, techniques, and systems that simulating, expanding and extending beyond human intelligence that aims at problem-solving[19]. The intelligent technology area started with grand dreams of human-level artificial general intelligence[20], which is referred to as general AI (also known as strong AI). However, the majority of currently active AI is narrow AI (also referred to as weak AI). Narrow AI is usually the software that is automating a traditionally human activity, and in most cases, it outperforms humans in efficiency and endurance[21]. It is called narrow because it performs tasks that typically require human intelligence, while it can only perform tasks in a particular and narrowly defined domain[22]. The typical example for narrow AI or weak AI is a chess program that can only "play" chess, and cannot learn how to do anything else. In education, it is also regarded as adaptive learning， which is a kind of narrow AI or weak AI.

Nowadays, intelligent technology typically involves eight tasks: problem-solving and game, logic and reasoning, knowledge representation and expert system, natural language processing, planning, perception, automatic control and robotics, and machine learning[23]. With the current popularization of the Internet, universal existence of sensors, the emergence of big data, development of e-commerce, the rise of the information community, and interconnection and fusion of data and knowledge in society, physical space, and cyberspace, the information environment surrounding intelligent technologydevelopment has changed profoundly. It is leading to a new evolutionary stage, which is driven by big-data driven intelligent technology, Internet crowd intelligence, crowdsourcing and human computation, cross-media intelligence, human-machine hybrid-augmented intelligence, and autonomous-intelligent system[24].

The rapid development of AI has enhanced the integration and innovation of related intelligent technologies. Such as original hardware and software, intelligent robots, smart vehicles, VR and AR, IoT devices, and smart terminals. At the same time, these smart technologies have been integrated into various industries and have been scaled up in the manufacturing, agriculture, logistics, finance, commerce, education, and other industries to empower relevant industries.

2.2 State of Intelligent Technology in China and the U.S.

2.2.1 Academic Research

Searching for keywords related to AI from Scopus shows that from 2008 to 2017, the number of academic publications in China and the U.S. in AI papers increased significantly. China grew by 155.4%, and the U.S. increased by 172.1%. This growth rate is similar to the world's AI research growth rate of 168.4%. The proportion of total publications in China and the U.S. in AI papers has not changed much (Table 2-1).

Table 2-1 AI Paper Publication Amount[25]

Year	China	Percentage	U.S.	Percentage	World
	# of Papers	Percentage	# of Papers	Percentage	
2008	2,667	18.77%	2,737	19.27%	14,207
2009	3,676	28.91%	2,186	17.19%	12,717
2010	3,010	21.37%	2,277	16.17%	14,083
2011	4,388	27.34%	2,675	16.67%	16,051
2012	3,247	18.73%	2,877	16.60%	17,332
2013	2,601	15.56%	3,156	18.88%	16,717
2014	2,842	14.30%	3,883	19.54%	19,870
2015	3,471	15.22%	4,767	20.91%	22,799
2016	3,850	16.65%	4,554	19.69%	23,127
2017	4,147	17.34%	4,710	19.69%	23,922

As shown in Table 2-2, **the number of AAAI**, a leading conference of AI, publications have increased year by year. In 2019, the number of submissions was 7,745, and the number of papers received exceeded 1,000 for the first time, reaching 1,150. In terms of the number of papers accepted, the number of U.S. publications has risen steadily, but the proportion has continued to decline. **The number** and proportion of papers published in China have increased year by year, from 42 (12.1%) in 2010 to 382 (33.22%) in 2019.

Table 2-2 Comparison on AAAI[26]

Year	China		U.S.		Total
2010	42	(12.1%)	192	(55.2%)	264
2011	45	(13.1%)	195	(56.7%)	242
2012	50	(13.1%)	189	(49.3%)	294
2013	44	(15.9%)	156	(56.3%)	203
2014	104	(21.9%)	223	(47.0%)	398
2015	138	(20.5%)	326	(48.4%)	539
2016	N/A	N/A	N/A	N/A	548
2017	N/A	N/A	N/A	N/A	639
2018	265	(33.21%)	268	(33.58%)	938
2019	382	(33.22%)	264	(22.96%)	1,150

In terms of the academic impact of the authors, it can be seen in Table 2-3 that the impact of Chinese papers has dramatically improved in the past ten years, from 0.61 to 0.96. The academic impact of U.S. is consistently higher than the world average and fluctuates around 1.8.

Table 2-3 Field-Weighted Citation Impact of AI Authors by Region(2008-2017) [27]

Year	China	U.S.	World
2008	0.61	1.80	1.00
2009	0.59	1.82	1.00
2010	0.64	1.85	1.00
2011	0.71	1.74	1.00
2012	0.71	1.80	1.00
2013	0.72	1.79	1.00
2014	0.83	1.96	1.00
2015	0.93	1.79	1.00
2016	0.94	1.83	1.00
2017	0.96	1.49	1.00

In summary, the annual number of papers published by China and the U.S. in the field of AI is similar, but the academic quality of papers in the U.S. is slightly better than that in China. From 2008 to 2017, the total number of AI papers published in China and the U.S. has significantly increased by 155.4% and 172.1%, reaching 4,147 and 4,710 respectively. In 2019, the paper of China and the U.S. accounted for 33.22% and 22.96% of the total in AAAI papers. In terms of the academic influence of AI, in 2017, the field-weighted citation value of U.S. was 1.49, exceeding that of China (0.96) and the international average (1.00).

2.2.2 Higher Education Institution Performance

In the AI college ranking (Table2- 4), three universities in mainland China have entered the top ten in the world, and five in the U.S. Among them, Carnegie Mellon University and Tsinghua University ranked first and second. However, the rankings of the follow-up universities in mainland China are very scattered, and the relevant universities in the U.S. are relatively concentrated, all in the top 20 in the world.

Table 2-4 Main Academic Institution Rankings[28]

No.	China (Mainland)	Count	Faculty	World Ranking	U.S. Institution	Count	Faculty	World Ranking
Institution	Count	Faculty	World Ranking	U.S. Institution	Count	Faculty	World Ranking	1
2	Peking University	32.9	82	5	Stanford University	34.6	40	3
3	Chinese Academy of Sciences	27.4	38	6	Cornell University	33.8	43	4
4	Zhejiang University	14.7	48	22	Georgia Institute of Technology	25.4	40	7
5	Fudan University	14.3	43	23	University of California - Berkeley	21.4	44	10
6	Shanghai Jiao Tong University	10.6	32	38	Massachusetts Institute of Technology	20.7	55	11
7	Nanjing University	8.6	24	49	University of Maryland - College Park	20.7	29	11
8	Harbin Institute of Technology	5.9	8	86	University of Massachusetts Amherst	18.0	30	14
9	University of Electronic Science and Technology of China	5.2	20	96	University of Illinois at Urbana-Champaign	17.7	36	15
10	Beihang University	5.1	25	99	University of Texas at Austin	17.5	21	16

From the distribution of AI experts as illustrated in Table 2-5, there is a big difference between China and the U.S. The U.S. far surpasses China in senior AI experts and leading AI experts, occupying the vast majority of relevant experts in the world. The number of senior AI talents in China is significantly different from that in the U.S. As shown in Table2- 6, only 33.7% of the employees were employed over ten years, while the proportion of AI employees in the U.S. for more than ten years reached the highest 71.5% in the world.

Table 2-5 Distribution of AI Experts[29]

	China	U.S.	World
AI Expert	14.77%	39.71%	18,107
Senior AI Expert (H index>=30)	10.94%	54.13%	4,918
Leading AI Expert (H index>=60)	6.35%	68.00%	742

Table 2-6 AI Practitioner Distribution[30]

Years of employment	China	U.S.
0-1	2.2%	0.6%
2-3	11.5%	3.7%
4-7	28.4%	11.2%
8-10	19.2%	13.0%
more than ten years	38.7%	71.5

To sum up, the three functions of higher education, namely talent training, scientific research, and achievement transformation, are essential engines for the development of a country's AI industry. Both China and the U.S. have the world's top AI universities, but the number of universities with high-level AI discipline in the U.S. far exceeds that in China. According to CSRanking, there are three in the U.S. and two in China among the five top AI universities worldwide. However, among the top 100 universities, there are 54 in the U.S. and only 10 in China. Since 2016, China has accelerated the construction of AI in colleges and universities, opening up more than 30 AI departments in universities.

Also, the high-end intelligent technical talents are the core of the intelligent technology and the number of high-end AI talents in China is still less than that in the U.S. The U.S. is leading the way in AI domain due to its early programming and numerous talents. It owns 54.13% of global reputable AI experts, 68% of leading AI experts, and 71.5% of AI practitioners with more than ten years' experience. while, China possesses only 10.94% of reputable AI experts, 6.35% of leading AI experts and 38.7% of AI practitioners with more than ten years' experience. However, the proportion of Chinese AI talents with a master's degree or above accounts for 62.1%, ahead of 56.5% in the U.S.

2.2.3 Industry Scale

The U.S. has started investing in AI since 1999. China conducted its first investment in AI in 2005. Investment in both countries has experienced rapid growth in the past decade. As illustrated in Table 2-7, the amount of AI investment in China exceeded that of the U.S. in 2015 and 2016. As of 2017, the total amount of AI financing in the world was about 191.4 billion yuan, the total amount of AI financing in the U.S. was about 97.8 billion yuan, accounting for 50.10% of the total global financing, and China reached 63.5 billion yuan, accounting for 33.18% of the world. China and the U.S. have become the two countries with the most significant amount of financing in the field of AI. In terms of financing focus, China's AI financing accounts for computer vision and image, natural language processing and autonomous driving, whereas intelligent chips, machine learning applications, and natural language processing are the three focuses in the U.S.

Table 2-7 Investment Scale[31]

Year	China (A Hundred Million, Yuan)	U.S. (A Hundred Million, Yuan)
2008	0.03	11
2009	1	9
2010	1	11
2011	7	23
2012	5	31
2013	14	56
2014	75	86
2015	149	116
2016	238	144
2017	142	451

The size of the enterprise in the U.S. was about twice that of China. In technology platforms, machine learning applications, processor/chip, and natural language processing field, U.S. companies far surpassed China, and Chinese companies surpassed the U.S. in both speech recognition and intelligent robotics field (Table 2-8).

Table 2-8 AI Enterprise Field Distribution[32]

Field	China	U.S.
Autonomous Driving	31	41
Speech Recognition	36	24
Intelligent Robotics	125	62
Computer Vision and Image	146	190
Technology Platform	35	144
Intelligent Drone	51	91
Machine Learning Application	61	241
Processor/Chip	14	33
Natural Language Processing	92	252
Total	591	1,078

In terms of patent applications for AI, the number of patent applications by both countries is increasing, and China and the U.S. are the main applicants for AI patents. After 2014, the number of patent applications for AI in China has exploded, especially in 2015-2016, the number reached nearly 5,000 patents (Table 2-9).

Table 2-9 Numbers of Patents[33]

Year	China		U.S.		World
2007	1,143	20.91%	3,894	71.24%	5,466
2008	1,503	24.74%	3,895	64.13%	6,074
2009	1,650	27.93%	3,473	58.78%	5,908
2010	1,907	27.13%	3,845	54.70%	7,029
2011	3,116	33.37%	4,810	51.50%	9,339
2012	4,054	34.98%	6,270	54.10%	11,590
2013	5,206	37.41%	6,993	50.26%	13,915
2014	6,255	39.27%	7,678	48.21%	15,927
2015	9,209	48.15%	7,806	40.81%	19,127
2016	14,511	49.61%	8,696	29.73%	29,248

In a word, the scale of the intelligent technology industry is an essential indicator of the overall competitiveness of a country's intelligent technology, and the U.S. has distinct advantages in the three dimensions, namely the number of AI enterprises, the scale of financing and the number of patents. In terms of the number of AI enterprises, the U.S. has 42% of the global AI enterprises, compared with 23% in China. The U.S. leads the world both in the domain of financing scale and patent number. Since 2015, China has begun to surpass the U.S. in the number of new patents.

Intelligent technology is mainly divided into basic level, technical level, and application level. The AI industry in the U.S. has a relatively overall layout and has strong technological innovation advantages in the core areas of the basic level such as algorithms, chips, and data. The U.S. has about twice as many companies in the basic and technical levels as China, but the gap is slightly smaller in the application level, where China has more enterprises in intelligent robotics and voice recognition than the U.S.

2.2.4 National Strategy

The rapid development of intelligent technology will profoundly change the face of human society and the world. To seize the strategic opportunities of intelligent technology, an increasing number of countries and organizations have rushed to develop national-level development plans in both China and the U.S. (Table 2-10).

Unlike other countries, the U.S. government does not have a coordinated national strategy to increase intelligent technology investment or respond to the societal challenges of intelligent technology. The White House laid the foundation for a U.S. strategy in three separate reports in 2016. The first report, Preparing for the Future of Artificial Intelligence[34], made specific recommendations related to AI regulations, public Research and Development (R&D), automation, ethics and fairness, and security. Its companion report, National Artificial Intelligence Research and Development Strategic Plan[35], outlined a strategic plan for publicly funded R&D in AI, while the final report, Artificial Intelligence, Automation, and the Economy[36], examined in further detail the impact of automation and what policies were needed to increase the benefits of AI and mitigate its costs. President Trump's White House has taken a markedly different, free market-oriented approach to AI. In May 2018, the White House invited industry, academia, and government representatives to a summit on AI.

China announced its strategy in intelligent technology theories, technologies, and applications in its July 2017 plan, The New Generation of Artificial Intelligence Initiatives[37]. The plan is the most comprehensive of all national AI strategies, with initiatives and goals for R&D, industrialization, talent training, education and skills acquisition, standard setting and regulations, ethical norms, and security. Since the release of the New Generation Initiatives, the government has published the Three-Year Action Plan to Promote the Development of New-Generation Artificial Intelligence Industry[38]. This plan builds on the first step of the Next Generation plan to bring China's AI industry in-line with competitors by 2020. Meanwhile, the action plans in different industries have been published. Table 2-10 below lists national strategies of China and the U.S. respectively.

Table 2-10 National Strategy in China and the U.S.

Year	Institution	National Strategy	Country
1998	The Networking and Information Technology Research and Development Program	Next Generation Internet Research Act (PL.105-305)	U.S.
2013	White House	National Robotics Initiative 2.0: A Roadmap for U.S. Robotics, from Internet to Robotics (2013)	U.S.
2013.4	White House	BRAIN Initiative	U.S.
2015.10	Office of Science and Technology Policy (OSTP)	New Strategy for American Innovation	U.S.
2015.11	Center for Strategic and International Studies	Defense 2045: Assessing the Future Security Environment and Implications for Defense Policymakers	U.S.
2016.10	The Networking and Information Technology Research and Development Program	National Artificial Intelligence Research and Development Strategic Plan	U.S.
2016.10	United States National Research Council	Preparing for the Future of Artificial Intelligence	U.S.
2017.9	United States Congress	Advancement of Revolutionary Technologies Act	U.S.

2017.10	Information Technology Industry Council	AI Policy Principles	U.S.
2015.7	State Council of the People's Republic of China	Guiding Opinions of the State Council on Vigorously Advancing the "Internet Plus" Action	China
2016.3	State Council of the People's Republic of China	Outline of the 13th Five-Year Plan for the National Economic and Social Development of the People's Republic of China	China
2016.4	Ministry of Industry and Information Technology, the Ministry of Finance and the National Development and Reform Commission	Robotics Industry Development Plan (2016-2020)	China
2016.5	The CPC Central Committee and State Council	Outline of the National Strategy of Innovation-Driven Development	China
2016.5	The National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Science and Technology, Office of the Central Cyberspace Affairs Commission	"Internet Plus" AI Three-Year Action Plan Implementation	China
2016.7	State Council of the People's Republic of China	13th Five-year Plan on Science, Technology and Innovation	China
2017.3	State Council of the People's Republic of China	Report on the Work of the Government	China
2017.7	State Council of the People's Republic of China	New-generation Artificial Intelligence Initiatives	China
2017.12	Ministry of Industry and Information Technology	Three-Year Action Plan for Bolstering the Development of the Next-Generation Artificial Intelligence Industry (2018-2020)	China
2018.4	Ministry of Education	Innovative Action Plan for Artificial Intelligence in Colleges and Universities	China

Both the U.S. government and the Chinese government regard intelligent technology as the leading strategy in the future and have established a relatively complete R&D mechanism. Since the release of the AmericaCompetes Act in 2007, the U.S. has attached great importance to the design of innovative strategy. In 2013, the U.S. government spent $2.2 billion of its national budget on advanced manufacturing. The Chinese government released the Next Generation of Artificial Intelligence Initiatives[39] in 2017 and has mentioned the development of AI in the Report on the Work of the Government for three consecutive years from 2016 to 2018. By August 2018, over 20 provinces in China have issued plans, making overall arrangements for strategic guidance and project implementation.

Opinions to Take away from the State of Intelligent Technology in China and the U.S.

