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德勤

**Global development of
AI-based education**

Contents

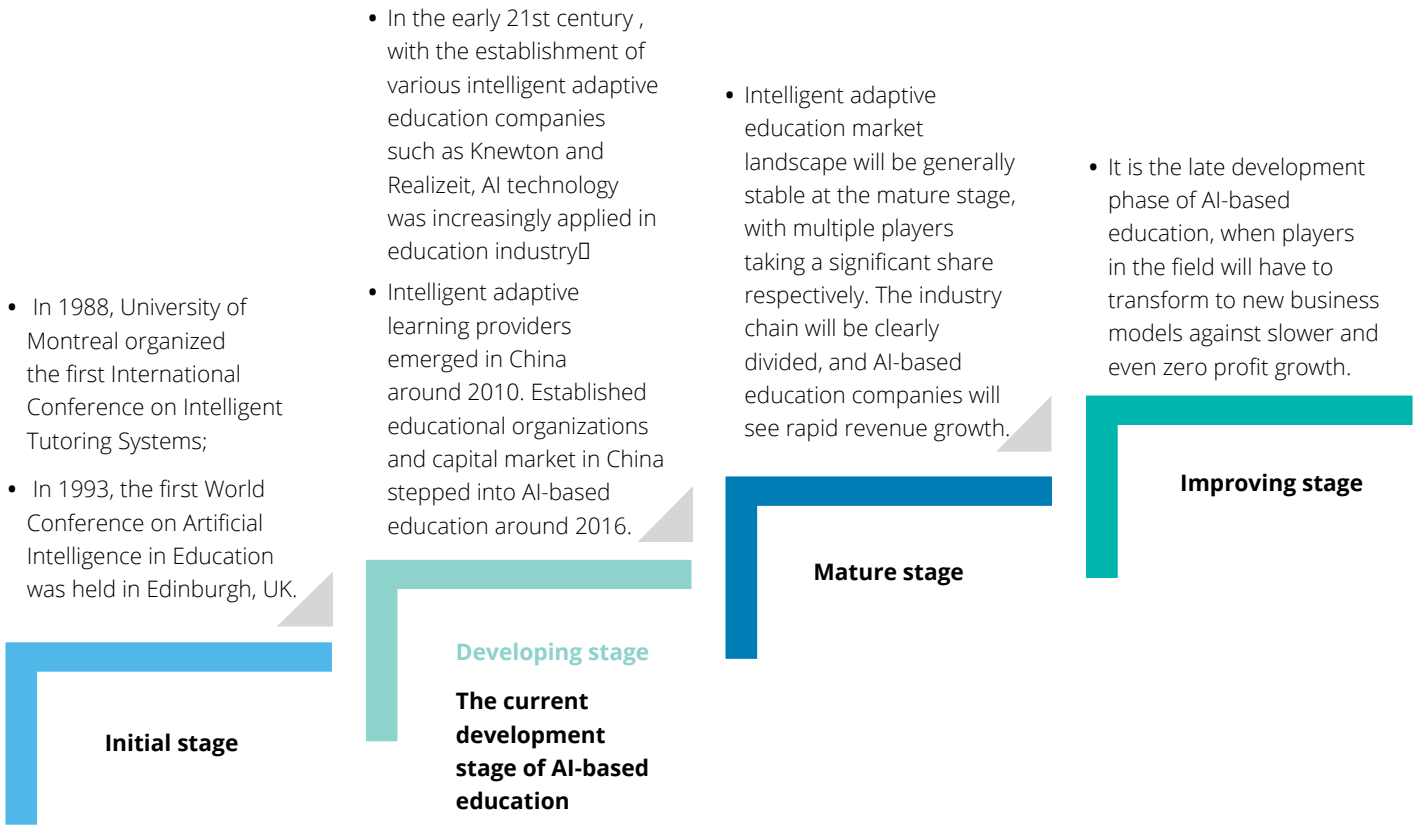# 1. Introduction to AI-based education

1.1 Development history

Artificial intelligence (AI) is accelerating the integration of information technology into education, providing support or even alternative approaches for practioners in the industry. AI-based education in the future will be driven by the use of data, intensive technology application, integrated innovation, and service optimization.

AI-based education is still developing and not yet fully mature. While AI is a hot topic, application of this technology in education industry requires long-term efforts. The initial stage of AI application in education focuses on planning and tentative exploration. Since Allen Newell and Herbert Simon from Carnegie Mellon University invented Artificial Intelligence (AI) in the 1950s, it has evolved to address problems of probabilistic and numeric nature, leading to the incorporation of approaches from mathematics, engineering and economics.In 1970's, Jaime Carbonell established intelligent tutoring systems, under which computers were used to assist education. In 1993, the first World Conference on Artificial Intelligence in Education was held in Edinburgh, UK. AI-based education has been developing over time. In the early 21st century, with the establishment of various intelligent adaptive education companies such as Cognitive Tutor, Knewton and Realizeit in the US, AI technology was increasingly applied in education industry. Intelligent adaptive learning is an AI-enabled education technology that simulates human teachers' one-on-one teaching process, deeply personalized for every type of student. An increasing number of intelligent adaptive learning providers including Yixue Education and Gold-Wood Learning have emerged in China since 2010. Established educational organizations such as Tomorrow Advancing Life and New Oriental, as well as capital market in China stepped into AI-based education around 2016. After decades of development, AI has evolved from a concept of reasoning to a technology combining natural language processing, speech recognition and image recognition based on deep learning, along with significant improvement in algorithm model. Big data provides AI with data support and cognitive computing capabilities. Besides, application of AI technology in education industry requires cooperation across different disciplines including neurology, cognitive science, psychology, mathematics and education. Multi-disciplinary application will facilitate the development of AI-based education.

Figure 1-1: Different development stages of AI-based education

- In 1988, University of Montreal organized the first International Conference on Intelligent Tutoring Systems;
- In 1993, the first World Conference on Artificial Intelligence in Education was held in Edinburgh, UK.

Initial stage

- In the early 21st century , with the establishment of various intelligent adaptive education companies such as Knewton and Realizeit, AI technology was increasingly applied in education industry
- Intelligent adaptive learning providers emerged in China around 2010. Established educational organizations and capital market in China stepped into AI-based education around 2016.

Developing stage

The current development stage of AI-based education

- Intelligent adaptive education market landscape will be generally stable at the mature stage, with multiple players taking a significant share respectively. The industry chain will be clearly divided, and AI-based education companies will see rapid revenue growth.

Mature stage

- It is the late development phase of AI-based education, when players in the field will have to transform to new business models against slower and even zero profit growth.

Improving stage

Source: Deloitte Research

1.2 Application at home and abroad

AI-based education is embracing substantial development both at home and aboard, with AI technology applied in education through different patterns. Under the model of "AI + education", companies prioritize the research and development of educational intelligent products and services to fully satisfy users' need, leveraging the advantages of AI technology. Customers of AI-based education want more convenient and efficient intelligent education.

Figure 1-2: Types of AI Application in education

Types of AI Application in education	Specific scenarios of AI Application in education	Domestic companies	Overseas companies
Intelligent adaptive learning	Combined with intelligent adaptive learning technology to create a virtual teacher, not only can permeate the whole teaching process, but also support personalized teaching. Each student can learn according to their own rhythm, which helps to improve learning efficiency and enthusiasm.	• Yixue Education(Squirrel AI) • 17zuoye; • Liulishuo; • Knowbox • 51Talk; • Toutiao	• IBM Watson; • Knewton; • DreamBox Learning; • Renaissance Learning; • Cognitive Learning • Duolingo;
Human-machine interaction	Intelligent source processing and search technology	• Est100 • iFlytek;	• LightSail Edution; • Grammarly;
Dual teacher classroom	Image recognition	• Box Fish	• Cerego
Speech assessment	Intelligent language processing and speech recognition	• danatech; • 91jzx;	• Wonder • Workshop;
Intelligent language processing application	Based on language processing , being able to build some grammatical frameworks	• Dji; • Singsound;	• RoboKind 'Millo'; • Sphero
Photo based question searching	Computer vision and image recognition	• Izrobot	

Source: Deloitte Research

Development of intelligent adaptive education in the US started as early as in 1990's, while China has not seen rapid development of the model until the past decade. Foreign language learning is well received in China, with K12 and English tutoring attracting most customers. In contrast, language learning is far less popular in the US than in China. Compared with the small share of language tutoring in AI-based education in the US, higher education is the focus, equal to K12 tutoring in the percentage of related service providers.