- The annual number of papers published by China and the U.S. in the field of AI is similar, but the academic quality of papers in the U.S. is slightly better than that in China. From 2008 to 2017, the total number of AI papers published in China and the U.S. has significantly increased by 155.4% and 172.1%, reaching 4,147 and 4,710 respectively. In 2019, the paper of China and the U.S. accounted for 33.22% and 22.96% of the total in AAAI papers. In terms of the academic influence of AI, in 2017, the field-weighted citation value of U.S. was 1.49, exceeding that of China (0.96) and the international average (1.00).
- The three functions of higher education, namely talent training, scientific research, and achievement transformation, are essential engines for the development of a country's AI industry. Both China and the U.S. have the world's top AI universities, but the number of universities with high-level AI discipline in the U.S. far exceeds that in China. According to CSRanking, there are three in the U.S. and two in China among the five top AI universities worldwide. However, among the top 100 universities, there are 54 in the U.S. and only 10 in China. Since 2016, China has accelerated the construction of AI in colleges and universities, opening up more than 30 AI departments in universities.
- The high-end intelligent technical talents are the core of the intelligent technology and the number of high-end AI talents in China is still less than that in the U.S. The U.S. is leading the way in AI domain due to its early programming and numerous talents. It owns 54.13% of global reputable AI experts, 68% of leading AI experts, and 71.5% of AI practitioners with more than ten years' experience. However, China possesses only 10.94% of reputable AI experts, 6.35% of leading AI experts and 38.7% of AI practitioners with more than ten years' experience respectively. The proportion of Chinese AI talents with a master's degree or above accounts for 62.1%, ahead of 56.5% in the U.S.
- The scale of the intelligent technology industry is an essential indicator of the overall competitiveness of a country's intelligent technology, and the U.S. has distinct advantages in the three dimensions, namely the number of AI enterprises, the scale of financing and the number of patents. In terms of the number of AI enterprises, the U.S. has 42% of the global AI enterprises, compared with 23% in China. The U.S. leads the world both in the domain of financing scale and patent number. Since 2015, China has begun to surpass the U.S. in the number of new patents.
- Intelligent technology is mainly divided into basic level, technical level, and application level. The AI industry in the U.S. has a relatively overall layout and has strong technological innovation advantages in the core areas of the basic level such as algorithms, chips, and data. The U.S. has about twice as many

companies in the basic and technical levels as China, but the gap is slightly smaller in the application level, where China has more enterprises in intelligent robotics and voice recognition than the U.S.

- Both the U.S. government and the Chinese government regard intelligent technology as the leading strategy in the future and have established a relatively complete R&D mechanism. Since the release of the America Competes Act in 2007, the U.S. has attached great importance to the design of innovative strategy. In 2013, the U.S. government spent $2.2 billion of its national budget on advanced manufacturing. The Chinese government released the Next Generation of Artificial Intelligence Initiatives in 2017 and has mentioned the development of AI in the Report on the Work of the Government for three consecutive years from 2016 to 2018. By August 2018, over 20 provinces in China have issued plans, making overall arrangements for strategic guidance and project implementation.

2.3 The Framework of Intelligent Technology for Education

Technology has been a critical factor affecting education ecology[40]. Every major technological reformation will bring about innovation and development for environment, methods, modes and content in teaching. Intelligent technology, as a new form of technology with "intelligence", exert influence on many aspects. It's a supplement to the education ecology, and it also interacts with other elements in education ecology, which promotes the reshaping of the relationship between the various elements in education ecology. In general, the impact of the intelligent technology on education ecology can be reflected in the following three aspects. The framework is shown in Figure 2-1.

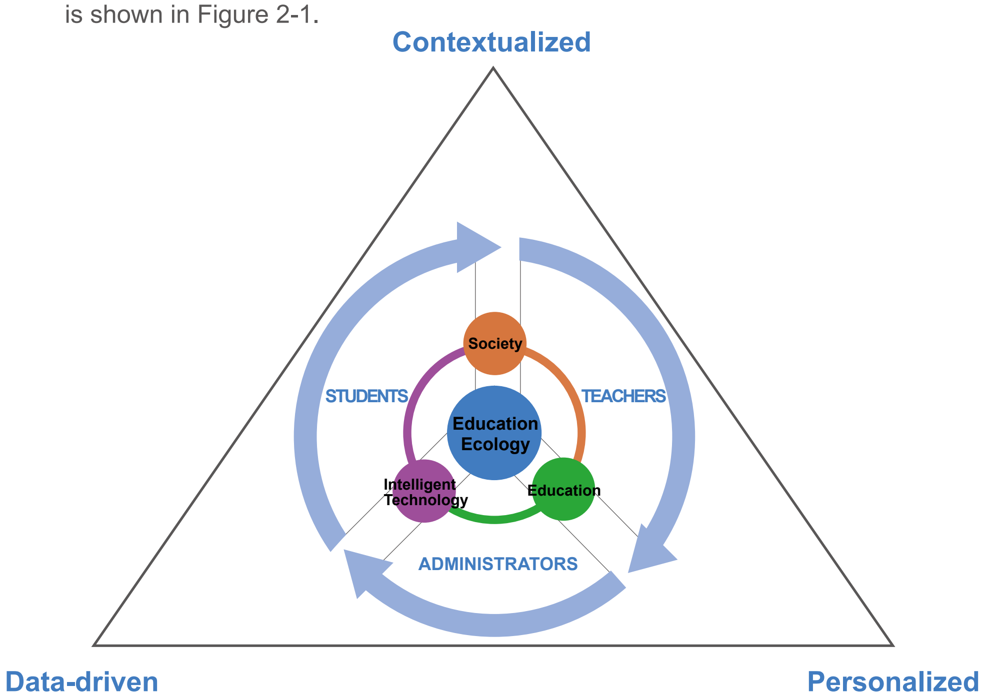


Figure 2-1 The Framework of Intelligent Technology for Education

● Intelligent technology, the "new species" in education ecology, enriches the education ecology.

"Education is a social activity that leads to self-improvement"[41]. The core of education ecology is to explore the relationship between people, education and surrounding environmental elements. Technology is passive in the traditional education ecology, which is affected by other roles (such as learners, teachers, managers, learning environments, etc.) and their relations, so it makes limited efforts to the educational reformation. As a result, there is a pervasive phenomenon that new technology only strengthens traditional education but not boosts the development of education in the intelligent era. Intelligent technology has such intelligent characteristics as self-adaptability, self-evolution, and two-way interaction, which enables it to actively participate in the construction of education ecology, and enriches the content of teaching environment, content, mode and other elements. Intelligent technology is adaptive, self-evolved and interactive, which enables it to take an active role in participating in the construction of education ecology and enriches the environment, content and modes of teaching. In teaching environment, the intelligent technology not only promotes the transformation from traditional teaching environment to the intelligent one with the methods of full recording, overall perception, and personalized learning plan, but also integrates virtual learning environment with the physical one, by which the learning environment becomes more open and ubiquitous; in teaching content, for one thing, the intelligent technology enables current teaching content to adopt various ways in organizing and expressing, for another, the intelligent technology with much technical knowledge can also extremely enrich the current teaching content; in teaching mode, the intelligent technology can support the popularization of personalized and adaptive learning methods, and promote the development of students in all-round education.

● Intelligent technology, the "toolbox" of education ecology, expands the behavior of all subjects in the education ecology.

It's basic for the intelligent technology to make people get educated in education ecology[42]. Thus, the role of intelligent technology in the education ecology must focus on the basic question, that is, how intelligent technology affects learners, educators, and managers in the education ecology. Intelligent technology facilitates the behavior of teaching subjects, which mainly reflected in:

(1) Intelligent technology can make learners more positive and involved in learning, and the learner is more prominent than other roles in education ecology. Intelligent technology has changed the traditional relation between teachers and students and the model of knowledge production. Students are no longer passively receiving knowledge from teachers, but can actively acquire knowledge through intelligent technology and participate in student-centered learning activities to achieve deep learning.

(2) Intelligent technology provides teachers and managers with more personalized methods in teaching and management to make teaching more effective, accurate and scientific. Intelligent technology in education, as characterized by autonomy, adaptability, etc., can serve students, teachers and managers according to their own requirement. For instance, through intelligent cross-media, teachers can provide personalized learning resources and activate learners' senses in multi-channel to improve their interest and efficiency in learning; through accurate evaluation to learners, the intelligent technology can support teachers in preparing lessons intelligently, assigning homework and conducting teaching; through collecting and analyzing the big data in learning, the intelligent technology can make the educational management scientific and make the educational decision-making intelligent.

(3) Intelligent technology and educational subjects are able to supplement each other, and thus educational intelligence can be extended by combining humans and computers. Human intelligence has great advantages in perception, reasoning, induction, and learning, whereas machine intelligence is better than human intelligence in searching, calculation, storage, and optimization. The two intelligences are highly complementary[43]. In the intelligent teaching environment, teachers and students both become the constitutive source of the learning life with human-computer integration, which arouses the realization, educational occurrence in learning, changes the source of binary system in teaching, realizes the new educational form and the new learning community with human-computer integration, intelligent simulation, and human involved.

- Intelligent technology, the "catalyst" for the development of education ecology, promotes education ecology to get the new characteristics: contextualized, personalized and data-driven.

In the intelligent era, it is a significant goal for education ecology to realize personalized support for subjects of education in diverse situations. The advent of intelligent technology has made education further close towards this goal. In terms of contextualized, intelligent technology can make a reasonable combination of technologies based on various educational situations. The according educational contents and services can be presented to different schools, educational subjects, times and scenarios. In terms of personalized, intelligent technology can provide sophisticated and effective personalized education services according to the characteristics and demands of teachers and students. In terms of data-driven, the big data benefits from the popularity and development of mobile Internet, intelligent terminals, the Internet of Things, and sensors, and originates from the dramatic increase of various devices and Internet applications. The big data has developed rapidly, which has effectively promoted machine learning and other technologies, and thereby seems to be extremely potential in the application of intelligent services.

In summary, with the influence of intelligent technology, the education ecosystem has a new structure, as shown in Figure 2-1. In the structure, intelligent technology and society, education, and educational subjects (teachers, students, and managers) form the core elements of the education ecology. Intelligent technology and each element are interconnected, influencing each other and achieving the dynamic balance. With the interactive impact of each element, the education ecology is transformed to the new form featuring contextualized, personalized, and data-driven, so that the all-round development of people can be realized in an intelligent society.

2.4 Ethical Concerns of Intelligent Technology in Education

In this section, general ethical concerns that arise from AI in education are mentioned. We begin with a general discussion of ethical obligations. Ethical obligations concern the fair and equitable treatment of people. Acting ethically might be distinguished from acting legally. One is legally obligated not to injure others except in very exceptional circumstances. Causing physical or psychological harm to others is generally a violation of the law in most places and most circumstances.

In the domain of medical care, those legal obligations are extended to include the ethical principle of not causing harm to patients. The Hippocratic oath – do not harm – has been regarded as a fundamental ethical principle in medical care for centuries.

In the domain of education, a similar ethical principle called the Education Oath was introduced by Spector[44] which states that: (a) do nothing to impair learning and instruction; (b) do what you can to improve learning and instruction; (c) base your actions on evidence that you and others have gathered and analyzed; (d) share the principles of instruction that you have learned with others; and, (e) respect the individual rights of all those with whom you interact.

What is embedded in that principle are obligations to others (e.g., learners), to the discipline (e.g., educational technology), to practice (e.g., evidence-based practice), to colleagues (e.g., share lessons learned), and to the community at large. There is also an implicit obligation to oneself – namely, as an educator, be a responsible agent.

Within the context of the broader principles of acting ethically as an educator, some specific areas of concern as follows arise:

1. the privacy rights of learners;
2. non-disclosure agreements made with business enterprises;
3. the rights of parents to educational progress and records of children;
4. conducting research involving learners;
5. the digital divide created by using new technologies not available to all;
6. treatment of those with disabilities and special needs;
7. the impact of intelligent technologies on teaching practice and teachers;
8. the impact of intelligent technologies on learning processes, support for learning and learners.

In each of these cases, one can ask what benefits and what harm can result from using technologies. For example, one can argue that smart learning technologies can accelerate the learning of advanced students, but it can also put less well-prepared learners at a disadvantage; that is to say, while some learners might benefit, others might be harmed.

Likewise, initially, new technologies are typically developed for representative learners who are generally healthy and free from learning disabilities and other impediments. As a result, some learners may benefit, while others might be put at a disadvantage.

Based on the analysis above, we believe that the ethics of intelligent technology for education application involves defining the subject of responsibility, protecting human privacy, non-biasing and non-discrimination, making decision-making transparent, protecting human interests from infringement, harmonious coexistence of people, society, machines and nature, early warning of dangerous behaviors, system stability, and control, etc. It can be summed up as the principle of accountability, principle of privacy, principle of equality, principle of transparency, principle of noharm, principle of identity, principle of precaution and principle of stability. These eight aspects reflect the characteristics of AI ethics which can be summed up as the model of "APETHICS[45]".

As shown in Figure 2-2, we take the initial letter C of the word "caution" for the precaution principle, and the rest take the first letter of the word to indicate the principle. The abbreviation "A" represents the principle of accountability in this model, and can also be regarded as the initial letter of "Artificial" in AI. "P" represents the privacy principle in this model, and can also be regarded as "+" (Plus). The first letter of the word, which happens to be the word "Ethics," is a combination of A (rtificial Intelligence) & P(lus) & Ethics. The following is the explanation about these principles.

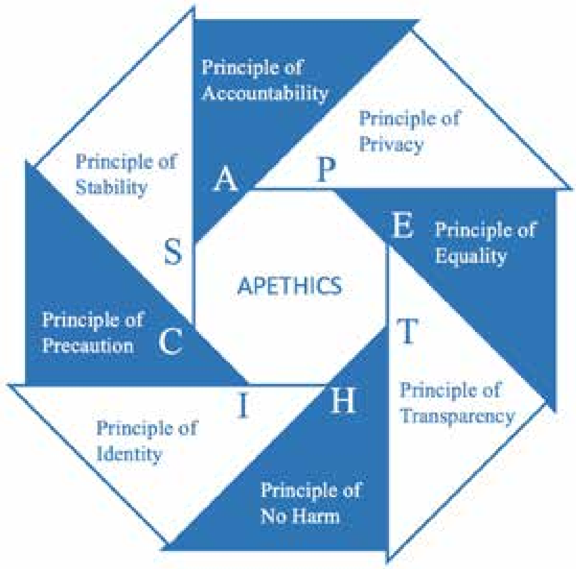


Figure 2-2 Conceptual Model of Intelligent Technology Ethics "APETHICS"

• Principle of Accountability

The "principle of accountability" mainly refers to the definition of the main body of responsibility. It clearly explains why and how the designers and deployers of intelligent systems assume their due responsibilities by establishing specific laws. Accountability is a liability system for all types of actors designed to solve problems that no one is responsible for. It's pretty hard to clarify the man who should be accountable for the problems. For instance, when self-driving cars making intelligent decisions independently results in injuries to people, in the case we should figure out who should be responsible for failures and accidents of self-driving cars. Maybe the driver, the manufacturer, or the corporate that designs AI? It is difficult to make the judgment clear. A general response was made by Preparing for the Future of Artificial Intelligence[46], based on the principles of risk assessment and cost-benefit, which made a decision that the subject who research and apply the AI should behave under the pressure of regulation. An attempt was made to clarify the subject that should be responsible, in Report of COMEST on Robotics Ethics[47] published jointly by UNESCO and COMEST. It has played a certain role in alleviating the problems of imperfect policy formulation, unclear subject responsibility, inadequate supervision responsibility, and frequent harm to human behavior. Promote responsibility by accountability and implement the responsibilities of scientists, designers, policymakers, and users at all levels, and strive to achieve the goal of "when the blame is blamed, accountability must be strict."

● Principle of Privacy

Cihai, an encyclopedia on Chinese characters, defines privacy as the right citizens to not disclose the facts and secrets related to their private life in accordance with the law. The Universal Declaration of Human Rights[48] once clearly stated that “nobody's private life, family, home, and communication can be interfered arbitrarily, and his honor and reputation must not be attacked”. In the AI era, the "principle of privacy" emphasizes that people should have the right to access, manage and control the data generated by intelligent machines to ensure that no information of users is provided to any unauthorized individuals or businesses. Nowadays, China’s laws on how to protect the privacy of learners from being violated in the era of intelligent technology are still not perfect. The laws on the definition of privacy violation, the specific acts of privacy violation, and the punishment of violation are still lacking. If the learner’s privacy is violated, then there is no such a good way to find a suitable solution. AI researchers beyond China advocate how to protect personal privacy during deep learning[49]. In the AI era, it will be indispensable to protect the privacy of learners, so as to promote the development of society by a harmonious way in the long run.

● Principle of Equality

“Principle of Equality" refers to eliminating the algorithm discrimination caused by algorithm deviation. The analysis on individual normal status is based on race, lifestyle or residence place, and the risk from this algorithm can be avoided. The essence of "algorithmic discrimination" is to predict users’ future by using past data. If the algorithm is based on inaccurate and biased data, then the biased result will come out. Many researchers believe that numbers always tell the truth, they can reflect facts and even serve society justly. However, existing research has found that algorithmic based on data can also result in wrong and biased outcome, also in which the digital discrimination would be even more secretive than that has occurred previously. Amazon has tried with price discrimination, which means that each consumer would buy the same product with different prices[50]. In order to eliminate this risk, the personnel controlling the data should identify some deviation of data and adopt appropriate strategies to evaluate the impact caused by the deviation.

● Principle of Transparency

The “principle of transparency” refers to the rules and algorithms of the machine that everyone can understand. Machines need to understand the learner's behavior to make decisions, and everyone, including learners, must understand how technology treats and analyzes itself. What if a student’s portrait is incorrect and it cannot be corrected? What should we do when the system collects students’ information but draws wrong conclusions? Currently, the process of "black box" making decision is discussed by lots of people. The "black box" can make decision independently. Many researchers try to figure out what’s exactly going on inside it. The tools, like counterfactual investigations, are used to research the "black box”[51]. The opinion that it’s necessary to do the research comes out from the Science[52]. The Defense Advanced Research Projects Agency (DARPA) has invested $ 70 million in a new program called "Explainable AI" so as to explain the deep learning that supports the drone and operations of mining intelligence[53]. Ethics is very closely related with design. The biases in social and culture must be noticed in developing AI to ensure that algorithms are universal applicable, and that algorithm discrimination is eliminated.

● Principle of No Harm

The "principle of humanity" can also be understood as the Principle of Do Not Harm, which refers to the harm that must be prevented by the unconscious behavior of the machine, regardless of any circumstances, culture, race, ethnicity, economic status, age, region, etc. We must uphold the rights and interests of human beings and must not infringe on human rights. There are both pros and cons. While intelligent technology offers convenience to human life and production, it will also bring devastating disasters to human beings due to improper application of technology. Google conducts behavioral tests on the behavior of the AI called DeepMind, and designs games, such as "collecting fruit" and “wolves hunting" to simulate the situation to see whether the DeepMind systems fight with each other or cooperate when several of them have similar or contrary goals. The result in preliminary stage of the research shows that robots and AI have "killer potential", they do not naturally put humans’ interests in first place[54], so technicians need to take humanity into account.

● Principle of Identity

The “principle of identity” refers to defining the “social identity” of intelligent machines, and thereby regulating their rights and obligations. For instance, it should be identified whether the citizenship and human right should be granted to robots or not. Intelligent machines are physical part of the world, and they are not independent. It is getting increasingly important to identify the intelligent machines. AI has been integrated into the field of education, for which the structure of human society is getting affected, with the form transformed from the human-society-nature to human-society-nature-intelligent machine. Two of the Chinese ancient theories, "unity of nature and humanity" from pre-Qin Dynasty and “integration of all things” from Song Dynasty and Ming Dynasty, all put the emphasis on the integrity, harmony, and unity between people themselves, people and things, people and society, people and nature[55]. In the era of AI, the integrity, harmony, and unity between people themselves, people and intelligent machines, people and society, people and nature, machines and nature, should be emphasized, so as to ensure the balance among technology, teachers, students, and environment.

● Principle of Precaution

The “principle of precaution” emphasizes the needs to take actions to avoid harm when machines are harmful to humans. Therefore, human beings need to regulate the behavior of machines. Through algorithms and functions, make the intelligent system get rid of bad behaviors[56] and reduce the occurrence of events that endanger humans.

● Principle of Stability

The “principle of stability” means that the system is stable and the decision is accurate, and the system does not exhibit undesirable behaviors or functional changes. It should be ensured that intelligent systems should have reliable and safe operation, should avoid injury in unforeseen circumstances, or should not be maliciously manipulated to carry out harmful actions.

Factors of Infusing ICT into Education in both China and the U.S.

The unprecedented development of intelligent technology reshapes the education to a large degree. Stakeholders of education such as teachers, students, school managers, parents etc., need to face up the opportunities and challenges brought by the intelligent technology. Thus, factors of infusing ICT into education in both China and the U.S. are well worth exploring. This part focuses on factors including public and private education, schools in rural areas, class size for personalized learning, student-teacher ratio for differentiated instruction, family-school communication, opportunity for entering public school, service system for ICT in education, broadband Internet, digital education resources, teacher professional development with ICT, with an attempt to lay a solid foundation for the in-depth study on influential factors of infusing ICT into education in both China and the U.S.

3.1 Public and Private Education

In China, there were 519,900 schools of all types and at all levels in the country, with 276 million students enrolled in various levels of education according to the national education statistics in 2018. Data in Table 3-1 shows that there were 180,700 private kindergartens, private primary schools, private junior high schools and private high schools in total, accounting for 36.56% of the total with 44,889,200 students which accounted for 19.04% of the total[57].

Table 3-1 Private Education in China in 2018

School Level \ Indicator	School Quantity	Proportion	Student Quantity (10 thousand)	Proportion	Income Per Student (yuan)	Size (100 million yuan)
Kindergartens	165,800	62.16%	2639.78	56.69%	N/A	N N/A
Primary Schools	6,179	3.82%	884.57	8.56%	3,417	295
Junior High Schools	5,462	10.51%	636.30	13.68%	4,378	257
High Schools	3,216	23.41%	328.27	13.82%	10,274	322

In the U.S., there were 98,280 public schools, consisting of 91,420 traditional public schools and 6,860 public charter schools in school year 2015-2016[58]. Moreover, there were 34,576 private schools, serving 5.7 million PK-12 students. Private schools accounted for 25% of the nation's schools and enrolled 10% of all PK-12 students[59]. Detailed data is shown in Table 3-2.

Table 3-2 Private Education in the U.S.

School Level \ Indicator	Number of Schools	Number of Students	Full-time-Equivalent Teachers	Average Number of Students
Elementary	21,907	2,190,500	202,628	100.0
Secondary	2,946	774,499	69,491	262.9
Combined	9,723	1,938,598	209,438	199.4

To sum up, as a supplement to public education, private education represents the maturity of a country's educational development. In China, the focus of private education is the two non-compulsory educational stages, namely non-governmental senior high school and non-governmental kindergarten. The quality of non-governmental higher education still has a relatively long way to go. In the U.S., private education plays a significant role in basic education and higher education. The U.S. also owns many world-class private universities.

3.2 School in Rural Areas

In China, the rural population accounts for 70% of the national population. The wide range of rural education is still the bulk of education in China. According to the China Rural Education Development Report 2019, the number of students in compulsory education reached 145 million in 2017, and the number of compulsory education schools (including small schools in rural area) was 321,901. Among them, the number of schools in urban areas was 41,196, with an increase of 2.72% from 2016. The number in towns was 79,072, with an increase of 0.46% from 2016. The number in rural areas was 201,633, with a decrease of 3.70% from 2016[60].

In the U.S., rural students make up about one-fifth of the national students and represent a variety of experiences and environments. Rural education is a vital area of education. About half of the school districts in the U.S., one-third of schools and one-fifth of students were located in rural areas[61]. The percentage of students attending public schools with different levels of poverty varies depending on the location of the school (i.e., city, suburb, town or rural). In the 2015-16 school year, approximately 40% of urban school students were in high-poor schools, while 20% of students attended urban schools, 18% of students attending suburban schools, and 15% of students attending rural schools[62].

In a word, rural education occupies a large proportion in the basic education of both China and the U.S., and the difference between urban and rural areas is still the core that needs to be paid attention to in the process of promoting the balanced education in both countries. In China, rural students account for two-thirds of the total number of students in schools, and schools in rural areas (towns and countryside) account for about two-thirds of the total number of schools. Rural education remains a major part of China's compulsory education. In the U.S., with a fifth of the students, a third of the schools and half of the school districts in rural areas, rural education is also a concern.

3.3 Class Size for Personalized Learning

The 2017 China Education Index published by Changjiang Education Research Institute (CERI) reflects the capabilities of educational governance, effects of improvement and levels of development in the country and even all the provinces (autonomous regions and municipalities) in 2017, in terms of scale, input, quality, information, equity, contribution, and innovation[63]. The top 10 educational provinces (autonomous regions and municipalities) in China are Beijing, Shanghai, Jiangsu, Guangdong, Shandong, Shanxi, Zhejiang, Hubei, Sichuan, and Tianjin.

China's Ministry of Education stipulates that the standard class size is 45 students for primary schools and 50 students for high schools. 98% of the classes in elementary and junior high schools have reached the standard class size of 45 and 50 respectively in 2018. Taking Beijing as an example. The number of students in each class for primary schools and junior high schools shall not exceed 40 in principle according to Beijing Municipal Education Commission, and that in senior high schools shall not exceed 45. As illustrated in Table3-3, the average class size in Beijing of all levels reached the standard. Meanwhile, provinces with large population like Shandong, Hubei and Sichuan did not fulfill the standard. However, each of these provinces managed to reduce more than 3,300 oversized classes (class with over 66 students) in 2018.

Table 3-3 Primary and High School Class Size of Top 10 Province

Indicator / School Level	Primary School	Junior High School	Senior High School
Beijing	34	30	32
Shanghai	38	33	34
Jiangsu	43	43	46
Guangdong	40	45	52
Shandong	43	50	56
Shanxi	36	45	55
Zhejiang	39	40	44
Hubei	40	47	55
Sichuan	41	47	58
Tianjin	36	38	42

In the U.S. News Best States for Education Ranking 2017[64], the states are ranked on performance in higher education, primary and secondary education as well as pre-K education. The indicators include percentages of adults with associate degrees or higher; the proportions of students finishing public four-year and two-year college programs within 150 percent of the regular time; the average tuition and fees for in-state students at public institutions and the average debt load of graduates from public and private colleges. The states also are ranked on percentages of children enrolled in preschool and on ten basic criteria for the quality of preschools, including teachers' training, class size and student-teacher ratio. They are compared in national testing of eighth-graders in math and reading, in rates of graduation from high school and readiness for college. This report chooses top 10 states in the ranking, including Massachusetts, New Jersey, New Hampshire, Connecticut, Maryland, Nebraska, Washington, Iowa, Utah, and Virginia.

The states and districts in the U.S. have different laws and policies toward class size. For example, in Boston, Massachusetts, according to its Union Contract, the limit of K- Grade 2 class size is 22 students, 25 students for Grades 3-5, 28 students for Grades 6-8, and 31 students for Grade 9-12[65]. Table 3-4 shows the class size of 10 states K-12 public schools.

Table 3-4 K-12 Public School Class Size in the U.S.

State	Class Size
Massachusetts	17.7-21.4
New Jersey	18
New Hampshire	16.2
Connecticut	18.4-21.2
Maryland	20.46
Nebraska	22
Washington	17-25
Iowa	18.6-21.7
Utah	24-29
Virginia	grades1-3: <30 grades4-6:<35[66]

In brief, class size is one of the key factors in the process of promoting personalized learning and effective use of ICT, and there are great differences between China and the U.S in the class size of basic education. The U.S. has a relative smaller class size than China in overall K-12 schools. In addition, both China and the U.S. has class size reduction plan, i.e., "Oversize Class Size Reduction[67]" in China and class size reduction in many states and districts[68].

3.4 Student-Teacher Ratio for Differentiated Instruction

In China, there is no national regulation for the student-teacher ratio in schools but there are standards for school faculty-student ratio. For schools located in urban area, the faculty-student ratio is 1:12.5 for senior high school, 1:13.5 for junior high school, and 1:19 for primary school[69]. Everything is determined according to the situation of the local school. In 2018, the student-teacher ratio is 17:1 in primary school, 13:1 in junior high school and 15:1 in senior high school. Table 3-5, 3-6, and 3-7 illustrate detailed situation of ten provinces from primary school to high school.

Table 3-5 General Situation of Primary School in Ten Provinces

Indicator / School Level	Number of Schools	Scale of Schools	Number of Students	Number of Teachers (10 thousand)	Class Size	Student-Teacher Ratio
Beijing	984	883	86.84	6.45	14:1	14:1
Shanghai	741	1,059	78.49	5.47	14:1	14:1
Jiangsu	4,075	1,326	540.21	30.02	18:1	18:1
Guangdong	10,258	918	941.96	50.78	19:1	19:1
Shandong	9,738	728	708.47	42.19	17:1	17:1
Shanxi	4,752	531	252.31	15.91	16:1	16:1
Zhejiang	3,286	1,077	354.01	20.51	17:1	17:1
Hubei	5,378	659	354.57	20.33	17:1	17:1
Sichuan	5,721	965	551.84	32.5	17:1	17:1
Tianjin	857	756	64.80	4.3	15:1	15:1

Table 3-6 General Situation of Junior High School in Ten Provinces

Indicator / School Level	Number of Schools	Scale of Schools	Number of Students	Number of Teachers (10 thousand)	Student-Teacher Ratio
Beijing	345	772	26.64	3.45	8:1
Shanghai	560	735	41.17	3.93	10:1
Jiangsu	2,148	972	208.69	18.19	11:1
Guangdong	3,536	1,007	356.1	27.98	13:1
Shandong	2,968	1,110	329.36	27.59	12:1
Shaanxi	1,621	648	104.97	10.00	11:1
Zhejiang	1,735	898	155.85	12.47	13:1
Hubei	2,041	729	148.71	12.90	12:1
Sichuan	3,722	669	249.14	20.13	12:1
Tianjin	338	776	26.22	2.69	10:1

Table 3-7 General Situation of Senior High School in Ten Provinces

Indicator / School Level	Number of Schools	Scale of Schools	Number of Students	Number of Teachers (10 thousand)	Student-Teacher Ratio
Beijing	304	539	16.4	2.15	8:1
Shanghai	258	616	15.89	1.79	9:1
Jiangsu	564	1,672	94.34	9.47	10:1
Guangdong	1,030	1,838	189.27	15.14	13:1
Shandong	592	2,795	165.49	13.44	12:1
Shaanxi	473	1,600	75.66	5.73	13:1
Zhejiang	580	1,333	77.34	6.96	11:1
Hubei	532	1,540	81.94	6.59	12:1
Sichuan	754	1,874	141.3	9.75	15:1
Tianjin	187	875	16.36	1.65	10:1

In China there are standards for student-teacher ratio in college and university. For most universities like comprehensive university and normal university, the standard student-teacher ratio is 18:1 in undergraduate level, and 16:1 for medical college[70]. Table 3-8 shows the details of ten specific provinces. According to the QS World University Rankings in 2019, we select the top 1 university and a provincial university in these ten provinces (autonomous regions and municipalities).

Table 3-8 General Situation of University in Ten Provinces

School Level \ Indicator	Number of Schools	Examples	Number of Undergraduates	Number of Teachers	Student-Teacher Ratio
Beijing	92	Tsinghua University	15,619	3,461	9:1
		Beijing University of Technology	13,817	1,861	16:1
Shanghai	64	Fudan University	13,361	2,871	15:1
		Shanghai University	20,448	3,022	18:1
Jiangsu	167	Nanjing University	13,243	2,195	15:1
		Soochow University	27,136	2,926	15:1
Guangdong	151	Sun Yat-Sen University	32,307	3,751	18:1
		South China Normal University	24,674	2,157	21:1
Shandong	145	Shandong University	40,789	4,153	17:1
		Qingdao University	34,000	2,595	20:1
Shaanxi	93	Xi'an Jiaotong University	17,538	3,022	13:1
		Northwest University	13,000	1,721	23:1
Zhejiang	107	Zhejiang University	24,878	3,611	15:1
		Zhejiang University of Finance & Economics	15,000	1,090	18:1
Hubei	129	Wuhan University	29,405	3,775	19:1
		Wuhan University of Science and Technology	24,523	1,600	18:1
Sichuan	109	Sichuan University	37,000	5,494	18:1
		Chengdu University of Technology	30,540	3,409	23:1
Tianjin	57	Nankai University	15,120	2,046	17:1
		Tianjin Medical University	10,132	8,429	12:1

In the U.S., the student-teacher ratio is 14:1 in primary school, 15:1 in junior high school and 15:1 in senior high school. Table 3-9 shows details in K-12 schools for each state. Similarly, different states and school districts have different regulation and standards toward student-teacher ratio in K-12 education. For instance, in Virginia the student-teacher ratio limit is 24:1 for K level, 24:1 for Grades 1-3, and 25:1 for Grades 4-6.

Likewise, based on the QS World University Rankings in 2019, this report selects the top universities of each state, one private and one public in most cases, and quantifies their specific condition in school scale, student enrollment, Full-time Equivalent (FTE) teacher, and student-teacher ratio. Overall, public colleges gain more advantages in school scale as private colleges usually have better student-teacher ratio. Table 3-10 illustrates the detailed data of each indicator as mentioned before.

Table 3-9 General Situation of Schools and Classes of K-12 in the U.S.

Indicator hool vel	Number of Schools	Number of Students	Number of Teachers	Student-Teacher Ratio[71]
Massachusetts	1,847	954,034	73,419.70	13:1
New Jersey	2,516	1,370,000	116,351	12:1
New Hampshire	488	176,685	14,667	12:1
Connecticut	1,493	535,025	52,230.00	13:1
Maryland	1,435	878,731	57,718	15:1
Nebraska	1,086	316,066	23,767.92	16:1
Washington	2,465	1,086,687	65,310	19:1
Iowa	1,347	498,826	36,279	14:1
Utah	1,055	646,178	26,610	23:1
Virginia	2,138	1,282,413	89,389	15:1

Table 3-10 General Situation of Schools and Classes of College and University

Indicator School Level	Number of Schools			Examples	Scale of Schools	Enrollment	Number of FTE Teachers	Student-Teacher Ratio
	4-Year	2-Year	Total					
Massachusetts	95	21	116					
				Harvard University				
				5,076 acres	6,766	2,400.00	6:1	6:1
				University of Massachusetts—Amherst				
				1,463 acres	23,388	1,400	18:1	18:1
New Jersey	53	22	75					
				Princeton University				
				600 acres	5,394	1,261	5:1	5:1
				Rutgers University--New Brunswick				
				2,685 acres	35,641	4,000	13:1	13:1
New Hampshire	17	8	25					
				Dartmouth College				
				237 acres	4,410	952	7:1	7:1
				University of New Hampshire				
				2,600 acres	12,967	N/A	18:1	18:1

Connecticut	31	12	43					
				Yale University				
				345 acres	5,746	4,483.00	6:1	6:1
				University of Connecticut				
				4,109 acres	19,241	8,234.00	16:1	16:1
Maryland	35	21	56					
				Johns Hopkins University				
				140 acres	6,109	4,663	7:1	7:1
				University of Maryland--College Park				
				1,335 acres	29,868	4,646	18:1	18:1
Nebraska	28	13	41					
	Note: Both are public colleges			University of Nebraska--Lincoln				
				623 acres	20,954.00	3,797.07	21:1	21:1
				University of Nebraska--Omaha				
				694 acres	12,624	500	17:1	17:1
Washington	65	15	80					
				University of Washington				
				634 acres	31,331	4,380	19:1	19:1
				Washington State University				
				1,742 acres	25,277	7,284	15:1	15:1
Iowa	44	18	62					
	Note: Both are public colleges			University of Iowa				
				1,730 acres	24,503	3,027	16:1	16:1
				Iowa State University				
				1,813 acres	30,406	6,000	19:1	19:1
Utah	29	3	32					
				Brigham Young University—Provo				
				557 acres	31,233	1,793	20:1	20:1
				University of Utah	University of Utah			
				1,535 acres	24,635	5,374	16:1	16:1
Virginia	78	44	122					
				College of William and Mary				
				1,200 acres	6,285	2,500	11:1	11:1
				University of Virginia				
				1,682 acres	16,655	3,014	14:1	14:1

To Conclude, the level of the student-teacher ratio is a potential condition to promote personalized learning as well as differentiated instruction, and it is approximately close between China and the U.S.