Figure 1-3: Percentage of Top 30 "AI + education" companies providing the following services
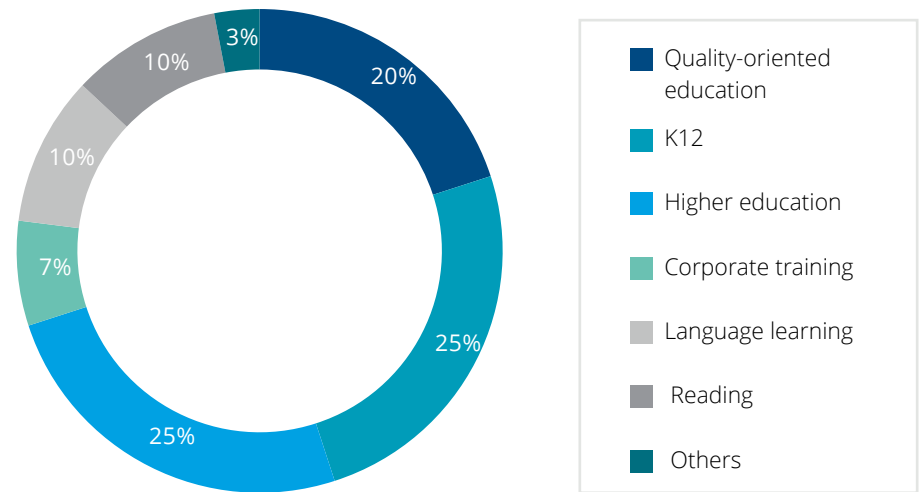
Source: iyiou.com, Deloitte Research

Intelligent adaptive learning technology has been used in the US and Europe for more than ten years, with over 100 million users across different ages. Both product and technology have evolved to an advanced level in these regions. China, however, is still at the initial stage in the application of intelligent adaptive learning technology, lagging behind in data accumulated. Despite

of such situation, China is likely to catch up from behind, based on large population and rapid development. As for technologies, foreign companies such as Knewton use probabilistic graphical model, item response theory and learning analytics, etc.; RealizeIt adopts information theory, bayesian algorithm and machine learning, etc.; and ALEKS mainly leverages knowledge

space theory. Leading AI-based education companies in China make use of a wide range of technologies too. For example, technologies applied by squirrel AI of Yixue Education broadly cover genetic algorithm, neural network technology, machine learning, graph theory, bayesian network, logistic regression model, knowledge space theory, information theory, bayesian theory, knowledge tracing theory, educational data mining and learning analysis technology.

Figure 1-4: Application of AI-based education in domestic and overseas markets

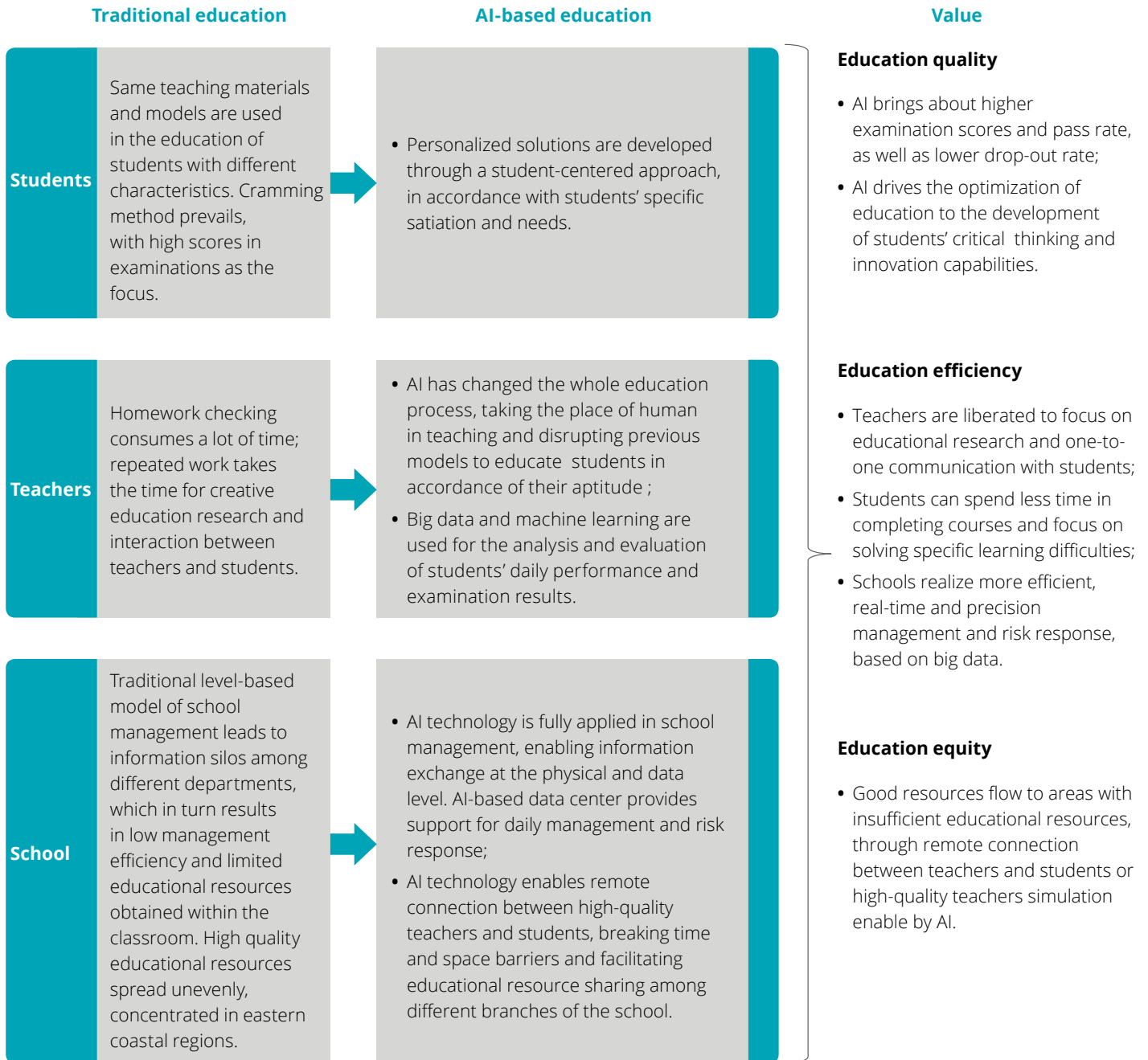|	Domestic market	Overseas market
Development background	Paid after-school tutoring is developing well in China, with positive prospect.	With various background, students may flow to diverse service providers.
Technology application	At the initial stage of applying intelligent adaptive learning technology, China is lagging behind in the accumulation of related data	Intelligent adaptive learning technology has been used in the US and Europe for more than 10 years, with over 100 million users across different ages
Content development	Intelligent adaptive education companies in the domestics market are inclined to developing teaching materials by themselves. As many different exam-oriented textbooks are used in China, these companies have to analyze potential examination questions aligned to different textbooks, providing detailed contents to prepare students for tests.	Mostly prepared by schools and publishing houses, teaching materials are featured with clear intellectual property rights and complete and systematics contents
Application scenarios	K12 and English tutoring	K12+, higher education and vocational education
Representative companies	Yixue Education(Squirrel AI), New Oriental, Tomorrow Advancing Life, Liulishuo	ALEKS, Realizelt, Knewton, Dreambox Learning, Duolingo, Renaissance Learning; Cognitive Learning

Source: Deloitte Research

1.3 Difference from traditional education and value added

AI application in education has a disruptive influence on traditional education, as AI has changed the goal and method of education. Teaching students in accordance with their aptitude is possible with the support of AI technology, which transfers the goal of education from high scores to quality improvement. Adaptive learning provides personalized solutions in accordance with students' specific situation and needs, changing the way of education. AI has disrupted the whole education process, playing a major role in teaching and liberating teaching human resources. Besides, AI is able to facilitate decision making based on educational big data, enabling precision teaching and improvement of learning speed and flexibility. The technology can also drive information flow within the school and resource sharing across different regions, breaking barriers to information and resource sharing.