3.5 Family-School Communication

As Suhomlinski said, “The effect of education depends on the consistency of education between the school and the family. Without this consistency, the teaching and education process of the school will collapse like a house made of paper.”

In China, the Committee for The Wellbeing of The Youth of Ministry of Education[72], the Family Education Professional Commission of the Chinese Society of Education (shortly known as the Family Education Professional Commission of CSE) [73], China Family Education Institute[74], Chinese Academy of Family Education[75] and the Family-School Co-development Committee in many places make extraordinary contributions to the harmonious development of parents and schools from different perspectives. Taking the Family Education Professional Commission of CSE as an example. The commission established in March 2003 with an attempt to “promote family education research, popularize family education knowledge, improve cooperation between family and school as well as help parents and children to grow together.” Adhering to the values of “maintaining academic integrity, promoting the public welfare and respecting intellectual property rights”, through holding academic conferences such as the International Forum on Family Education, establishing the expert panel of family education lectures and organizing a national tour of the "New Parents' Hall". It lays a solid theoretical foundation for the development of a harmonious and organized relationship between family and school. While in the U.S., there are several organizations focusing on parental school communication, for instance, National Parent Teacher Association (PTA) [76], The National Association for Family, School and Community Engagement (NAFSCE) [77], and National Education Association (NEA)[78] , etc. Among these organizations, PTA is the most influential one. Founded in 1897 as the National Congress of Mothers by Alice McLellan Birney and Phoebe Apperson Hearst, National PTA is a powerful voice for all children, a relevant resource for families and communities, and a strong advocate for public education. For more than 120 years, National PTA has worked toward bettering the lives of every child in education, health, and safety. Today’s PTA is a network of millions of families, students, teachers, administrators, and business and community leaders devoted to the educational success of children and the promotion of family engagement in schools.

In China, concerns about the progress of the current practice on parental school communication, the National Family Education Survey Report (2018)[79] released recently focuses on the whole country and investigates the current situation of family education in primary and secondary schools in China. The samples covered 31 provinces (autonomous regions and municipalities) in China and 325 districts and counties in Xinjiang Production and Construction Corps of more than 110,000 fourth-grade students, over 70,000 eighth-grade students and more than 30,000 head teachers of these students. The results in Figure 3-1 shows that, as for the head teacher in grade 4 and grade 8, what parents most concern about their children was “test scores” (88.3%, 90.1%), which was significantly higher than “behavioral issues” (35.4%, 42.3%), “hobbies or specialties” (6.6%, 2.1%), “psychological status” (14.2%, 26.7%) and other aspects.

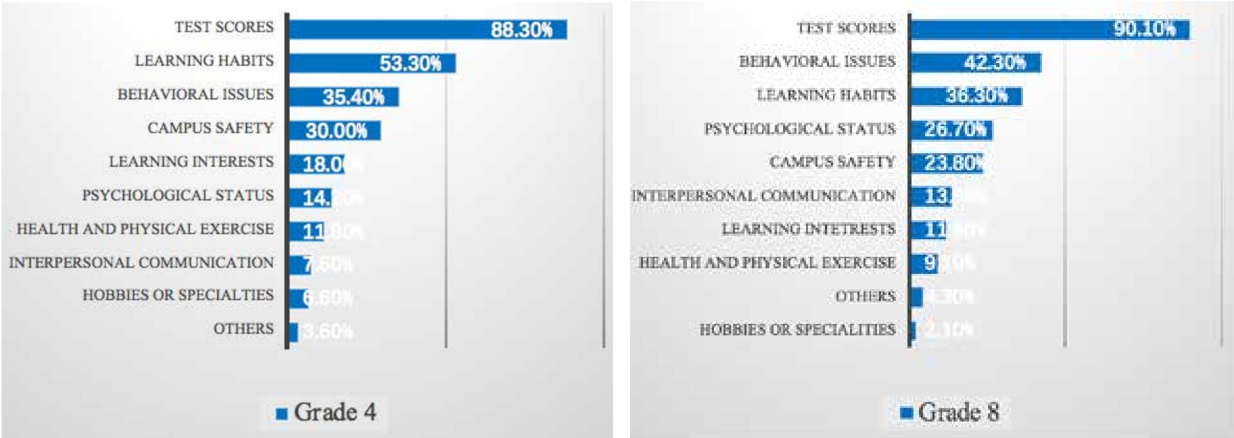


Figure 3-1 What Parents Most Concern About Their Children—From the Head Teachers in Grade 4 and Grade 8

As a result, according to the impression of the head teachers on parents, 33.7% of the head teachers in grade 4 and 35.6% in grade 8 reported that more than half (over 50%, the same below) of the parents believed that "educating children is the responsibility of schools and teachers", while 15.8% of the head teachers in grade 4 and 14.4% of the head teachers in grade 8 reported that most (more than 80%, the same below) of the parents agreed with this statement.

As shown in Figure 3-2, in terms of the communication between head teachers and parents, the most common content was "learning habits" (57.2%, 47.3%) and "test scores" (52.3%, 61.4%), significantly higher than "family education" (24.6%, 18.3%), "learning interests" (18.0%, 11.8%) and "health and physical exercise" (16.0%, 15.4%).

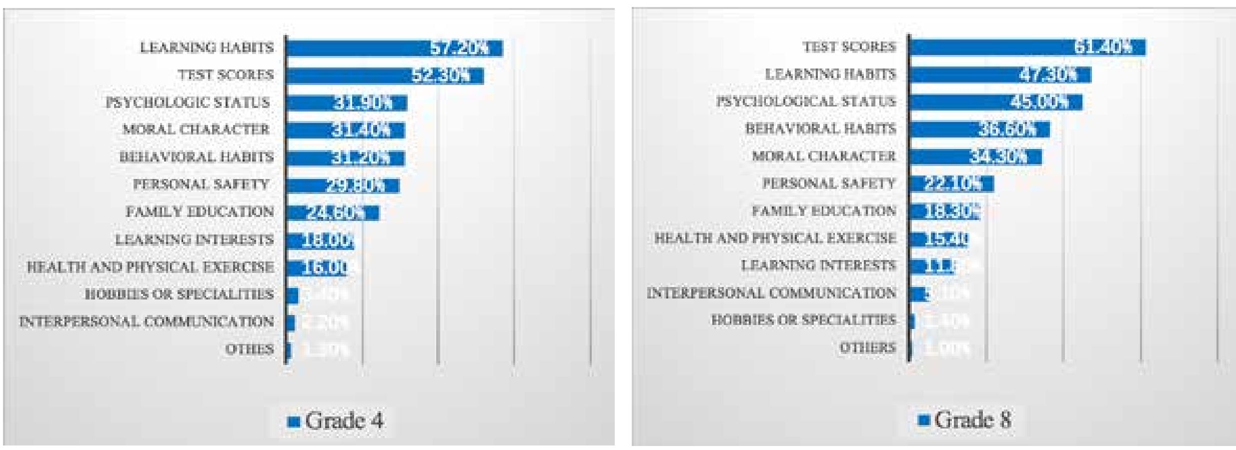


Figure 3-2 Contents of Communication between Parents and Head Teachers of Grade 4 and Grade 8

Overall, 95.6% of the head teachers in grade 4 and 97.4% in grade 8 reported difficulties in communicating with parents, which shows that the current communication between head teachers and parents is not optimistic. Schools, teachers, and parents need to face up to the problems and find solutions to solve them in a timely and effective manner.

In the U.S., according to the 2017-2019 School of Excellence Data Report[80], the "School of Excellence" program organized by national PTA has gained a great many remarkable achievements. Specifically, there were 143 National PTA School of Excellence designees in 2017-19 across 28 state PTA congresses, including two DoDEA schools in Germany and Italy. Top 5 highest recognition by the state were Florida (25), Texas (18), Georgia (16), Virginia (13) and California (11).

- Concerning the demographic breakdown of the student population, national PTA served 57% of Caucasian, 20% Hispanic/ Latino, 12% Black/African American, 7% Asian American, 3% Other and 1% American Indian (Figure 3-3).
- Concerning the grade range, "School of Excellence" program covered 70% elementary schools, 15% middle schools, 8% secondary schools and 7% K-8 schools (Figure 3-4). National PTA served over 107,000 students, 32% are title 1 schools.

Overall, in one school year, PTAs and schools that completed the national PTA "School of Excellence" program improved family receptions scores by 21% across all indicators of the PTA National Standards for Family-School Partnerships. Additionally, 50% reported growth in PTA membership or increased participation among families and school staff.

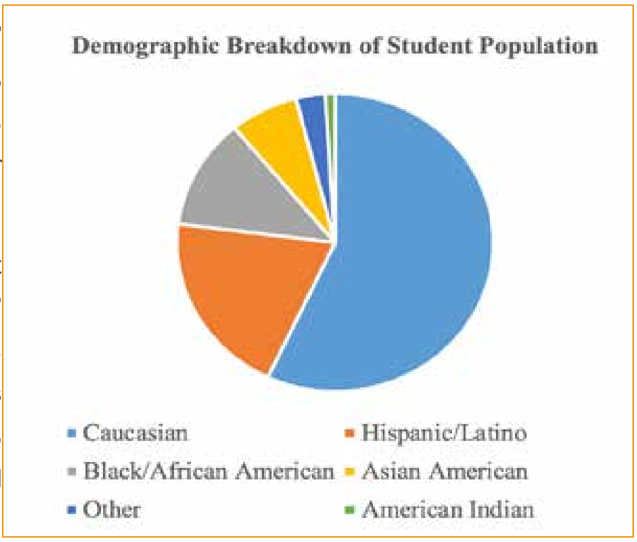


Figure 3-3 Demographic Breakdown of Student Population

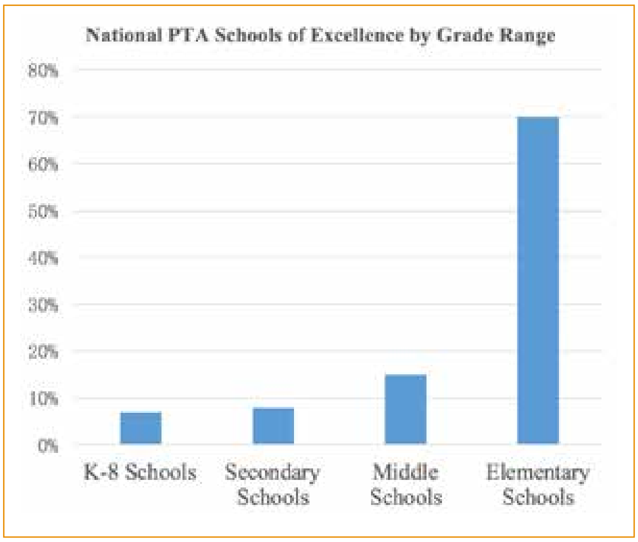


Figure 3-4 National PTA Schools of Excellence by Grade Range

In conclusion, family-school communication is the starting stage and basis for the balanced development of adolescents. The forms of parental school participation are different between China and the U.S. In China, parents usually communicate with teachers via the communication platforms (such as Parent Committee, WeChat Group, etc.) to know about students' exam results, study habits, and security, etc. In the U.S., the parent-teacher associations (such as PTA) covers a wide range from the nation to state and district, in which parents take the initiative to participate in school affairs and play a decision-making role in school events.

3.6 Opportunity for Entering Public School

In order to rationally allocate education resources and promote education equity further, Article 12 of the Compulsory Education Law of the People's Republic of China stipulates that local governments at all levels should ensure that school-age children and adolescents are enrolled in schools close to their residence[81]. In the U.S., public schools belong to school districts, which are governed by school boards. Each district is an independent special-purpose government, or dependent school system and is under the guidelines of each state government and local school boards. A school district is a legally independent company and a political institution. School districts are local governments with powers similar to that of a town or a county including taxation and eminent domain, except in Virginia, whose school divisions have no taxing authority and must depend on another local government (county, city, or town) for funding.

The admission qualifications in China are mainly linked to the place of residence registration. Parents are eager to purchase real estates in high-quality school districts in order to obtain the residence registration of these areas. This has resulted in the phenomenon of "school-district housing," which means the price of housing in the high-quality school districts is higher than the average price in the commercial residence districts. In the U.S., students usually attend a public school close to their home at elementary and secondary levels. If one has a preference for a particular public school or school district, it is usually necessary to buy or rent a property in that area. It is quite reasonable for Americans to ask an estate agent to find them a home in a particular school district.

Taking Shenzhen in China (Table 3-11) and New York in the U.S. (Table 3-12) as an example. In 2018, the prices of new and second-hand housing in Shenzhen both fell, but in 11 prestigious school districts, 25 small and medium-sized schools, which was a total number of 140 districts, the price of prestigious school district housing was still considered to rise, therefore, prestigious school district housing remains the hardest currency in the Shenzhen property market. Among the 140 prestigious school districts, 118 have an increase from 1% to 9%, and only 22 experienced a slight decline. Based on the price increase and the average price level of the school district housing, Nanshan has surpassed Futian. The chart below is about the average increase in housing price in some prestigious school districts in Shenzhen[82]. In New York, these are top 5 school districts in the latest ranking[83] in Table 3-12.

Table 3-11The Rate of Increase in School District Housing in Shenzhen

The Rate of Increase in School District Housing in Shenzhen (2018.1-2019.10)						
District	Area	School	Average Price (RMB/sq.m.) (01/2018)	Average Price (RMB/sq.m.) (01/2019)	Price Differences (RMB/sq.m.)	Rate of Increase
Nanshan District	Houhai Area	Hyde School	90,551	98,487	7,936	8.76%
	Nantou Area	Qilin Middle School+ Nantou Primary School	91,131	98,609	7,479	8.21%
	Shenkou Area	Yucai No.2 Middle School + Yucai No.1 Primary School+ Yucai No.2 Primary School+ Yucai No.3 Primary School+ Yucai No.4 Primary School	81,677	87,796	6,119	7.49%
Futian District	Xiangmihu Area	Shenzhen Senior High School Junior Department	101,952	109,581	7,629	7.48%
	Baihua Area	Shenzhen Experimental School+Liyuan Primary School (North Campus) + Baihua	98,574	105,019	6,445	6.54%
	Hongling Area	Hongling High School Junior Department + SZ Futian Yuanling Foreign Language Primary School	67,338	71,345	4,007	5.95%
	Shixia Area	Hongling Middle School Shixia Department + Yiqiang Primary School	60,146	63,154	3,009	5.00%
Luohu District	Cuizhu Area	Cuiyuan Middle School + Cuizhu Primary School	60,094	62,834	2,741	4.56%
	Dongmen Area	Shenzhen High School Junior Department + Luoling Primary School	62,309	64,128	1,820	2.92%
Baoan District	Baoan Area	Baoan High School Junior Department + Baomin Primary School+Baoan No.1 Foreign Language Middle School	58,203	59,455	1,253	2.15%
Luohu District	Dongxiao Area	Shenzhen Cuiyuan Middle School Dongxiao Branch+ Dongxiao Primary School	50,540	51,119	579	1.15%

Table 3-12 Top 5 School Districts in New York

2019 Top 5 School Districts in New York							
District	Rank	Number of students in K-12	Student-teacher ratio	Proficient in math	Proficient in reading	The highest price	The lowest price
Jericho Union Free School District	1	2,978	10:1	89%	84%	$2,899,000	$619,000
Great Neck Public Schools	2	6,574	11:1	84%	78%	$4,980,000	$828,000
Edgemont Union Free School District	3	1,913	13:1	82%	78%	$7,995,000	$153,000
Scarsdale Union Free School District	4	4,783	13:1	84%	77%	$8,995,000	$153,000
Syosset Central School District	5	6,232	11:1	89%	79%	$4,950,000	$450,000

In short, aimed at protecting the right of equal access to education for school-aged adolescents, both China and the U.S. implement a similar policy of admission priority for public schools during the stage of compulsory education. Parents in both countries have similar concerns in the selection of schools, striving for the admission priority of high-quality schools and access to high-quality education resources. This has contributed to the rise of high-priced "school district housing."

3.7 Service System for ICT in Education

In China, the service system for ICT in education is mainly composed of three major parts: government departments, academic institutions, and social forces. For the government departments, the Ministry of Education is one of the functional departments of the State Council. Department of Science and Technology[84] is one of the departments in the Ministry of Education. One of its main functions is to take responsibility for the construction of ICT in the education system, and it will form an ICT leading group in terms of specific development needs[85]. The "Network Security and ICT Leading Group of the Ministry of Education," headed by the Minister of Education, promotes daily work routines in the leading group office in the Department of Science and Technology, and local educational administrations at all levels have also established organizing institutions of ICT in Education at the corresponding levels. The direct departments of the Ministry of Education, including the National Center for Educational Technology, the Education Information Network Center and the Open University of Chin[86], and so on, covered ICT in Education in the fields of basic education, vocational education and distance education. At the same time, the local education administrations have also established provincial and municipal e-educational centers and educational information centers. The Open University has also established branches in various places to implement the various ICT tasks.

In addition to educational management departments at all levels, as research and development entities, research institutions such as colleges and universities, academic groups and cross-disciplinary research platforms provide the required intellectual support in the development of deep integration of information technology and education[87]. Various enterprises of ICT in Education are also involved in the supply of various system platforms, learning resources, instructional/learning tools and other products and services. Also, the three major operators (China Mobile, China Unicom, and China Telecom) provide network communication services, network infrastructure, solutions for ICT in Education and digital instructional resource services to the whole country[88]. Besides, teachers, students, and administrators in various public and private schools are the primary users of ICT in Education, and their appeals in application lay an essential foundation for collaboratively promoting ICT in Education.