Figure 1-5: AI transforms traditional education and creates new value

Traditional education	AI-based education	Value

Students

Same teaching materials and models are used in the education of students with different characteristics. Cramming method prevails, with high scores in examinations as the focus.

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- Personalized solutions are developed through a student-centered approach, in accordance with students' specific satiation and needs.

Education quality

- AI brings about higher examination scores and pass rate, as well as lower drop-out rate;
- AI drives the optimization of education to the development of students' critical thinking and innovation capabilities.

Teachers

Homework checking consumes a lot of time; repeated work takes the time for creative education research and interaction between teachers and students.

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- AI has changed the whole education process, taking the place of human in teaching and disrupting previous models to educate students in accordance of their aptitude;
- Big data and machine learning are used for the analysis and evaluation of students' daily performance and examination results.

Education efficiency

- Teachers are liberated to focus on educational research and one-to-one communication with students;
- Students can spend less time in completing courses and focus on solving specific learning difficulties;
- Schools realize more efficient, real-time and precision management and risk response, based on big data.

School

Traditional level-based model of school management leads to information silos among different departments, which in turn results in low management efficiency and limited educational resources obtained within the classroom. High quality educational resources spread unevenly, concentrated in eastern coastal regions.

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- AI technology is fully applied in school management, enabling information exchange at the physical and data level. AI-based data center provides support for daily management and risk response;
- AI technology enables remote connection between high-quality teachers and students, breaking time and space barriers and facilitating educational resource sharing among different branches of the school.

Education equity

- Good resources flow to areas with insufficient educational resources, through remote connection between teachers and students or high-quality teachers simulation enable by AI.

Source: Deloitte Research

AI has changed the way to apply same contents and models in teaching different students, through analyzing learning models and individual differences among students. Statistics suggest that students under AI-based educational model are able to achieve better learning results, with shorter time in completing courses, and higher pass rate and examination scores, compared with those under the traditional educational model. Meanwhile, quality-oriented education is likely to be widely adopted with the support of AI technology, which enhances all-round development of students by improving their critical thinking, innovation and other abilities, while elevating exam-oriented education efficiency.

Human teachers are liberated by AI assistants from repetitive and tedious exam paper correcting and daily management to focus on creative work of educational research and one-to-one communication with students. AI-based decision making with the support of big data from educational activities helps teachers to better understand the educational satiation.

AI breaks the barriers to information and resource sharing. The emergence of smart campus concept, interconnection among school facilities, department integration and information exchange have provided a data base for management decision making and risk response. Remote teaching and online education have enhanced education equity, enabling high-quality educational resources to flow from eastern coastal regions to remote and poor areas.

Compared with traditional education, AI-based education has enhanced education quality, efficiency and equity, creating value for students, teachers and regional education systems.

1.4 Critical technologies

Many AI related technologies have a profound impact on education, of which five technologies derived from the integration of basic theories of computer science including algorithm, graph theory and inferential statistics with edge-cutting theories in other fields are critical for AI-based education.

Figure 1-6: Illustration of critical technologies for AI-based education
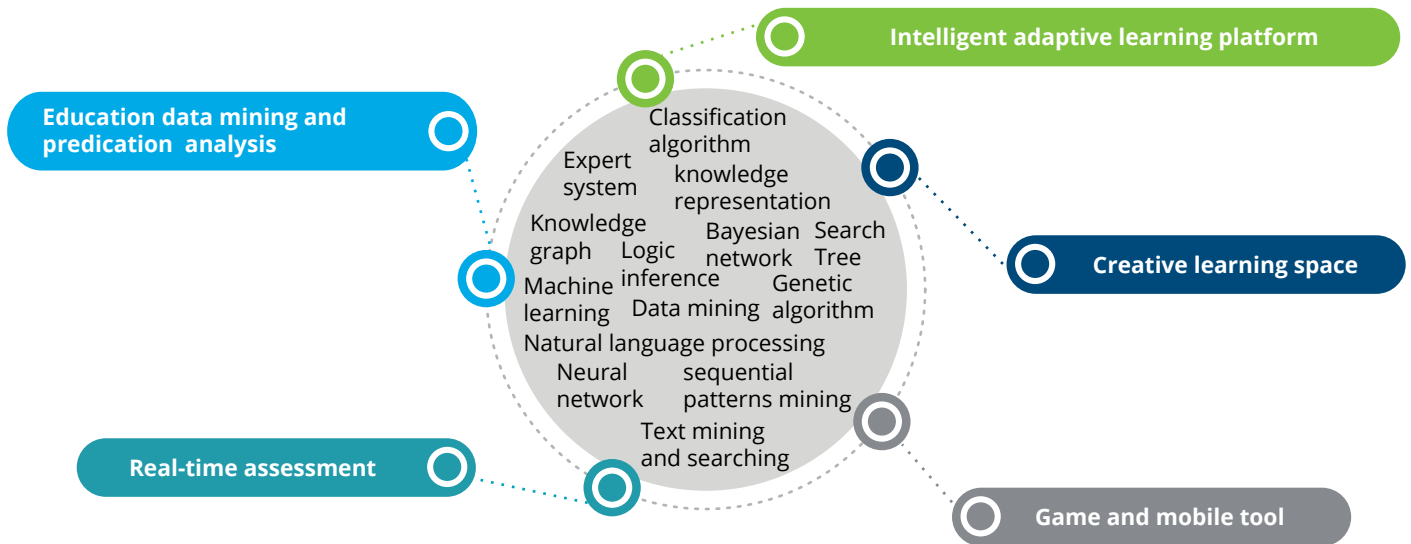
Source: Deloitte Research

- Genetic algorithm augmented logistic regression model helps develop optimal study path for students to maximize learning efficiency. This model recommends the right next lesson based on students' learning objectives and current learning status, and adjusts lessons in real time based on their evolving understanding of knowledge. After receiving students' feedback to learning content pushed to them, the system will develop student profiles covering their learning habits, interests and methods, while automatically optimizing its pushing logic. Compared with neural network algorithm used for deep learning, generic algorithm enables comprehensive search for quick access to global optimal solution, avoiding trapped in a local optimum.

- Graph theory: To implement intelligent adaptive learning, it is imperative to understand students' comprehension detail as an excellent teacher does. Given the difficulty in defining student's understanding of knowledge through comprehensive quiz testing, it is necessary to test smallest unit of knowledge, in order to accurately understand students' knowledge mastery in detail.

- Machine learning technology: It recommends the most suitable content for each student based on individual student's preference, learning habits and style. Some students favor learning in a relaxed and lively way, while others prefer to learn in a rigorous manner. AI system will record each student's preference and make appropriate recommendations accordingly. Based on students' learning status and objectives, intelligent adaptive learning will automatically provide lessons that best suit students' needs, at the right level of difficulty and in the right sequence, so that they will not lose confidence nor feel unchallenged because of setting goals too high or too low. In this way, students at different achievement levels may gradually improve their credit scores bit by bit, i.e. from 40 points to 60 and 70 points, or from 70 points to 80 and 90 points.