In the U.S., Department of Education Office of Educational Technology (OET) develops national educational technology policy and establishes the vision for how technology can be used to transform teaching and learning and how to make everywhere, all-the-time learning possible for early learners through K-12, higher education, and adult education[89].

Chief Information Officer (CIO) provides management advice and assistance to the Secretary of Education and other senior staff on information resources investment and operations[90]. National Center for Education Statistics (NCES) is the primary federal entity for collecting and analyzing data related to education in the U.S. It fulfills a congressional mandate to collect, collate, analyze, and report complete statistics on the condition of American education[91]. Moreover, other organizations such as the International Society for Technology in Education (ISTE)[92], Association for Educational Communications and Technology (AECT)[93], Education Management Organization (EMO)[94], Society for Information Technology and Teacher Education (SITE)[95], and companies such as Apple, Microsoft are also taking an active part in the overall advancement of ICT in Education of the U.S.

It can be concluded that instructional support and technical service are the guarantees for ICT in schools. China and the U.S. have different structures of ICT in Education. China's Ministry of Education has established the top-down specialized IT support institutions (e.g., National Centre for Educational Technology), coordinating with research institutes and enterprises to lead the promotion and application of IT in primary and high schools. In the U.S., apart from the federal departments (e.g., OET), each state has relatively independent educational technology offices and associations (e.g., ISTE, AECT, et al.) involved in ICT in Education.

3.8 Broadband Internet

Infrastructure construction, as the foundation for intelligent technology supporting the development of ICT in Education, has an essential role during the construction of ICT in Education. In the beginning of 2018, the Ministry of Education in China issued the "Key Points of ICT in Education and Network Security in 2018", which pointed out that it was necessary to realize network access and raise the Internet speed at all levels of schools, and establish a number of regional and inter-school education of innovation and practice about ICT in Education[96]. In April 2018, the Ministry of Education issued the "Guidelines for the Construction and Application of CyberLearning Space", which promoted more standardized and organized development of "cyberlearning space for everyone" from the perspectives of network space connotation, network space composition, personal space function, public application service, data analysis service and space security[97]. In order to fully realize the goal of infrastructures serving for education, China's infrastructures of ICT in Education will build an integrated platform of "Internet plus education." Under the guidance of a series of policies, the infrastructure construction of each schooling stage has been improved[98].

The U.S. Department of Education has set a goal to provide a robust infrastructure for all students and educators[99]. The National Education Technology Plan lists four essential factors for robust infrastructure:

(1) anytime, everywhere access to high-speed Internet, both in and out of school;

(2) mobile technology that effectively connects students and educators with the internet and with each other;

(3) rigorous learning content and resources;

(4) guidelines to support responsible, safe use of technology[100].

In 2018, the proportion of schools in China ordinary primary schools (including teaching points) accessing the Internet was 97.82%, the proportion of schools accessing the Internet in junior high schools nationwide was 98.96%, and the proportion of schools accessing the Internet in the country's ordinary high schools was 98.78%[101]. In 2017, the proportion of schools accessing broadband Internet in the top 10 educational provinces was shown in Figure 3-5. The proportion of primary and secondary schools accessing broadband Internet in all provinces exceeded 80%. Among them, the development level of Jiangsu and Zhejiang was relatively higher, with the number of over 99%. The proportion of schools with bandwidths faster than 10Mbps in primary schools exceeded 80%, among which Zhejiang was relatively higher, over 99%.

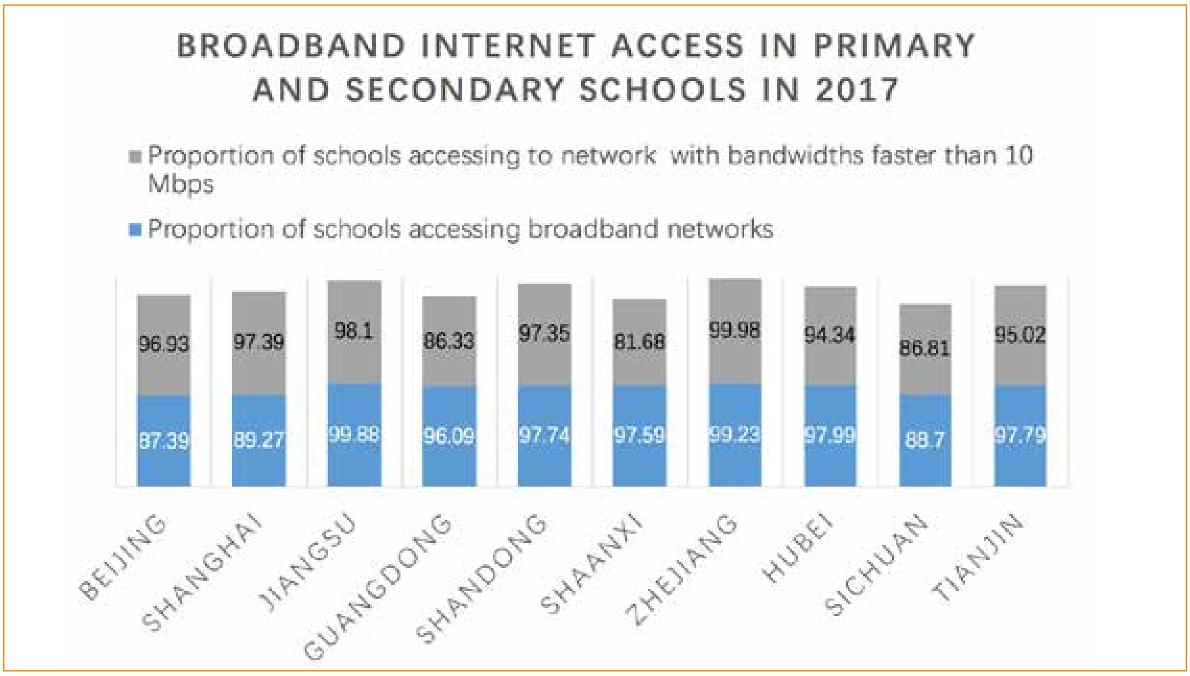


Figure 3-5 Broadband Internet Access in Primary and Secondary Schools in 2017 in China

By the end of 2017, the proportion of provincial schools in all the provinces in China that have achieved full coverage of wireless networks on campus was shown in Figure 3-6. The development of Zhejiang and Beijing were relatively better. Among them, more than half of the provincial universities in Zhejiang and Beijing have achieved full coverage of the wireless network.

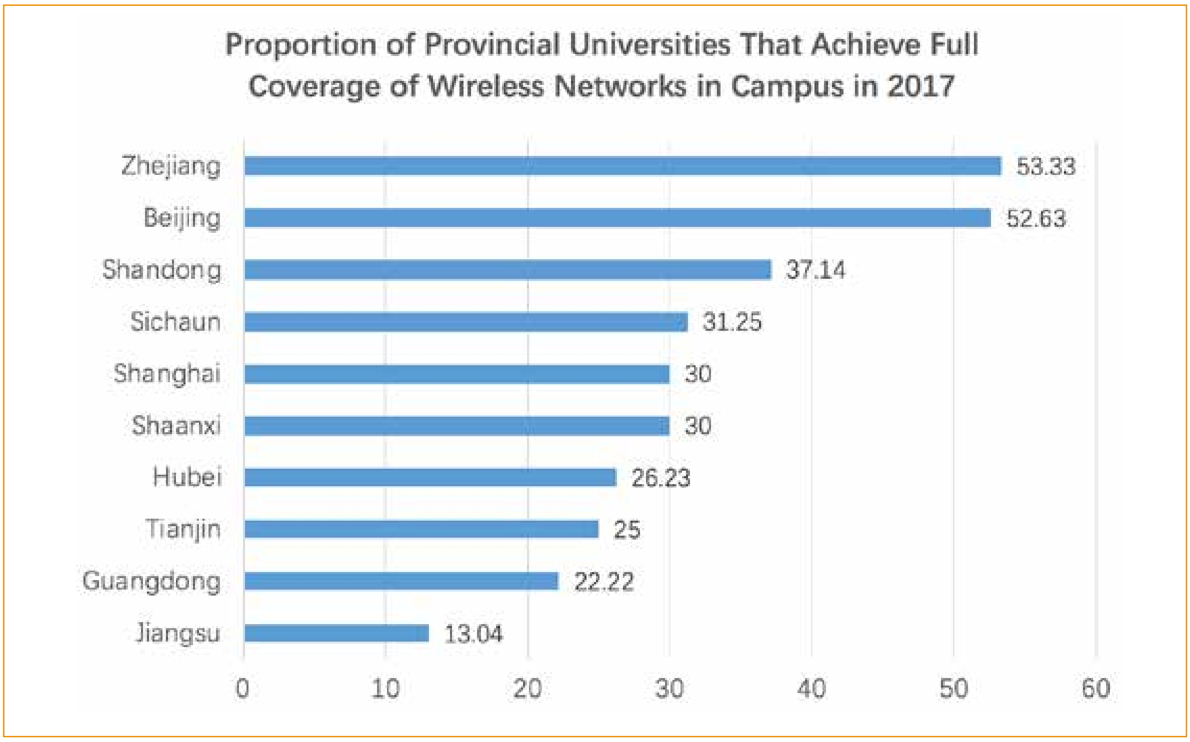


Figure 3-6 Proportion of Provincial Universities in China That Achieve Full Coverage of Wireless Networks in Campus in 2017

Driven by a series of policies in the U.S., in 2018, 98% of public schools have next-generation fiber infrastructure, and 96% have enough Internet connectivity to make digital learning available in their classrooms[102]. As shown in Figure 3-7, most states' school districts that were exceeding the 100 kbps per student minimum connectivity goal. Among them, 100% of Utah's school districts were exceeding its goal, and at least 67% of Maryland's school districts also did well by 2017.

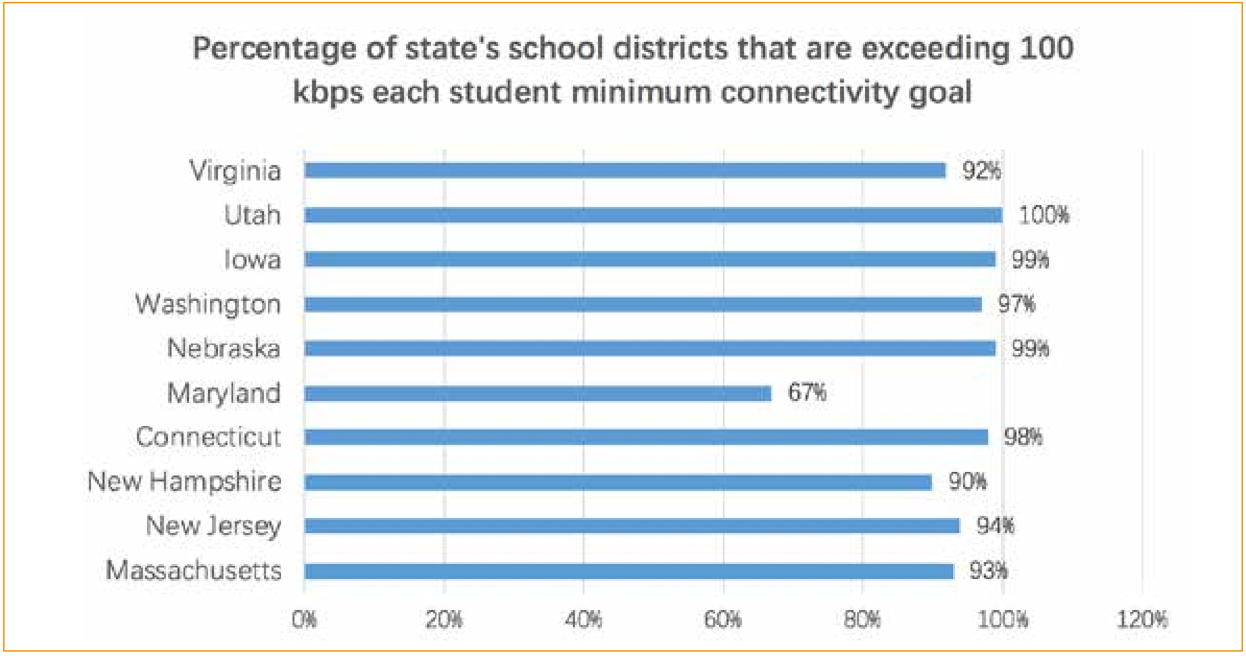


Figure 3-7 Percentage of State's School Districts in the U.S. That Are Exceeding 100 kbps Each Student Minimum Connectivity Goal

Since 2015, the number of students meeting the minimum connectivity goal has been kept rolling. Virginia has the most significant number of students meeting the minimum connectivity goal, and New Hampshire has the lowest number by 2017 (Figure 3-8).

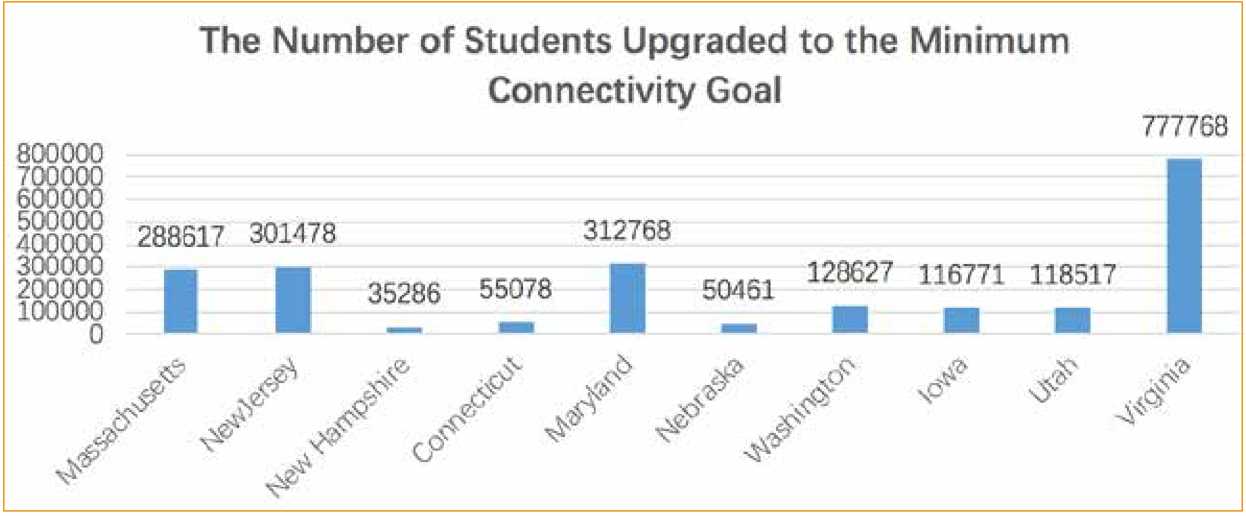
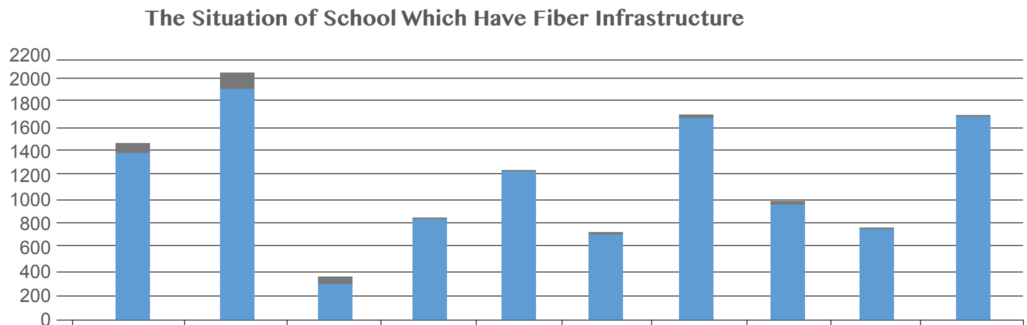


Figure 3-8 The Number of Students Upgraded To the Minimum Connectivity Goal in the U.S.

According to Figure 3-9, almost all schools have fiber infrastructure. Only five schools of Utah, six schools of Connecticut, seven schools of Maryland and so on still need fiber infrastructure by 2017.



	Massachusetts	New Jersey	New Hampshire	Connecticut	Maryland	Nebraska	Washington	Iowa	Utah	Virginia
The number of schools that still need fiber	84	135	64	6	7	24	25	28	5	12
The number of schools that have fiber infrastructure	1436	1983	338	881	1280	740	1745	1007	798	1749

Figure 3-9 The Situation of School Which Have Fiber Infrastructure

Overall, ICT infrastructure is a prerequisite for ICT in Education, and both China and the U.S. have already owned equipped ICT infrastructure. In China, 97.82% of primary schools have Internet access, 98.96% of junior high schools and 98.78% of senior high schools respectively. In the U.S., 98% of public schools have next-generation fiber infrastructure. 96% of the U.S. public schools have sufficient Internet access to provide digital learning in class.

3.9 Digital Education Resources

Digital Education Resources (DER) are the results of the development of education in the information age. It is a collection of resources that has been digitally processed and used in an environment of informatization and is explicitly designed to serve education and instructions[103]. The capacity of service of China's digital education resources has enhanced, and the supply structure has been gradually enriched. China has gradually formed three major resource systems supported by the public welfare which is provided by the government, the customized resources provided by enterprises, and the school-based resources independently developed by schools. By the end of November 2018, the National Public Platform of Educational Resource had opened 12.51 million teacher spaces, 5.99 million student spaces, 5.49 million parental spaces, and 400,000 school spaces. We will continue to promote the regional pilot platform to access the national public service system of digital education resources. We have access to 70 online platforms, including 17 provincial platforms, 27 municipal platforms, and 26 district-level platforms[104].

In addition, the "Full Coverage of Digital Instructional Resources in Small Rural Schools" Project proposed in the "Thirteenth Five-Year Plan for ICT in Education" has developed a new version of textbooks for students from grade 1 to 3 in primary schools, which are a series of high-quality digital resources including Chinese, math, English, music, fine arts and other three subjects[105]. There are three models for the setting-up of school-based resource centers: independent construction, direct purchase of entire sets of resources, and joint development with the entrusted enterprise. About 59% of the vocational institutions have built their school-based resource centers[106]. There are two forms of digital education resources in higher education, namely digital libraries and digital instructional materials[107]. With the construction and development of the public service platforms for educational resources, the co-construction and sharing of resources in higher education have already reached a good scale. According to the latest statistics in 2018, the average number of online courses in colleges and universities nationwide was 186.8 with an increase of 9.9% from the previous year. Among them, there was an average of 301.2 online courses in undergraduate institutions with an increase of 9.7% from the previous year. At the same time, since MOOCs entered into the education research and the reform in China, there have been hundreds of platforms related to MOOCs, including NetEase Cloud Classrooms, XuetangX, iCourse, MOOCs of Chinese Universities and Chinese MOOCs, which gathered abundant learning resources and a large number of learners.

Take iCourse as an example. By the end of October 2018, there were 188,000 new registered users and 3179 new users on the portals. There were 15.67 million downloads and installation of mobile terminals for MOOCs of Chinese universities on iCourse. The platform opened 5,873 courses and added 44,000 new resources with 4.5 million new registrations[108].

As the important part of the DER, according to the State Educational Technology Directors Association (SETDA) in the U.S., Digital Instructional Materials (DIM) are created, viewed, distributed, modified, stored on and accessible with computers or other electronic devices. Examples include computer programs, computer software, digital images, digital audio, digital video, websites, databases, electronic books, electronic textbooks, etc. Report statistics show that 29 states have a definition for instructional resources that includes the option for digital instructional resources, 6 states require the implementation of digital instructional resources, 30 states allow the implementation of digital instructional resources, 26 states have a state digital learning repository, and 15 states have dedicated state funding for digital instructional resources[109].

A variety of formats provide digital education opportunities in the U.S. Current strategies, and examples of successful implementations are described below.

Open educational resources

Open educational resources (OER) can enrich the educational content in online or traditional schools as educators and instructional designers share original lesson plans and other resources. Lessons may be updated to increase accuracy or modified to personalize content. Multiple platforms have been designed to help educators locate appropriate resources. Use of these openly licensed instructional resources is encouraged by the government, states, and educators who use these resources supported by the Office of Educational Technology's #GoOpen initiative. Funds are available for states who prepare teachers to create and use these resources, and 20 states, including Arizona, California, Connecticut, Delaware, Georgia, Illinois, Indiana, Maryland, Massachusetts, Michigan, North Carolina, Oklahoma, Oregon, Rhode Island, Tennessee, Utah, Vermont, Virginia, Wisconsin and Washington[110], and over 100 PreK-12 districts[111] have established statewide repositories to help teachers to access open online resources.

Open Courseware

Open Courseware (OCW) are university courses that are easily accessible and are shared for free through the internet. Goals of universities that participate in OCW may be to increase educational outreach for independent learners, to prepare students for future courses better, or to provide feedback that can help educators to develop more effective courses[112].

Massachusetts Institute of Technology (MIT)'s OCW (https://ocw.mit.edu/index.htm) was a pioneer of open coursework in the U.S., first delivering online courses in the early 2000s. MIT works to ensure that the majority of its course offerings are available online, and the website offers a class index searchable by topic, course number, and discipline. Also, the website delivers an educator portal that provides teaching resources, teacher insights, and courses to improve teacher pedagogy. MIT does not offer course credit, certification, or degrees through its OCW program.

Flipped instruction

Flipped classrooms reverse the traditional classroom learning environment by delivering web-accessible content to students before they come to class. Homework is then reviewed through class activities that reinforce the learning[113].

Khan Academy (https://www.khanacademy.org) produces instructional YouTube lessons that provide content in a broad range of disciplines. The website also offers practice exercises that support learning both in and out of the classroom. Through the website, teachers can track their students' progress and find supplementary resources for instruction.

Blended and full-time online schools

Students attending full-time online schools do not typically attend school in a physical facility. Instead, they receive all of their instruction from online digital courses. Blended schools offer a hybrid education which integrates online learning with school-based instruction[114].

North Carolina Virtual Public School (https://ncvps.org/) was established by the North Carolina e-learning Commission in 2005 and serves middle school and high school students. Although this fully online school is a supplemental public service to the public schools of North Carolina, the expanded academic course options are available to learners in any geographic location.

Other uses for digital resources

In the U.S., lesson content may be conveyed digitally in a variety of other ways. Digital field trips that incorporate virtual reality, learning games, building global connections, and working with industries to facilitate project-based learning experiences can all enrich a student's learning.

> To sum up, high-qualified DER are one of the cores of ICT in education. Both China and the U.S. focus on the construction of high-quality resources, but the main operator is distinct. China focuses on public institutions such as the Chinese government and schools (National Public Platform of Educational Resources, etc.). The U.S. is dominated mainly by non-governmental organizations, such as CK-12, Khan Academy, North Carolina e-learning Commission, etc.

3.10 Teacher Professional Development with ICT

"Human" is the key factor that affects the ICT in Education. In particular, the attitudes, thoughts, and abilities of teachers on information technology directly affect the deep integration of information technology and teaching. In March 2018, the Ministry of Education in China issued the "Action Plan for Revitalization of Teachers and Education 2018-2022", which clearly stated that it is necessary to research and develop the standard of abilities on information technology application for normal school students, and promote the transformation of instructional methods with independence, cooperation, and inquiry and improve their information literacy and ICT teaching capabilities[115]. In 2017, the U.S. Department of Education set a goal to improve education by building a multifaceted technology network that can improve the quality of instruction for all learners[116]. Because teachers may influence students more than any other factor at school[117], the network aims to link teachers with other individuals, resources, and learning experiences that can increase the effectiveness of instruction. Technology is an integral part of the Department of Education's focus, as technology resources support opportunities for collaboration within and beyond the school, provide new tools for use in instruction and evaluation, offer access to an abundance of resources, and support communication between teachers and students.

In the process of ICT in Education development, China has carried out information technology training for all primary and secondary school teachers. In 2013, the improvement project of national primary and secondary school teachers' IT application capacity was implemented[118]. At the end of 2017, a new round of training for more than 10 million primary and secondary schools (including kindergartens) across the country was completed. In 2018, the new cycle of IT application ability improvement for primary and secondary school teachers was implemented. The improvement project emphasizes the training for improving teachers' IT application ability through the reform and development of school information education, and promotes training of ICT to all local teachers through demonstration training programs in terms of the local conditions. At the same time, it also carried out training on the ICT instructional ability for teachers in vocational institutions and universities, and the information leadership training for principals to comprehensively improve the information literacy of school administrators at all levels.

Besides, in 2017, the principal training selected 20 base schools in Liaoning, Jilin, Shandong, Hunan, Hubei, Guangdong, Shanxi, Zhejiang, Sichuan and other nine provinces as host institutions for the training, holding 14 training sessions from the end of October to the end of December with nearly 2,000 primary and secondary schools' principals involved. The training focuses on the cyberspace teaching and management display and communication of the base school. At the same time, through the theme presentations, it introduces the connotation, progress, and development of the public service system of ICT in education, and provides an opportunity for a comprehensive understanding of the current development of cyberlearning space. Some training courses also hired experts and scholars in the field to deliver theme reports, invite front-line users to present their feelings and introduce the cyberlearning space for supporting teaching and school management. Training has enabled trainees to seize a great opportunity for learning and communicating. It has played a significant role in popularizing the concept of cyberlearning space and promoting its construction in schools[119].

2018 Kahoot! EdTrends Report in the U.S. for Educators highlights trends in EdTech, top technologies, and tools used in classrooms, as well as challenges and opportunities for educators. This report is based on results from a survey of more than 1,500 K-12 teachers across the U.S., data from the Kahoot! Platform and the expert insights of a teacher interviewed.

As elaborated in the report, teachers who rely on data-driven instruction and intervention are also more likely to conduct a formative assessment (83%), followed by summative assessment (72%) as a way to better instruct students and improve their performance based on data insights. This shows that teachers are now using data to consistently adjust their teaching based on student performance and needs, rather than relying on one-off testing methods. 1 in 3 teachers are using technology to encourage working in teams and collaboration, 58% are using tech tools for project-based learning, and 55% to encourage creative thinking. Honing independent thinking and problem-solving skills is not far off, with 54%.

In summary, teacher professional development with ICT is a key guarantee of ICT in education. China and the U.S. differ slightly in the methods of teacher training. China emphasizes large-scale staff training (such as National Training Plan, The Project 2.0 of the Improvement of Teachers' ICT Capability in Secondary and Primary Schools). In the U.S., in addition to large-scale training, it also focuses on providing continuous instructional support for teachers through online communities. Other professional organizations such as AECT and ISTE also play a role in teacher training.

Opinions to Take away from Factors of Infusing ICT into Education between China and the U.S.

- As a supplement to public education, private education represents the maturity of a country's educational development. In China, the focus of private education is the two non-compulsory educational stages, namely non-governmental senior high school and non-governmental kindergarten. The quality of non-governmental higher education still has a relatively long way to go. In the U.S., private education plays a significant role in basic education and higher education. The U.S. also owns many world-class private universities.
- Rural education occupies a large proportion in the basic education of both China and the U.S., and the difference between urban and rural areas is still the core that needs to be paid attention to in the process of promoting the balanced education in both countries. In China, rural students account for two-thirds of the total number of students in schools, and schools in rural areas (towns and countryside) account for about two-thirds of the total number of schools. Rural education remains a major part of China's compulsory education. In the U.S., with a fifth of the students, a third of the schools and half of the school districts in rural areas, rural education is also a concern.

- Class size is one of the key factors in the process of promoting personalized learning and effective use of ICT, and there are great differences between China and the U.S in the class size of basic education. The U.S. has a relative smaller class size than China in overall K-12 schools. In addition, both China and the U.S. has class size reduction plan, i.e., “Oversize Class Size Reduction” in China and class size reduction in many states and districts.
- The level of the student-teacher ratio is a potential condition to promote personalized learning as well as differentiated instruction, and it is approximately close between China and the U.S.
- Family-school communication is the starting stage and basis for the balanced development of adolescents. The forms of parental school participation are different between China and the U.S. In China, parents usually communicate with teachers via the communication platforms (such as Parent Committee, WeChat Group, etc.) to know about students' exam results, study habits, and security, etc. In the U.S., the parent-teacher associations (such as PTA) cover a wide range from the nation to state and district, in which parents take the initiative to participate in school affairs and play a decision-making role in school events.
- Aimed at protecting the right of equal access to education for school-aged adolescents, both China and the U.S. implement a similar policy of admission priority for public schools during the stage of compulsory education. Parents in both countries have similar concerns in the selection of schools, striving for the admission priority of high-quality schools and access to high-quality education resources. This has contributed to the rise of high-priced "school district housing."
- Instructional support and technical service are the guarantees for ICT in schools. China and the U.S. have different structures of ICT in Education. China's Ministry of Education has established the top-down specialized IT support institutions (e.g., National Centre for Educational Technology), coordinating with research institutes and enterprises to lead the promotion and application of IT in primary and high schools. In the U.S., apart from the federal departments (e.g., OET), each state has relatively independent educational technology offices and associations (e.g., ISTE, AECT, et al.) involved in ICT in Education.
- ICT infrastructure is a prerequisite for ICT in Education, and both China and the U.S. have already owned equipped ICT infrastructure. In China, 97.82% of primary schools have Internet access, 98.96% of junior high schools and 98.78% of senior high schools respectively. In the U.S., 98% of public schools have next-generation fiber infrastructure. 96% of the U.S. public schools have sufficient Internet access to provide digital learning in class.
- High-qualified DER are one of the cores of ICT in education. Both China and the U.S. focus on the construction of high-quality resources, but the main operator is distinct. China focuses on public institutions such as the Chinese government and schools (National Public Platform of Educational Resources, et al.). The U.S. is dominated mainly by non-governmental organizations, such as CK-12, Khan Academy, North Carolina e-learning Commission, etc.
- Teacher professional development with ICT is a key guarantee of ICT in education. China and the U.S. differ slightly in the methods of teacher training. China emphasizes large-scale staff training (such as National Training Plan, The Project 2.0 of the Improvement of Teachers’ ICT Capability in Secondary and Primary Schools). In the U.S., in addition to large-scale training, it also focuses on providing continuous instructional support for teachers through online communities. Other professional organizations such as AECT and ISTE also play a role in teacher training.

Comparative Study of Intelligent Technology in Education between China and the U.S.

The application of intelligent technology in education has been in existence for a long time. In the 1950s, the computer was used as a tutoring tool. It was the prototype of technology applied in education. ITS is the new development of computer-aided tutoring under the promotion of intelligent technology, and it is one of the typical applications of intelligent technology in education[120]. The development of intelligent technology, especially the rapid development of image recognition, voice recognition, natural language processing, and the gradual maturity of relevant educational products provide more possibilities for educational reform and intelligent tutoring. It also provides strong support for education and tutoring in environmental construction, decision support, talent training, emotional companionship, precise services, tutoring support, and intelligent evaluation. This part will analyze the research, application, and practice of intelligent technology in the field of education in China and the U.S. in order to promote the development of education.

4.1 Typical Scenarios of Intelligent Technology in School

In the process of infusing intelligent technology into school, the first concern is ICT infrastructure and AI tools. The hardware infrastructure and related tutoring tools are the necessary elements for the application of intelligent technology. The ideal environment can sense the learning scenarios, identify characteristics of the learners, provide appropriate learning resources and convenient interactive tools, automatically record learning processes and evaluate learning outcomes to promote effective learning.

The configuration of the basic environment provides conditions for teachers, students, and parents to use relevant tools to become AI-empowered teachers, students, and parents, by assisting students in various forms of learning both inside and outside of school. This also provides conditions to realize a new learning mode. Different from the traditional tutoring mode of “Unified Specifications, Unified Pace, Unified Detection,” the new learning mode may be more likely the 4A mode of “Anytime, Anywhere, Anyway, Any pace.” In this mode, the ICT learning method allows students to pay attention to the diversity and individual differences so that the “learner-oriented” educational concept can be realized.

The aim and core of intelligent technology utilization in education is the transformation of the educational system. For schools, the scientific decision-making and the optimization of management are the focal points. For example, in public management, quality monitoring, course electing, professional selection, life design and more other fields, we can use big data, cloud computing, intelligent sensing and other technologies to efficiently collect and deeply mine schooling data to help schools establish the logical process of prioritizing governance tasks and key governance operations, providing data-driven decision-making and management to promote constant improvement in schools.

In summary, the three aspects of infrastructure, learning subject, and teaching mode, as well as institutional transforming, constitute the framework of transforming the educational system of intelligent technology in school. Also, according to the relevant research and application of China and the U.S., it partially corresponds to nine specific scenarios shown in Figure 4-1. In China and the U.S., due to the differences in social culture, technological development, and basic academic conditions, there are different focuses on researches and applications of these nine scenarios. Following this, we will specifically analyze the typical scenarios of intelligent technology applications in China and the U.S.

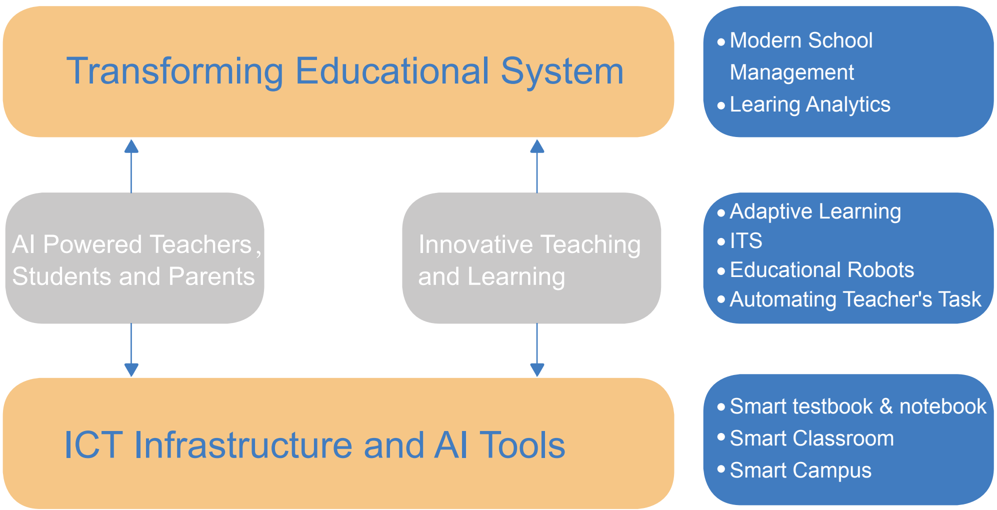


Figure 4-1 The Framework of Transforming Educational System of Intelligent Technology in School

(1) Smart Classroom

Traditional classrooms are increasingly using new intelligent technologies such as face recognition, affective computing, multimodal integration, and big data analysis. With the support of various sensors and media terminals, they have evolved into smart classrooms. The "intelligence" of smart classrooms involves the optimal presentation of tutoring contents, the convenient access of learning resources, the deep interactions during class teaching, the context-awareness and detection, classroom layout and electrical management[121].

The research on smart classrooms in China has increased year by year since 2012, mainly focusing on the design and evaluation of smart classrooms, and teaching methods in smart classroom. The construction of smart classrooms has also appeared frequently in national and provincial policy documents, and the standards for the construction of smart classrooms have also been released. In some regions, the evaluation of smart classroom demonstration schools has also been carried out. The construction of smart classrooms provides hardware conditions for intelligent education, which is conducive to the promotion of transforming teaching structure, and thus promoting the improvement of teaching quality.