- Bayesian network: It predicts students' learning ability in order to help determine the timing for the next stage of learning. For example,

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the system needs to analyze test results to decide when it is appropriate for the learner to start with linear equation in two variables, based on the extent to which he comprehends linear equation in one variable. This requires an appropriate data processing mechanism to identify the connection between the two concepts as well as students' comprehension level.

- Deep learning and natural language processing: Natural language processing is used to automatically generate labeled learning materials; deep learning can be used to analyze student profiles and learning materials, therefore automatically selecting appropriate content for students from a vast pool of learning resources.

- Knowledge space theory and information entropy theory: Information can be measured from the perspective of metrology. Leveraging information entropy theory, we may test key concepts to gain deeper insights to students' learning status, supplemented with iterative refinement to identify their weaknesses and learning status more efficiently and precisely.

- Educational data mining and learning analytics: The application of big data in education mainly falls into two categories, educational data mining and learning analytics. Educational data mining measures and analyzes learning process and activities, collecting students' learning data including learning time, duration and test performance, followed by data analysis to develop learning models for different students. Learning analytics predicts and monitors students' test scores to provide related intervention measures. This learning model helps develop personalized learning objectives, with tailored incentives for each student. All students strive to grow beyond themselves, which effectively avoids comparison among peers, therefore improving students' sense of self-achievement. Learning analytics also provides teachers with detailed student data, including how much time they have invested and their comprehension level, with information that helps the system and teachers improve teaching methods. It also helps recommend courses that are designed in the order of increasing difficulty.

AI-based education has developed in the US for a long time, with a large number of users across different ages, and both product and technology having evolved to an advanced level. China, however, is still at the initial stage, lagging behind in data accumulated. Despite of such situation, China is likely to catch up from behind, with the increase of capital flowing to the area and the advantage of demographic dividend.

2. Analysis of AI-based education systems

2.1 Analysis of intelligent adaptive education structure and model
2.1.1 Application of AI-based education
Disruptive application of in education includes intelligent adaptive education, innovative virtual learning space, data analysis and data privacy. Some major trends of AI application in education and key technologies supporting the application are listed in the table below. The report mainly discusses AI-based intelligent adaptive education,

which is radically different from the traditional education model (also called factory model of education). In agricultural and industrial societies, more than ten years education is enough to for people to handle the challenges in work and life. But in AI society, as the boundary between education and work is increasingly blurred, lifelong learning will become the norm. AI-enable intelligent adaptive education will play a more

important role in response to the changing requirements for learning. Intelligent adaptive teaching system is a computer system providing timely and personalized instruction or feedback for each learner. All intelligent adaptive teaching systems are designed to improve learning value and efficiency, based on multiple computing technologies, especially computational intelligence. Such systems are closely related to AI-based design and cognitive learning theory.

Figure 2-1: Application of AI-based education

Application of AI-based education	Supportive AI-related technologies
Personalized intelligent adaptive education	Real-time formative assessment, AI + intelligent adaptive teaching systems, AI tools, self-improvement systems
Transformation to active learning, PBL, CBL, computational thinking	AI (machine learning, KR&R, robotics, computer vision, NLP)
Changing the definition of successful schools and students	Adaptive learning method and personalized learning approach, AI-based planning
Innovative learning space	AI-based classrooms, virtual labs, A/R, V/R, hearing and sensing technologies
Real-time analysis	EDM and predictive analysis
Privacy and trust	Digital ecosystem
Breaking limits	mobile, online learning and virtual personalized assistants

Source: AI-based Adaptive Education Whitepaper

2.1.2 Intelligence levels of intelligent adaptive learning

Many companies have not reached the best intelligence level in their intelligent adaptive learning products, which can be classified into five levels in terms of the application status of AI in education. Level 0 and Level 1, considered as products at the early stage of AI application, transfer learning contents based on simple rule judgement. Level 2 products provide courses of different difficulty. Level 3 products, as the best practice of intelligent adaptive learning so far, involve knowledge map and probability model. Level 4 products provide high-quality contents to teachers and students through computer technology-based intelligent adaptive systems, to support both teaching and

learning and make the whole process measurable. With intelligent adaptive learning systems at this level, users will have access to multiple approaches to the correct answer to any question. As the most desirable AI application in education, Level 5 products focus on shaping students' imagination and creativity, monitoring their learning status and analyzing emotional condition and subjective initiative, to improve learning capabilities and creativity and stimulate subjective initiative. Products at this level will drive the all-round development of students, instead of just assisting students in understanding of specific knowledge.

covering learning progress and teaching method. Intelligent adaptive education in China is still developing at a level below intermediate. Although many companies have not reached the best intelligence l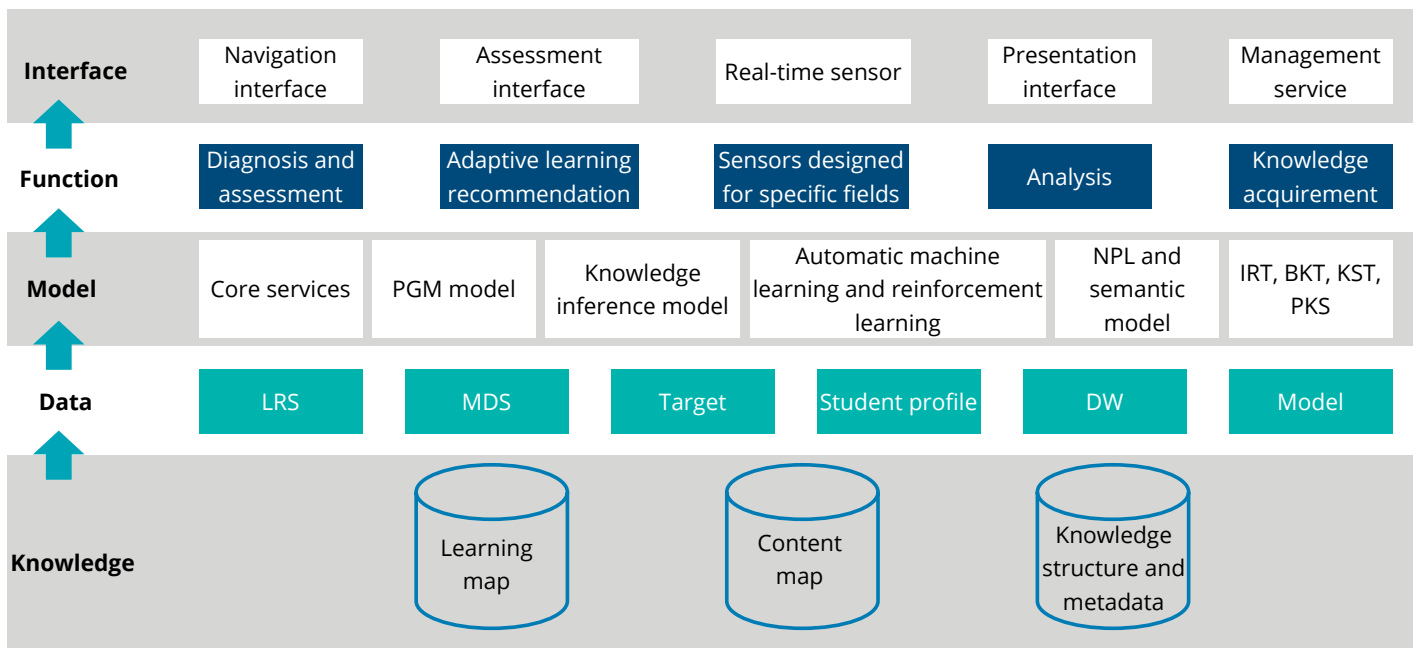evel in their intelligent adaptive learning products, increasingly frequent interaction throughout the educational process based on intelligent adaptive systems will generate more and more data, which will provide a clearer picture of the process of teaching and learning and enable more accurate information recommendation. Intelligent adaptive education systems are likely to be used more widely.

Figure 2-2: Intelligence levels of intelligent adaptive

Level of intelligent adaptive education	Level name	Definition	Stage
Level 0	Human-based intelligent adaptive learning	Systems recommend courses automatically based on human evaluation of students' learning abilities.	Early
Level 1	Intelligent adaptive learning based on simple rules	As a decision tree in nature, rule-based intelligent adaptive learning is applicable in evaluating the correctness of students' behaviors rather than their understanding of specific knowledge, to provide guidance for the recommendation of courses.	Early
Level 2	Intelligent adaptive learning based on difficulty level and IRT	Item response theory (IRT)-based evaluation systems recommend courses of proper difficulty in a real-time manner, i.e. the difficulty level of courses provided to students is decided by their performance.	Intermediate
Level 3	Intelligent adaptive learning based on knowledge network and probability model	With regard to the entire knowledge graph, the system leverages education data mining or Bayesin knowledge tracing to infer students' understanding of knowledge through exercises, therefore adjusting study path in real time while recommending optimized learning tasks. The key is to develop knowledge graph that connects all key concepts, as well as task-specific dialog system powered by natural language processing.	Intermediate
Level 4	Intelligent adaptive learning based on multiple learning elements, capability objectives and subdivided knowledge map	Intelligent adaptive learning at this level is designed to improve students' knowledge systems, learning abilities, learning habits and creativity, considering multiple learning elements (including emotional factors, learning interest and motivation, subjective initiative and attentiveness) and integrating knowledge map, subdivision abilities and thinking methods.	Upper-intermediate
Level 5	Intelligent adaptive learning based on cognitive science, NLP interaction, symbolic reasoning and deep learning	AI-enabled intelligent adaptive learning, based on human-in-the-loop, simulates students and human-machine communication to develop teaching strategies leveraging reinforcement learning and genetic algorithms. Intelligent adaptive learning provides learning scenarios and learning partners by combining symbolic reasoning, cognitive science and deep learning and integrating individual learning with collective learning. While increasing students' knowledge, it also helps students develop knowledge system and improve learning capability, habits and creativity.	Advanced

NLP: Natural Language Processing
Source: Principles behind Intelligent Adaptive Learning, Deloitte Research, Yixue Education-Squirrel AI

Intelligent adaptive learning provides each learner with personalized plans covering learning progress and teaching method. Although many companies have not reached the best intelligence level in their intelligent adaptive learning products, increasingly frequent interaction throughout the educational process based on intelligent adaptive systems will generate more and more data, which will provide a clearer picture of the process of teaching and learning and enable more accurate information recommendation. Intelligent adaptive education systems are likely to be used more widely.

2.1.3 Intelligent adaptive learning system model

Standard adaptive learning model is designed from three dimensions including contents, data and algorithm, integrating multiple technologies into the adaptive education system and focusing on diagnosis and assessment of knowledge understanding, adaptive learning recommendation, analysis and knowledge acquirement, based on automatic machine learning and knowledge permutation model.

Figure 2-3: Technological structure model of intelligent adaptive education

Source: AI-based Adaptive Education Whitepaper, Deloitte Research

The general model of intelligent adaptive learning system first proposed by Peter Brusilovsky from the School of Information Sciences of the University of Pittsburgurgh is divided into two key parts by technological structure: system model (including learner model, teaching model, knowledge model and interface model) and intelligent adaptive engine.

**Figure 2-4: Reference model of intelligent adaptive teaching system**
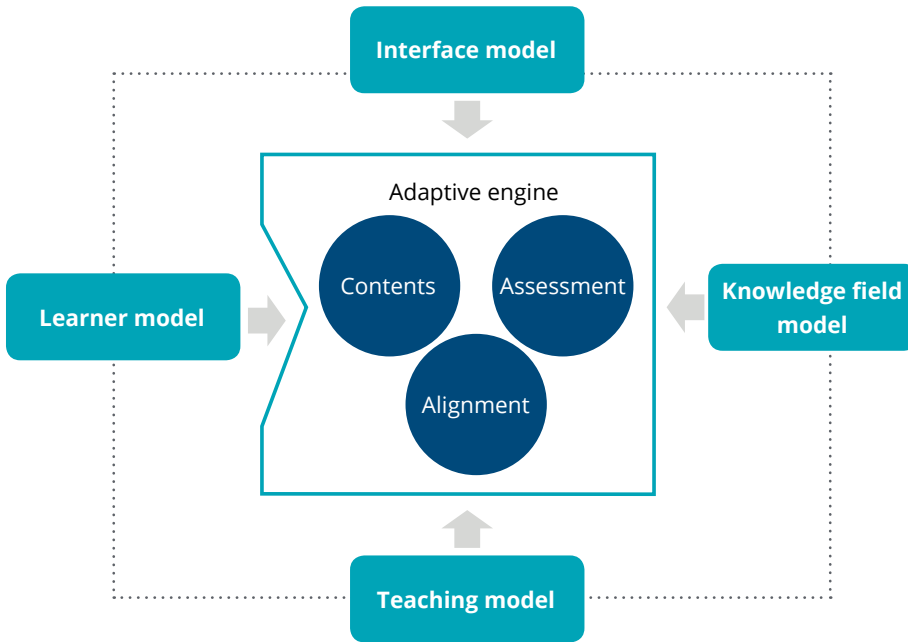
Model plays a fundamental and core role in the intelligent adaptive learning system, with adaptive engine providing power for the system. The building of learner model and knowledge field model is critical for intelligent adaptive teaching model, and requires systematic and multidimensional modeling and establishment of association rules.

01. Learner model

Multidimensional behavior data of learners are generated during the learning process concurrently. Therefore, it is necessary to integrate and analyze psychological and behavioral data systematically to establish learner model. In the intelligent adaptive learning system, learner model is critical for improving independent learning capabilities. The first level of learner model focuses on students' thinking and capability, which is used to assess their learning abilities. The second level of learner model maps knowledge points, to give a full picture of learners' knowledge mastery.

Learner data modeling, which reflects the relations between learning results and a series of variables including learning materials, learning resources and teaching behaviors, can be used to predict the future learning trend of students. Intelligent analysis of learner data will provide students with useful learning resources and tasks. With more objective feedbacks provided by educational data, teachers will be able to optimize their education planning and course development, and adjust educational contents and plans according to students' learning state.

Figure 2-5: Learner data model
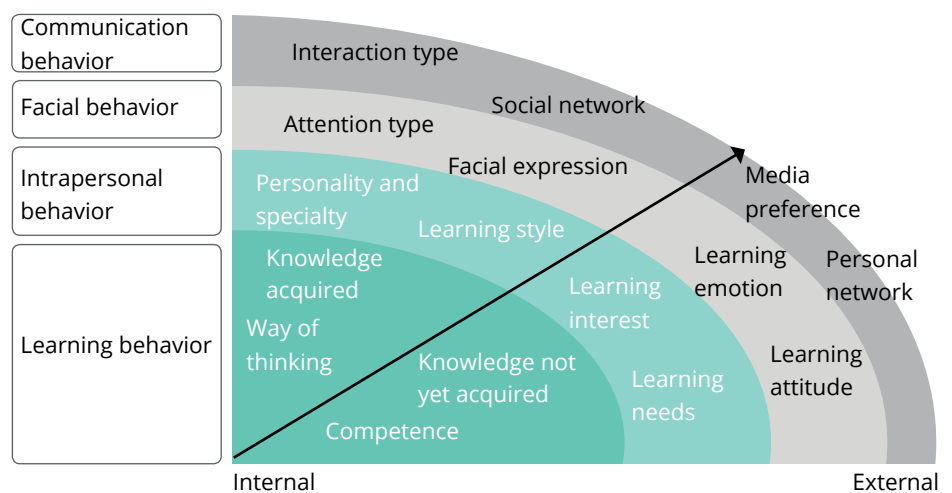
02. Knowledge field model

Knowledge field model describes knowledge structure and establishes knowledge structure map with detailed learning contents, usually including desirable expert knowledge, mistakes regularly made by students, rules of making mistakes and misunderstanding.