(2) Smart Campus

Smart campus refers to an open environment for education and instruction, and a convenient, comfortable environment for learning. The smart campus can comprehensively perceive the physical environment, identify learners' characteristics and learning scenarios, provide seamless and connective network communications, and effectively support the analysis, evaluation and intelligent decision-making of the teaching process[122].

The research on smart campus has been increasing year by year since 2010, mainly focusing on hardware configuration, function integration, cloud computing, application of the IOT and so on.

Based on intelligent technology, smart campus fully integrates teaching, research, management, and campus life, which expand the dimension of time and space in school, enriches the campus culture, and provide strong support for instruction. In order to effectively support instruction, enrich campus culture and indeed expand the dimension of time and space, smart campus construction needs to use sensors and IoT technology to perceive, capture and transmit information about people, equipment and resources at any time in any place. Also, it is necessary to perceive, capture and transmit the learner's individual characteristics (including learning preferences, cognitive characteristics, attention status, learning style, etc.) and learning scenarios (including time, space, partners, activities, etc.).

(3) Smart Textbook & Notebook

Another way that intelligent technology is helping out in the classroom is the ability to incorporate smart content into lessons by providing students with smart textbooks and notebooks. With the development of intelligent technology, the era of simple PowerPoints and lectures is coming to an end. Now, professors or teachers will be able to show what they are talking about in great detail. Traditionally, students learn about the human body through textbook or flashcards. With the help of intelligent technology, they can learn about the human body through interactive models and 3D graphics. Intelligent technology can also help teachers to craft course resource that is customized according to the learning capabilities of every student[123]. At the same time, students can use smart notebook to take notes just like using the traditional notebook, however, the data of students' taking notes can be collected to provide the authentic learning data for learning analytics.

(4) Adaptive Learning

The new generation of learners who have grown up in the digital environment has put forward higher demands for learning. The learning methods with unified pace, fixed time and place is being broken. They are eager to adopt a learning method that is self-paced with any time and place[124]. The difference between adaptive learning and traditional learning is that the main teaching methods are different. Traditional education is usually based on classes or groups, and teachers provide unified instructional content and schedule, also students' practice and assessment are unified. However, adaptive learning is based on individuals, accepting different learning progress and contents with a higher degree of individualization in practice and evaluation contents.

In China, the adaptive learning system will become an effective way to connect the teaching inside and outside of class. It can break the limitations of time and space and the boundaries of classroom learning, making learners learn at any time and in any place. The system can provide a comprehensive, multi-dimensional learning analysis model for learners and form a knowledge map from the learning environment, learner characteristics, learning resources and tools, learning behaviors and evaluation feedbacks, while completing the data processing and analysis from the dimensions of regions, schools, classes, students and so on.

In the U.S., from kindergarten to graduate school, one of the critical ways of influencing future education is to apply intelligent technology at a higher level in personalized and adaptive learning. Adaptive learning can either present personalized content for individual students or guide them to learn by providing a personalized path[125]. It is assumed that intelligent technology in schools can track the progress of each student and either adjust the course or inform the teacher about the resource that a given student has difficulty comprehending.

Some of this is already happening through growing numbers of adaptive learning programs, games, and software. These systems respond to the needs of the student, putting greater emphasis on specific topics, repeating things that students have not mastered, and generally helping students to work at their own pace, whatever that may be. This kind of custom-tailored education could be a machine-assisted solution to helping students at different levels work together in one classroom, with teachers facilitating the learning and offering help and support when needed. Adaptive learning has already had a significant impact on education across the nation (especially through programs like Khan Academy), and as intelligent technology advances in the coming decades, adaptive programs like these will certainly improve and expand.

(5) ITS

The ITS is an intelligent computer-aided teaching system that uses intelligent technology to imitate the role of human teachers in teaching provides learners with individualized learning guidance and helps learners with different demands and characteristics to acquire knowledge and skills[126].

The study of ITS in China began around the late 1980s. Chinese scholars regard that ITS is a teaching system that provides individualized guidance, and the foci of researches vary in different periods. In the 1990s, the main researches in China focused on the domain of knowledge establishment, ITS system model, ITS integrated development environment, and involved with the design and implementation of natural language human-computer interface in the system. Around the year of 2000, researches began to focus on the teaching process, knowledge representation and reasoning, learner models and teaching strategies, and began to study the ITS application in Web technology, distributed system, hypermedia, Agent, Ontology, data mining, and other technologies. In recent years, researches focus more on adaptive, dynamic student models, learning and reasoning mechanisms, etc. The application of semantic web, ontology, grid, and other technologies has also attracted much attention. Overall, the ITS is not mature enough, and the research has yet to be deepened. A wide range of educational applications will take some time.

In the U.S., one-on-one tutoring has long been considered the most effective way to teach. Unfortunately, one-to-one tutoring is untenable for all students. Since the 1960’s to present, ITS has been heralded as one of the most promising approaches to deliver individualized instructions[127]. ITS uses intelligent technologies to simulate one-to-one tutoring, delivering learning activities best matched to a learner’s cognitive needs and providing targeted and timely feedback, all without an individual teacher having to be present. According to Nye (2015), the U.S. leads the research of ITS, with 393 papers in the 815 papers published from 2009 to 2013 all over the world with their inclusion criteria[128].

Intelligent technology programs (such as ITS or adaptive tutors) engage students in dialogue, answer questions, and provide feedback. Intelligent technology can provide personalized learning for students both in and outside of the classroom. When students need to reinforce skills or master ideas before an assessment, intelligent technology will be able to provide students with the additional tools they need for success. Some tutoring products based on intelligent technology have been implemented in the U.S. and can help students complete basic mathematics, writing, and other subjects. These programs can teach students basic knowledge, but so far, helping students develop high-order thinking and creativity is not ideal, which still needs to be promoted by real-world teachers.

(6) Automating Teacher's Task

The automation of teaching tasks is an important direction for development. From the perspective of the teaching process, the pre-course involves instructional design and resources preparation. Teaching involves interaction, lecture, and testing of units. Post-teaching includes assignments correction and academic evaluation. Homework correction, testing of units and academic evaluation are the most automated aspects, followed by materials preparation and class teaching. Instructional design and interaction can achieve the least degree of automation and should become the focus of teachers in an intelligent age.

In China, intelligent technology is used to free teachers from cumbersome, mechanical and repetitive mental work, and become valuable tools and partners for teachers. On the one hand, intelligent technology can replace teachers' daily work such as correcting assignments, freeing them from repetitive, mechanical matters. On the other hand, intelligent technology will empower teachers in the future and become an integral part of their work. The human-computer collaboration will accomplish intelligent work that could not be completed before[129]. In the intelligent age, as the number of teaching activities involving intelligent technology will continue to rise, people who take the identity of "teacher" will become increasingly diverse. The real "people" who perform the role of "teacher" needs to play the role of analyst for student growth data, the leader of value belief, the guide of personalized learning, the companion of social learning and the caregivers of psychological and emotional development[130].

In the U.S., intelligent technology can also perform teacher's routine tasks such as facilitating learner, grading assignments, and generating test questions. For example, at the Georgia Institute of Technology, students are fascinated by a new teacher's assistant named Jill Watson[131], who can quickly and accurately answer students' requests. However, the students do not know that Ms. Watson's true identity is a computer equipped with an IBM-AI system. Such virtual facilitators can be highly useful in the in the field of education.

For grading assignments, it is now possible for teachers to automate grading for nearly all kinds of multiple choice and fill-in-the-blank testing and automated grading of student writing may not be far behind. Today, essay-grading software is still in its infancy and not quite up to par, yet it can (or will) improve over the coming years, allowing teachers to focus more on in-class activities and student interactions than grading.

For generating test questions, computer-based adaptive testing adjusts the difficulty of successive questions based on the accuracy of student's answers, enabling more precise identification of a student's mastery level. Proctoring or proctored test is a mechanism to ensure the authenticity of the test taker and prevent him/her from cheating via a proctor during the duration of the test.

Intelligent technology will also work in identifying classroom weaknesses. For instance, intelligent technology will identify when groups of students miss specific questions, and letting the teacher know when they need to organize materials to be re-taught. In this way, intelligent technology will also hold teachers accountable and strengthen the best teaching practices.

(7) Teaching Robots

Teaching robots in schools can be used as teaching assistants to support the use of teaching equipment, provide learning contents, manage learning processes, answer the FAQs, etc., or can be used as learning partners to assist the time and task management, share learning resources, activate learning atmosphere, participate or guide learning interactions, forming a new mode of teaching. Teaching robots may be able to become "participants" in families as peers or tutors, assisting the "family education" and promoting children's learning and healthy growth[132]. The typical teaching robots in China include teaching robots, children's entertainment educational companions, and smart toys. Teaching robots are typical examples of the application of intelligent technology, voice recognition and bionics technology in education, with features such as teaching applicability, openness, extensibility, and friendly human-computer interaction. As an emerging field, related researches of teaching robots mainly focus on the areas such as hearing ability, visual ability, recognition ability, speaking ability, emotion detection ability, and long-term interaction ability.

In the U.S., teaching robots are primarily used to provide language, science or technology education and that a robot can take on the role of a tutor, tool or peer in the learning activity[133]. The teaching robots used in special education is expected to grow fast. The U.S. accounted for a significant share of the overall educational robot market in 2017. The U.S. is the early adopter of teaching robots, which results in the maximum demand for robots from this region[134]. These lifelong learning companions is another use area of the educational robots. Pearson has already suggested that in the future students will have an AI lifelong learning companion. Essentially, this next generation of students will grow up with an AI companion that knows their personal history and school history. Therefore, it will know each student's strengths and weaknesses. It can also interpret the emotional response of the student it is working with and, based on those cues, create a personalized motivational strategy[135].

(8) Learning Analytics

Learning analytics technology can be used to measure, collect, analyze and report the data about students' learning behaviors and learning environment, in order to understand and optimize learning and its environment[136]. Learning analytics technology focuses on the data related to learners' learning information and uses different analysis methods and data models to interpret the data. Then it explores learners' learning process and situation according to the results of interpretation, discovering learning rules; or interprets learners' learning performance according to data, and provides them with corresponding feedback so as to promote learning to make it more effective. Based on learning science, teaching theory, curriculum design theory and existing research results, learning analytics chooses variables such as learner characteristics and frequency of online interactive activities, analyzes and monitors students' learning situation, evaluates teaching quality of teaching activities, and discovers problems in learning in time, so as to ensure the implementation of smart education[137].

(9) Modern School Management

The school management is based on intelligent technology and data management and supported by smart campus index system, data decision-making platform, and report service platform, through big data, cloud computing and intelligent perception technology, etc. It collects and delves into the school data efficiently and deeply, establishes the logical process of priority governance tasks and key governance businesses, and provides early warning centers, student portraits, data centers, report services, and other functions to provide effective support for the smart decision of schools.

Opinions to Take away from Typical Scenarios of Intelligent Technology in School between China and the U.S.

- The typical application fields of intelligent technology in education are different in China and the U.S. The application of off-campus compensatory instruction is prominent in China, which is usually aimed at extracurricular training and scores improving. The U.S. emphasizes the application of in-campus personalized learning, focusing on the use of technology to promote the development of students' thinking skills and competency.

- The main application modes of intelligent technology in education are different in China and the U.S. China emphasizes the construction of infrastructure, with the construction of smart learning environment as the main feature. Its purpose is to promote the transformation of school instruction, reduce the burden on teachers and promote students to learn easily and effectively. The U.S. focuses on the research and application of ITS, emphasizing that AI promotes the instruction of STEM discipline.
- There are differences in the policy-making on the application of AI in education between China and the U.S. China emphasizes the overall reform of AI in education by the use of intelligent systems to improve instructional quality and optimize talent cultivation. The U.S. focuses on the research and talent cultivation of AI and promotes the in-depth fusion of AI and education by improving the quality of STEM education and establishing AI and education projects.

4.2 Key Products and Technology of Intelligent Technology in the Educational Industry

From 2012 to 2017, the financing amount of Artificial Intelligence in Education (AIED) companies in China showed a rapid growth trend, especially in 2015, which started to explode. In 2017, the financing amount of AIED reached 4.217 billion yuan[138]. In the U.S., MarketsandMarkets forecasts the global market of AIED to grow from USD 373.1 Million in 2017 to USD 3,683.5 Million by 2023[139]. It is expected that AI in U.S. education will grow at a CAGR (Compound Annual Growth Rate) of 47.77% during the period 2018-2022 according to the AI Market in U.S. Education Sector report[140].

In terms of key intelligent technologies infused into education, China follows closely on three aspects: data acquisition (speech recognition, image recognition, sensors, etc.), data processing (semantic recognition, big data, adaptive, cognitive computing, emotional computing, etc.) and human-machine interface (AR/VR, robots, 3D printing)[141], which greatly improve the serviceability of AI to education. However, most AIED companies are still in the early stage of development. In the U.S. education sector, AI is increasingly used to enhance student learning; intelligent interactive programs using various technologies such as machine learning, natural language processing, and deep learning to help in overall learning of students. There are a number of intelligent technology companies with various products providing service to instruction, learning and school management.

About the learning, Chinese products include types such as online tutoring, personalized/adaptive learning, photo searching, subject learning. Specifically, XUEERSI[142] is an online primary and secondary education brand, owned by TAL Education Group (original XUEERSI, listed on the New York Stock Exchange in 2010). Its Personalized Learning Mission System (IMS) IDO introduces face recognition, voice recognition, and tactile interaction into online classrooms, allowing online learning to have more quantifiable data and traceable learnings. Taking Squirrel AI adaptive learning as an example. It uses a self-developed adaptive learning system, adopts a teaching mode combining online and offline, and gives full play to the high efficiency of online learning and the supervision and guidance of offline teachers. It is dominated by artificial intelligence system and carries out a complete teaching process of "testing, learning, practicing and testing," aiming at students' weak points in knowledge and matching suitable learning content. Through the function of "testing," the knowledge graph of students can be drawn to understand the state of each student's knowledge points, and then the complex knowledge points could be broken down in detail.

In the U.S., companies such as Carnegie Learning[143] combines consumable textbooks, intelligent 1-to-1 math tutoring software, and transformative professional learning and data analysis services into a comprehensive and cohesive learning solution. Carnegie Learning's instructional approach is based upon the collective knowledge of cognitive learning scientists, master practitioners, and ongoing research initiatives. It is not only aligned with the most current math education standards, but also based on a scientific understanding of how people learn, and a real-world understanding of how to apply that science to conceptual math understanding as well as more in-depth learning skills like creativity, collaboration, critical thinking, and communication. Also, Knewton[144] provides an underlying engine for adaptive learning for institutions and schools. Its main operational process is that institutions and schools nest their learning systems on the Knewton platform and digitize their curriculum resources in Knewton's system. By continuously assessing students' mastery of materials, they dynamically recommend appropriate learning methods and contents for each student to meet the demand for personalized learning and predict future learning.

There are many AIED companies in the teaching/instruction category, mainly including assignment correction, intelligent evaluation, and companion, Chinese companies like Izuoye[145], Pigai[146], pay close attention to the assignment correction. Take Izuoye for example, which is an App that can help oneself check children's assignment, providing the identification and correction of various types of questions in elementary school, such as math word questions, multiple choice questions, true or false questions, etc. Izuoye's recognition engine uses Deep Learning algorithm to improve the recognition ability of pupils by continuously learning from their assignment book. Also, Liulishuo[147], National Standard Mandarin Intelligent Test System[148] etc. focus on intelligent evaluation. Liulishuo is an APP for improving English speaking, whose greatest feature is to evaluate the users' English pronunciation accurately. This App attempts to build the largest "Chinese English Speech Database" to improve the accuracy of oral scoring by speech recognition technology and AI algorithm.

In the U.S., companies such as Thinkster math[149], use AI and machine learning in math tutor App to visualize how a student is thinking while he or she works on a problem. This helps improve how fast and precisely teachers can spot problem areas. Thinkster coaches do not just observe how students work out problems. They understand and visualize their thinking using our Active Replay Technology (ART), identify where students make mistakes and provide guidance so students can solve new problems that improve their understanding of math. The math tutoring program leverages human interaction and groundbreaking intelligent technology to create personalized learning programs. The technology tracks how a child arrives at an answer, something that after-school "learning centers" have long overlooked. Universal textbooks are only helpful for cardboard cut-out versions of students who look, think, problem-solve, and process information the same. Content Technologies, Inc. [150] (CTI) is an AI company using Deep Learning to create customized textbooks that fit the needs of specific courses and students. Teachers import syllabi into a CTI engine. CTI machinery then masters the content and uses algorithms to create personalized textbooks and coursework based on core concepts. When was the last time your classroom read a textbook cover-to-cover, utilized every page of practice questions or saw correlations between in-class work and assigned reading? CTI hopes to fill that gap and help publishers create effective textbooks right for each learner.

With regards to the school management, China Telecom uses face recognition technology, based on classroom instructional videos, applying somatosensory computing and emotional monitoring, as well as cross-validation of somatosensory, to provide users with cloud-based classroom instructional evaluation service. Meanwhile, the application can recognize and record students' learning behaviors such as raising hands, standing, yawning, sleeping, and teachers' orientation, the locus of action and speech speed. An extensive database of teaching emotions is constructed to calculate the emotions of teachers and students according to the expressions of students and teachers.

In the U.S., Google Classroom[151] is a web-based platform that integrates educator's "G Suite" for Education account with all your G Suite services, including Google Docs, Gmail, and Google Calendar. Classroom saves time and paper and makes it easy to create classes, distribute assignments, communicate, and stay organized. Teachers can quickly see who has or has not completed the work, and provide direct, real-time feedback and grades right in the Classroom.

Opinions to Take away from Key Products and Technology of Intelligent Technology in the Educational Industry between China and the U.S.

- The types of intelligent education products are different between China and the U.S. In China, students' academic performance is emphasized a lot in the stage of basic education. There are many applications for homework correcting and question searching, usually for the purpose of improving testing scores. However, independent innovation and critical thinking are encouraged in the U.S.'s basic education and there are many intelligent education products focusing on STEM discipline instruction, which are usually aimed at improving students' problem-solving ability.