03. Teaching model

Teaching model defines the rules about how to obtain access to each knowledge field based on the information provided by student model and how to change user model. Combining knowledge field model and learner model, teaching model allows teachers to figure out what instruction strategies and actions they should take next. In a hybrid active system, learners are also likely to take actions, ask questions or seek for help. ITS should always be prepared to decide "what to do next", which is determined by the tutoring model that integrates researchers' teaching theories.

04. Interface model

User interface explains learners' performance through multiple input media (voice, typing and click) and provides output (texts, figures, cartoons and agencies) through different media. In addition to traditional function of human-machine interface, some systems also have other functions including natural language interaction, speech recognition and learners' emotion detection.
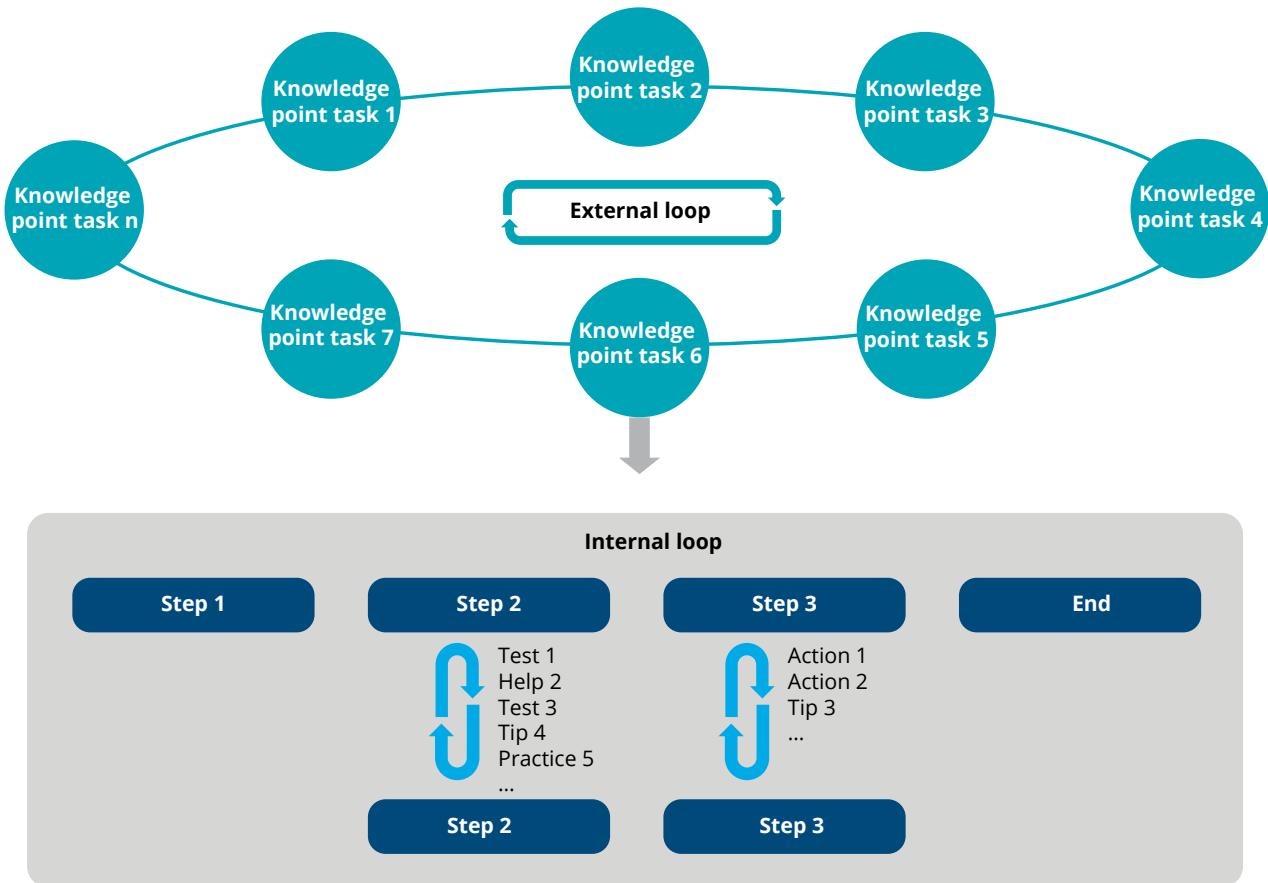
05. Intelligent adaptive engine

Intelligent adaptive engine collects information about the characteristics of students and knowledge objects from learner model database and knowledge field model database, and transforms these information into numbers. In addition, the engine works out the similarity value of characteristics with association rules, and recommends proper knowledge objects to students to meet their personal needs based on the similarity value obtained.

Intelligent adaptive engine usually combines inter-knowledge point adaptive mechanism and intra-knowledge point adaptive mechanism. The system firstly detects students' learning state through proper task assignment. Once students adopt suggestions, the system will apply intelligent adaptive intervention to students performing tasks.

Figure 2-6: Intelligent adaptive content teaching

2.2 Three main application scenarios for intelligent adaptive education

Intelligent adaptive education products fall broadly into three categories by application scenario: language learning scenario, teaching aid scenario and intelligent adaptive platform.

The first category is foreign language learning products that score sentences from pronunciation and grammar and assist teaching intelligently. English learning has long been an important part of the global education market where well-developed learning products and data in test question

banks are mainly applied to spoken English testing and assignments. Established brands include English Liulishuo, Duolingo, etc.

The second category is teaching aid products that are well applied in Chinese and U.S. markets. With tests and exercises at the core, these products serve as assistants driving teaching and intelligent education through intelligent tests. Both Chinese brands featured by iFLYTEK Education, Zuoyebang and Tencent Education and foreign brands marked by Renaissance Learning and Knewton leverage their platform strengths to complete

users' intelligent adaptive tests and assessments for teaching assistance.

The third category is building intelligent adaptive teaching platforms to integrate testing, teaching, learning, exercise and assessment into the intelligent adaptive learning system. Several educational tech stars including Dreambox, byju's, IBM Watson Education, are emerging in the foreign intelligent adaptive learning sector while China is still in its infancy led by Yixue Education-Squirrel AI with a large gap with the foreign market in maturity.

Figure 2-7: Comparison of main technical subjects in intelligent adaptive learning scenarios
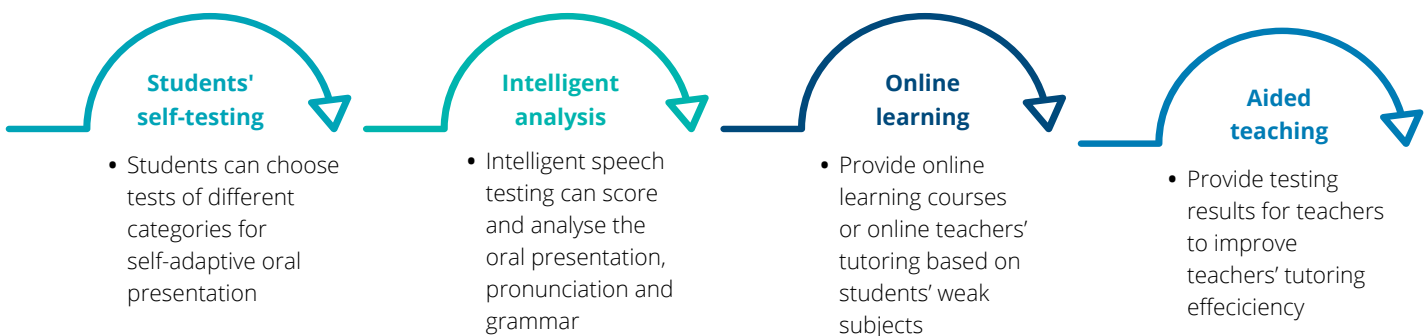
	Language learning scenario	Teaching aid scenario	Self-adaptive platform
Scenario details	Score sentences from pronunciation and grammar and assist teaching intelligently	Improve knowledge structure based on tests and exercises and assist teaching	Develop an integrated closed-loop intelligent teaching of test, exercise, teaching and learning on self-adaptive platforms
Gap between China and foreign markets	• China: led by To C, many English related APPs provided • Foreign markets: To B and To C	• Developed markets at home and abroad • China: tests for support and exercises to help understand knowledge points • Foreign markets: intelligent testing to facilitate intelligent education	• Large gap of maturity • Starting up in China led by To C model and online intelligent model assisting offline users
Main applications	• Oral presentation testing • Homework assigning • Layered course scheduling • Partner robot • Learning attitude judgement	• Oral presentation testing • Compositions correcting • Test paper preparation and reading • Photo-based questing searching	• Plan learning paths • Push learning contents • Detect disadvantages • Predict learning speeds

Source: Deloitte Research

2.2.1 Language learning scenario

Language learning scenario is mainly for testing English pronunciation. With increasing attention on oral English in the English education, intelligent educational products for testing English pronunciation are developed through technologies including speech recognition and natural language processing to help learn and test the standard level of oral English pronunciation and intonation, fluency and speaking skills. The application technologies include speech recognition and natural language processing.

Figure 2-8: Illustration of language learning scenario

Students' self-testing
• Students can choose tests of different categories for self-adaptive oral presentation

Intelligent analysis
• Intelligent speech testing can score and analyse the oral presentation, pronunciation and grammar

Online learning
• Provide online learning courses or online teachers' tutoring based on students' weak subjects

Aided teaching
• Provide testing results for teachers to improve teachers' tutoring effeciency

Source: Deloitte

Advantages of speech testing: standard tests and detailed analysis to improve efficiency. Intelligent educational products for English speech testing replace teachers to help students in oral English practice, oral English testing, and score statistics. They can significantly improve teachers' work efficiency and drive intelligent adaptive oral English learning by machines assisting teaching. They can help in several oral English categories including pronunciation of phonetic symbols, essay reading and oral presentation to reduce teachers' workload and improve working efficiency, enabling teachers to provide individualized teaching in accordance with intelligent testing results. Stable and objective score results of intelligent tests can be analyzed accurately to generate efficient feedbacks.

Disadvantages of speech testing: external factors affecting testing results. The results of English speech testing has an effect on the results of intelligent scoring due to innate uncertainty of spoken English, different pronunciation habits and intonation, external factors such as noise, generating inaccurate analysis results. As it cannot judge pronunciation and intonation to generate analysis and feedbacks, its interactivity also needs to be improved.

English Central, a foreign language learning brand: customization at To B end and To C business model to capture the market by providing multiple language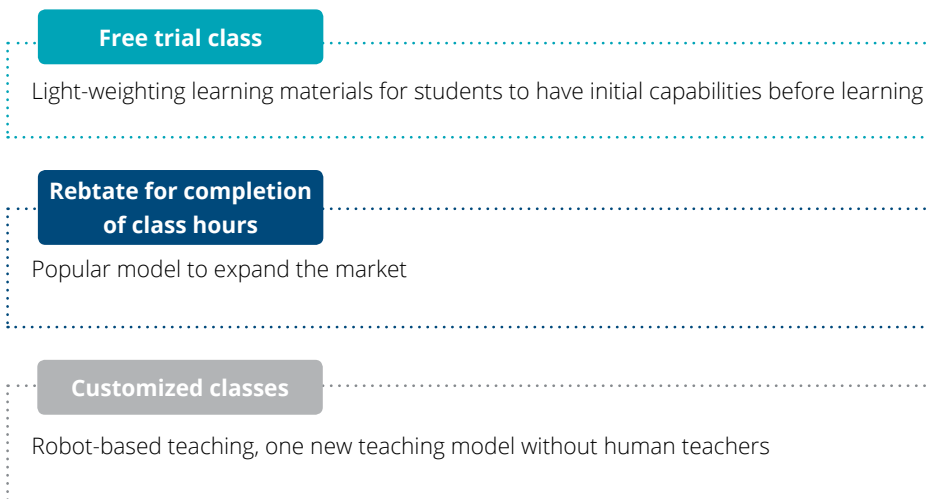 versions for students of different native tongues. The foreign English speech testing application English Central applies its proprietary speech recognition technology to listen users' speeches and score them based on pronunciation and grammar, providing services from teaching, watching, speaking and teaching. In terms of teaching, the one-on-one online teaching model allows students to focus more on learning. It uses To B and To C business models and offers intelligent language learning services directly for individual consumers and enterprises and schools, including K12, language schools, universities and companies, etc.

Domestic language learning application English Liulishuo: free trial class plus rebate for achieving goals and "learning without teachers" to expand the market. It is an English learning APP in China mainly designed for C-end consumers. Users' English levels are graded by scoring with AI through English level tests. Varying courses are provided for users at different levels to correct their pronunciations supported by English exercises such as listening and generate analysis reports of their learning status. The business model that users check in every day and receive rebates upon their completion of class hours is gaining popularity and attracting students with its intelligent robot-based teaching model, driving its market expansion.

Figure 2-9: Business model of English Liulishuo

Free trial class
Light-weighting learning materials for students to have initial capabilities before learning

Rebtate for completion of class hours
Popular model to expand the market

Customized classes
Robot-based teaching, one new teaching model without human teachers

Source: Deloitte Research

Figure 2-10: Comparison of main language learning products

	Category	English Central	English Liulishuo	Boxfish	Duolingo	ETS
Main business model	To B	Enterprises and schools, including K12, language schools, universities, companies		Various international and public schools		Provide English test scores for reference
	To C	One-to-one private teaching	C-end users at all ages		Provide multiple language learning model through gaming models	Provide exam services
Main market segments	Early childhood education		√	√		
	K-12	√	√	√		√
	Higher education	√	√		√	√
	Going abroad, exams		√		√	√
Subjects	Detailed subjects	English listening, speaking, reading and writing	Oral English	English class teaching	Individualized English	English for exams

Source: Deloitte Research

English Liulishuo, Boxfish, ETS and Duolingo are main products at home and abroad, all with English teaching aid services at their core and they have specialized in different sectors from the perspective of their business models and market segments. Language testing applications in China have their focuses. English Liulishuo is specialized in oral English for users at all ages to improve their oral English through intelligent speech testing. Boxfish focuses on class teaching in close cooperation with B-end schools to promote products directly to students. Duolingo applies the strategy of free lifetime English learning to help users learn through gaming models with a focus on customized learning. EST is the largest non-profit organization for English exams by providing specialized exams targeting K-12, vocational education and English exams.

Future developments of language learning products Precise speech recognition. Minimizing the effect of personal pronunciations and external factors on speech recognition and testing is the technology trend of language intelligent learning testing, which will enable intelligent judgement to be more objective and accurate to deliver targeted tutoring on speech, grammar and sentence for users.

Intelligent human-machine interaction. Currently, language learning products only provide one-way communication for users, yet being unable to offer free talk services in educational scenarios through intelligent language and real-time communication and correction. In the future, intelligent AI will empower these APPs with intelligent language analysis, critical thinking and logical capability to judge the grammar and speech mistakes of users' single sentence and simulate the judgement of comprehension and logic of paragraphs in real exams.

Focus on marketing and expansion. Domestic intelligent language learning brands need to develop customized courses to meet varying demands from companies, schools and individuals by customizing special language pools meeting the course and role requirements of schools and companies to align with individualized learning needs of different groups. Besides, through more partnerships with offline organizations to adopt the online intelligent educational models to offline organizations, offline tutoring or the application of AI technology to offline education will be one way towards the future.