- The commercial models, application fields and technical characteristics of intelligent education products between China and the U.S. are distinct. Influenced by parents' acceptance of off-campus training, China's commercial model is mainly To C, while America's is To B. As for the application field of products, China's K-12 tutoring and language learning gain the most popularity, while the application of higher education in the U.S. accounts for a large share. From the perspective of technical characteristics of products, China's speech recognition and image recognition technologies are widely used, while U.S.'s products based on Natural Language Processing technologies account for a high proportion.

- The application fields, categories, and characteristics of intelligent education products are similar in China and the U.S. They cover the domains from K-12 to higher education, vocational education and off-campus training, etc. The intelligent education products of both China and the U.S. include adaptive learning, intelligent tutoring, intelligent evaluation, teaching robots, etc, which all reflect more application for teachers' teaching and students' learning, and less application for school management.

- The intelligent education industry in both China and the U.S. is developing rapidly with good market expectations. Since 2015, the financing amount of AIED related enterprises in China has increased tremendously, reaching 4.217 billion RMB in 2017. MarketsandMarkets forecasts the global market of AIED to grow from 373.1 million USD in 2017 to 3,683.5 million USD by 2023. It is expected that AI in the U.S. education will grow at a CAGR (Compound Annual Growth Rate) of 47.77% from 2018 to 2022.

- In China and the U.S., the maturity of enterprises specializing in the application of AI in education needs to be improved, and most of them are still in the initial stage of development. Some products of Chinese enterprises have such problems as insufficient data collection and mining, overgeneralization of learning model and inadequate adaptive adjustment. In the U.S., although some enterprises have already served a large number of students and accumulated dozens of years of experience and data, the products of most enterprises, especially teaching robots, are difficult to meet the demand of students, parents and teachers truly.
- Both China and the U.S. put emphasis on the application of intelligent technology in adaptive learning, automating teacher's task and teaching robots, but the fusion of intelligent technology and instruction is not deep enough, and the function of supporting instruction needs to be improved.

4.3 Typical Cases of Intelligent Technology in Education

4.3.1 Cases in China

(1) Classroom video information collection-The No.11 Middle School in Hangzhou[152]

The No.11 Middle School in Hangzhou, Zhejiang Province, is a provincial secondary key high school. Currently there are 24 classes. The school is fully equipped with modern education technology and is a modern experimental school of educational technology in Zhejiang Province. The campus network provides teachers and students with a wide range of interactive platforms for teaching and tutoring, with sensitive and rapid information interactions, achieving "one to one" individual guidance which is conducive to the student's personalized development.

The No.11 Middle School also applies the "Smart Class Behavior Management System" to classroom teaching. The system can realize "recognizing face" attendance, and at the same time, it can also statistically analyze the behavior of students in the classroom through the camera, giving real-time feedback on abnormal behaviors. Face attendance is achieved by installing three combined cameras in the classroom. When students stand up before class, they can finish checking the attendance in a few seconds. Each of the three cameras is wrapped in a grey ball. During the course, students and teachers are not aware of cameras' activities. The system scans students in every 30 seconds, analyzing their learning states and behavioral characteristics in terms of their reading, raising hands, writing, standing up, listening and leaning on the table, with the combination of facial expressions, including happiness, sadness, anger or dislikes[153]. The system mainly includes the following four essential functions.

Class attendance: It automatically recognizes the face features of each student in the classroom, and matches the information in the students' face database, automatically counts the number of students attending the class, provides intelligent assistance for academic staffs, and also realizes the connection of student data in the shifting teaching.

Classroom behavior observation: It automatically provides statistics of fundamental parameters such as the number of speakers, the time of their speaking and the proportion of all students. It also integrates multi-dimensional information to calculate classroom activity, automating the statistical work of indicators that require intensive workforce, and significantly improving teachers' classroom observation and evaluating class effectiveness.

Classroom emotional analysis: The system automatically analyzes of teachers' and students' facial expressions and voice emotions, deeply understands the teaching style of teachers and students' emotional changes in the process of learning, through the analysis of the overall classroom mood can also understand the individual student's mood and classroom mood fit.

Classroom content analysis: The system automatically identifies the teachers' lecture content and students' speech content, converts the content into text. Then it uses the knowledge map to understand the text deeply, realizes knowledge point extraction and knowledge association analysis. Moreover, it provides a good reference for teachers to develop personalized learning programs.

(2) Robot assistants get into the classroom-Wuhan No.20 Senior High School[154]

Wuhan No.20 Senior high School was founded in 1909 as the "Hankou Saint LoiS Girls' High School". It is currently the public full-time general key high school in charge of the Wuhan Municipal Education Department. The school has 34 classes and 2,208 students.

In the art appreciation class of grade 2, robots Xiao Gu and Xiao Yong (IFLYTEK CO., LTD.[155]) appreciate the artworks with their classmates. These two types of robots use the functions of voice recognition, information searching, and image evaluation to assist teacher's explanations. When the teacher presents classic Chinese paintings such as "Two Horses", "Shull Map", "Running Horse", "Ink Plum Flowers" and "Ink Orchid Flowers" combined with the PowerPoints, etc, the "teaching assistant" introduced the background of the relevant authors one by one, guiding them to feel the artistic conceptions in the paintings. The most interesting thing is that in the practice session when the students finish paintings on the spot, they only need to send the paintings to the "teaching assistants." As soon as the paintings are sent to the "teaching assistants," it only needs a blink and "snap" with a soft voice and comments[156].

(3) Automatic Assignment Review System-Shanghai Shixi High School[157]

The school is located in the prosperous Jing' an Si Street in Shanghai and divided into two parts, and has a total of 20 classes. It was rated as a civilized unit in the district, a demonstration school for behavioral norms of the primary school students, and a pilot school for small classes.

The school has an automatic review system. The student completes the paper homework or examination and uploads it by tablet or mobile phone. Then the system automatically reviews it. The student corrects the error according to the system review and then uploads the photo again. The teacher checks the students' corrections and conducts a targeted evaluation in the classroom.

The automatic review system can perform automatic statistics and can also record the trend of changes in class work and the change of correct rate. The automatic review system allows teachers to achieve precise teaching, and the system will prompt for content that needs to be highlighted.

The classroom can bring up the homework of each student on the spot which provides resources for teaching. The system automatically generates a class knowledge map for teachers' teaching reference. For students, they can immediately give feedback, correct mistakes in time and improve in time. The system automatically generates the wrong questions, forming a book and the knowledge map of the students.

(4) Learning Analytics-Xinxiang No. 11 Middle School[158]

Xinxiang No. 11 Middle School is an ordinary high school directly under Xinxiang City, Henan Province. It is a model school in Xinxiang City and has more than 55 teaching classes. Xinxiang No. 11 Middle School uses a learning and analysis system to promote mathematics learning (onion mathematics[159]), Learnings are conducted online, including learning, practicing, writing exercise books, testing, diagnosing, correcting and so on. The system will catch all learning data with a comprehensive analysis. The data includes those of the assessment, exercise, video viewing learning, and self-learning strategies and behaviors. This can more accurately calculate the degree of student participation and learning mastery in the learning process.

Teachers can also help the assistant to carry out teaching in different layers in the classroom through such resources software and intelligent teaching assistants. They can also arrange similar tutoring exercises for students after classes to help them to carry out layered tutoring. At the same time, students can return to their homes or learn independently through machines in the self-study classes, which is equivalent to extending the entire learning process of teachers to the inside and outside of the classroom through the assistance of this technology and AI.

After two years of using this system, the results of the experimental class were significantly higher than the compared class, with an excellent rate and the average score significantly different[160].

(5) Intelligent confrontation based on AI tutor-Squirrel AI[161]

The Squirrel AI intelligent education uses Bayesian to claim network, topic-based simulation modeling technology, AI adaptive learning technology and educational psychology theory, and models the interaction between teachers and students in the teaching process, building a paralleled classroom. Similar to AlphaGo Zero, it is capable of self-gaming. In the classroom, students and AI teachers can interact and make feedbacks. AI teachers constantly adjust the teaching plan through the evaluation of teaching and learning for different students, and realize the self-training process of AI teachers to exceed itself.

In October 2017, Zhengzhou, 78 students were divided into two groups, and a group of three 17-year-old middle and high-level teachers gave real-life lectures. Another group of students thoroughly studied using the Squirrel AI intelligence adaptation system. In the next four days, there were targeted and concentrated teaching guidance of mathematics for junior high schools. Through the pretest and posttest, the learning effects of the two groups of students were objectively compared.

The results showed that the intelligent adaptation educational robot defeats the real person teaching, and the average core score-raising was 36.13 points (machine teaching) over 26.18 points (real person teaching). For the maximum score and the minimum score, the machine group was also relatively higher for 5 points and 4 points[162].

(6) Intelligent robots help targeted poverty alleviation in education

On January 13, 2018, the “National First Batch of Robots to Help Left-behind Children Healthy Growth Accurate Education and Poverty Alleviation Standardization Demonstration Point” settled in Guang'an Sichuan

Province. Representatives of left-behind children from four villages including Longmiao Village, Longkong Village, Dingba Village, and Dashi Village accepted robot donations at the ceremony. For left-behind children in poverty-stricken areas, the intelligent robot Xiaobao will assume the responsibility of teachers and parents[163]. It not only teaches children different knowledge through the rich educational resources of the Internet but also accompanies the children to grow up happily.

Xiaobao can realize the function of identifying human objects by scanning the human face and storing different scan results through data storage. Face recognition technology allows Xiaobao to know every family member. Xiaobao robot can realize interactive communication between Chinese and English, realize voice wake-up and can be called on anytime, with Chinese and English for communicating. Xiaobao robot built education software for prenatal education, preschool education, and K12 professional education as well as storytelling, answering questions, playing games, entertaining and learning. The learning companion of Xiaobao intelligent helps children to fall in love with learning.

4.3.2 Cases in the U.S.

(1) Intelligent Learning Community-Edmodo[164]

Edmodo is an online educational social media networking service like Facebook and allows teachers and students to connect daily and for virtual communities with Internet forums, social blogs, email, Twitter, instant messages, and video chats for teachers, students, and parents on a closed, secure website.

Edmodo's communications tools allow students to engage in social learning, in a way that empowers all students to speak up more often, giving everyone a voice. Teachers who use Edmodo engage more students, reach more parents, and get everyone more involved.

With over 90 million registered users in 400,000 schools across 192 countries, the Edmodo platform is one of the largest and most active learning community platforms in the world.

(2) Tailored Learning Path-DreamBox

DreamBox captures every interaction a student makes while working within and between lessons. As it dynamically adapts and individualizes instruction in real time, it provides millions of learning paths tailored to each student's unique needs. It is a ground-breaking, student-driven learning environment that leverages gaming fundamentals to inspire and empower students to build 21st-century thinking and problem-solving skills, master key concepts, increase achievement, and boost long-lasting confidence in learning[165].

The Center for Education Policy Research (CEPR) at Harvard University has completed a study of nearly 3,000 math students using DreamBox in Grades 3-5 in two districts. The study showed meaningful achievement gains. In particular, for every 20 minutes, a student spent on DreamBox their MAP score was increased by 2.5 points. Because the study indicates a linear relationship between time spent on DreamBox and achievement gains, students who use DreamBox for the recommended 60 minutes per week stand to experience an increase of 7.5 points on the MAP[166].

(3) Blended Textbook- Carnegie Learning[167]

The Middle and High School Math Solutions combine write-in consumable textbooks and intelligent 1-to-1 tutoring software into a comprehensive, blended learning solution that provides the most effective blend for teachers and the instructional balance that students need.

The U.S. Department of Education awarded the RAND Corporation a $6 million grant to study Carnegie Learning Algebra I Blended Curriculum over two years (2007–2009). Participating schools were randomly assigned to either continue with the current algebra curriculum for two years or to “adopt Carnegie Learning Algebra I.

- Over 18,000 students in 147 schools throughout seven states.
- Schools were randomly assigned to the control or experimental group.
- RAND researchers used “intent-to-treat-analysis;” schools did not receive extra assistance to implement the curriculum.

Carnegie Learning blended approach nearly doubled growth in performance on standardized tests relative to typical students in the second year of implementation. On average, Carnegie Learning Blended Curriculum (textbooks and software) moved students at the 50th percentile to the 58th — nearly double the gains of a typical year’s worth of learning.

(4) Data-Driven Analytics-Microsoft Azure Cloud

There is a rich set of tools in the Azure cloud that developers can leverage to build AI-powered applications for schools to harness. Tools such as the Office Graph API, Cognitive Services and Media Analytics can be combined with ML to provide deep analytical insights into student performances and then be visually displayed using Microsoft Power BI dashboards[168].

The Tacoma Public School District utilized these for AI-powered analytics and improved their student graduation rates from 55% to 82.6% throughout six years[169].

By pooling all available institutional data on the students in the Azure cloud, along with accessing additional data from government departments and even social media, the Tacoma Public School District was able to use ML and AI to gain deep insights into their students and identify in real time any ‘at risk’ students who required immediate intervention and support.

(5) Personalized Reading-Lexia Core5 Reading[170]

Lexia Core5 Reading supports educators in providing differentiated literacy instruction for students of all abilities in grades pre-K-5. Lexia’s research-proven program provides explicit, systematic, personalized learning in the six areas of reading instruction, targeting skill gaps as they emerge, and providing teachers with the data and student-specific resources they need for individual or small-group instruction.

Students at Sterling Intermediate are experiencing impressive growth as a result of using Core5. Those who were meeting Core5 recommended usage over at least 20 weeks made meaningful progress. The percentage of students working in or above their year in Core5 increased from 45 percent to 86 percent, and the percentage of students working 2+ grades below their year in Core5 decreased from 22 percent to just 5 percent[171, 172].

Statements and Conclusions

The following ten highlights capture the big picture themes of transforming education through intelligent technology between China and the U.S.

1. The three functions of higher education, namely talent training, scientific research, and achievement transformation, are essential engines for the development of a country's AI industry. Both China and the U.S. have the world's top AI universities, however, the number of universities with high-level AI discipline in the U.S. far exceeds that in China. According to CSRanking, there are three in the U.S. and two in China among the five top AI universities worldwide. However, among the top 100 universities, there are 54 in the U.S. and only 10 in China. Since 2016, China has accelerated the construction of AI in colleges and universities, opening up more than 30 AI departments in universities.

2. Intelligent technology is mainly divided into a basic level, technical level, and application level. The AI industry in the U.S. has a relatively overall layout and has strong technological innovation advantages in the core areas of the basic level such as algorithms, chips, and data. The U.S. has about twice as many companies in the basic and technical levels as China, but the gap is slightly smaller in the application level, where China has more companies in intelligent robotics and voice recognition than the U.S.

3. Education is considered as an essential scenario for the application of intelligent technology both in China and in the U.S. In the field of education, intelligent technology needs to consider different learning context, adaptation to the characteristics of target learners, and improvement over time in response to learning process data. Intelligent technologies such as recommender technology, learning analytics, robots, intelligent VR/AR can provide personalized service and create a smart environment for learning, teaching as well as school management.

4. Rural education occupies a large proportion in the basic education of both China and the U.S., and the difference between urban and rural areas is still the core that needs to be paid close attention to in the process of promoting the balanced education in both countries. In China, rural students account for two-thirds of the total number of students in schools, and schools in rural areas (towns and countryside) account for about two-thirds of the total number of schools. Rural education remains a significant part of China's compulsory education. In the U.S., with a fifth of the students, a third of the schools and half of the school districts in rural areas, rural education is also a concern.

5. Instructional support and technical service are critical guarantees for ICT in schools. China and the U.S. have different structures of ICT in Education. China's Ministry of Education has established the top-down specialized IT support institutions (e.g., National Centre for Educational Technology), coordinating with research institutes and enterprises to lead the promotion and application of IT in primary and high schools. In the U.S., apart from the federal departments (e.g., OET), each state has relatively independent educational technology offices and associations (e.g., ISTE, AECT, et al.,) involved in ICT in Education.

6. ICT infrastructure is a prerequisite for ICT in Education, and both China and the U.S. have already owned equipped ICT infrastructure. In China, 97.82% of primary schools have Internet access, 98.96% of junior high schools and 98.78% of senior high schools respectively. In the U.S., 98% of public schools have next-generation fiber infrastructure. 96% of U.S. public schools have sufficient Internet access to provide digital learning in class.

7. Teacher professional development with ICT is a key guarantee of ICT in education. China and the U.S. differ slightly in the methods of teacher training. China emphasizes large-scale staff training (such as National Training Plan, Project 2.0 of the Improvement of Teachers' ICT Capability in Primary and Secondary Schools). In the U.S., in addition to large-scale training, it also focuses on providing continuous instructional support for teachers through online communities. Other professional organizations such as ISTE and AECT also play an important role in teacher training.

8. The typical application fields of intelligent technology in education are different in China and the U.S. The application of off-school compensatory instruction is prominent in China, which usually aiming at extracurricular training and scores improving. The U.S. emphasizes the application of in-school personalized learning, focusing on the use of technology to promote students' ways of thinking.

9. There are differences in the policy-making for the application of AI in education between China, and the U.S. China emphasizes the overall reform of AI in education by the use of intelligent systems to improve instructional quality and optimize talent training. The U.S. focuses on the research and talent training of AI and promotes the in-depth infusion of AI into education by improving the quality of STEM education and establishing “AI + Education” projects.

10. The types of intelligent education products are different between China and the U.S. In China, students' academic performance is emphasized more in the stage of basic education. There are many applications for homework-correcting and question-searching, usually to improve scores. However, independent innovation and critical thinking are encouraged in the U.S. basic education, and many intelligent education products are focusing on STEM discipline instruction, which usually aiming at improving problem-solving ability.

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