2.2.2 Teaching aid products

Teaching aid products connect students, parents and teachers, analyze reports and recommend test questions more intelligently. These products can assign homework online and correct intelligently and generate students' learning status reports by applying image recognition, natural language processing and data mining technology. Take assignments as an example. Teachers can assign homework online which will be corrected by AI to generate students' learning status reports and mistakes collections, provide feedbacks for teachers, parents and students and recommend test questions in a

self-adaptive way based on students' learning status. Parents can supervise the status of students' homework online and teachers can customize teaching plans for students in different learning statuses based on student analysis reports while the system will sort out students' mistakes and recommend exercises for them intelligently.

More objective intelligent correcting. In contrast to human correcting, intelligent correcting can mark mistakes and analyze reasons in time, correcting faster, more detailed and objectively. Products featured with intelligent correcting and exercises recommendation can help teachers analyze students' assignments and provide personalized learning status reports, reducing the time for teachers and parents to communicate, enabling parents to better understand students' learning status and supervise learning. Considering the current situation, intelligent correcting is applied to math and English, especially widely used for intelligent correcting of English compositions and math subjective questions. Such real-time and objective correcting can deliver accurate analysis of learning status and ultimately enhance teachers' efficiency and enable students to develop self-adaptive learning.

Figure 2-11: Illustration of testing and question bank products

Intelligent correcting	Analysis of learning progress	Teachers' assistant	Self-adaptive learning
APP — Correct and provide results in time and mark reasons of mistakes	**Delivery to parents** — Analyze students' mistakes and generate reports on learning status	**Teachers' teaching** — Accurately capture students' learning progress	**Students' self-learning** — Enable students to develop self-adaptive learning and complete recommeded exerciese

Source: Deloitte Research

Foreign products can be customized to provide adaptability for self-adaptive learning. Among foreign teaching aid products, STAR 360 products launched by Renaissance Learning are used for standardized computer self-adaptive testing during K12 education to assess and analyze students' levels of learning, advantages and disadvantages, and provide student data for teachers. Star 360 is composed of three computer-powered self-adaptive tests: Star Reading, Star Math and Star Early Literacy, and Star Custom.

China's teaching aid product market has been mature with a distinctive strategy of To B model by cooperating with organizations. Among domestic products, RealSkill products jointly launched by iFLYTEK and New Oriental focusing on intelligent correcting and oral English practice are designed for IELTS and TOTEL exams. As shown by tests of New Oriental, the scores of RealSkill and interviewers are almost the same, reaching 96.91% while the accuracy of intelligent correcting by RealSkill reaches 92.64% and its recognition rate of handwritten texts reaches 95%. Examinees can build a learning closed loop composed of intelligent scoring, sentence by sentence correcting, behavior analysis, intensive sample interpretation and learning record through online learning to acquire new preparation experience for exams scientifically.

Figure 2-12: Illustration of RealSkill learning closed-loop
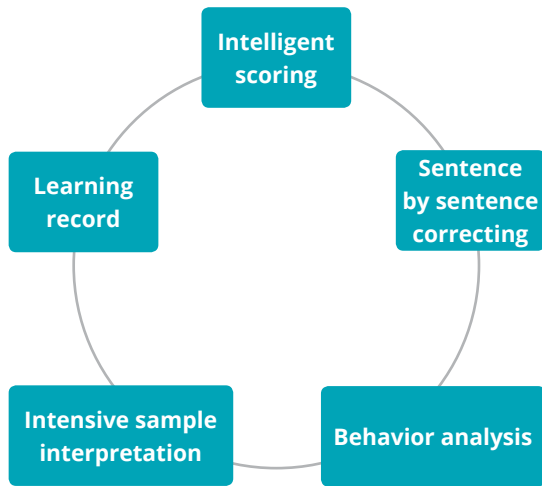
Source: Deloitte Research

Other companies in China include Yiqixuexi, Knowbox, Xueba100. Yiqixuexi, for example, gathers teachers to prepare and review test papers and assign homework while the system applies knowledge graphs and intelligent adaptive algorithms to collect data and push individualized test questions during learning. Xueba100 offers a testing function to identify where students are weak based on exercises they complete by leveraging algorithms while its practice function can push automatically exercises with relevant difficulties and knowledge points to help reinforce students' understanding of knowledge. The system can provide automatic testing services and push relevant exercises.

Figure 2-13: Comparison of teaching aid products

		Knewton	Yiqixuexi	Renaissance Learning	iFLYTEK
Market segments	**Educational levels**		**K-12 education**		
Business models	To B	Education publishers, hardware developers, online teaching platforms, learning management systems, APP providers, etc.	Public schools	Customized courses	Smart classes plus cooperation with schools
	To C			For K-12 users	Personalized learning
Subjects	Specific subjects	No limitation on subjects	All subjects	English, math, etc.	Customized subjects
Specific application scenarios	Question searching				
	Online teaching assistance	√			
	Homework		√		
	Intelligent adaptive testing	√	√	√	√

Source: Deloitte Research

Domestic teaching aid products have grown stronger, most of which are designed for K-12 educational groups. Though the learning model of all subjects, 17Zuoye is oriented towards B-end public schools and marketing its online homework platform. Considering core parts of products, Knewton offers learning paths by its own systems combining with clients' course materials, just building self-adaptive learning platforms to assist teachers instead of preparing contents. For digital self-adaptive learning courses, Knewton embeds partners' contents into its systems by API and its AI intelligent self-adaptive learning platform responds to students' actions in the system in real time by collecting students' behavior data consistently. The system will automatically push the next action for students once they complete a certain action. With technologies at present, it can only help teaching instead of replacing teachers. Knewton is targeting publishers and educational companies and provide them with self-adaptive learning engines (cloud platforms), starting cooperation with schools to offer self-adaptive course products since 2016. Being cooperative with the B end as its business model, it digitalizes all course materials and provides adaptive learning plans for these products. Knewton has also transformed into preparing

contents and developing self-adaptive course products since 2016. By analyzing Knewton's products, we can see Knewton as an AI-based self-adaptive learning platform who embeds partners' contents into its own system by API and breaks up learning contents into knowledge points, digitalizes course materials into its system and generates relevant knowledge graphs. By collecting students' behavior data consistently through its AI-based intelligent self-adaptive learning platform, combined with student behavior, algorithms recommend personalized course learning paths, set tasks and goals, respond to students' actions taken in the system in real time. The system will automatically push the next action for students once they complete a certain action.

Future trends of teaching aid products

Moving forward, teaching aid products will be applied in front-line, one-to-one precision teaching scenarios. As important teaching aid tools, intelligent adaptive platforms will become the future trend for the following reasons:

Text, speech, image and video recognition will replace single text-based products. In the future, teaching aid products will go beyond text test banks but cover all learning resources for teaching. For example,

various media (text, figure, speech, video, VR, AI, AR) will drive testing and learning to develop beyond texts but involve different teaching styles, intelligent testing and test questions of varying categories, expanding the width of intelligent learning and inspiring students' learning interest.

Interactive test banks and testing will replace single exercises. Teaching aid products will not only allow students' one-way inputs, but provide intelligent interactive learning, enabling students to raise questions in time and get intelligent responses online in the system which in turn provides tests and learning feedbacks anytime just like a real teacher to tutor students.

All subjects will be covered for differentiated competition. Currently, most teaching aid products do not cover all subjects in primary and junior high school teaching. Therefore, they need to cover more subjects and online intelligent education powering multiple subject learning at the same time will become a trend. Online teaching aid and offline activities can be closely integrated to serve teaching products. The growth at To B end will generate new profit sources for products. They can strategically cooperate with teaching aid platforms and acquire better interpretations of knowledge points and feedbacks on students' analysis reports.
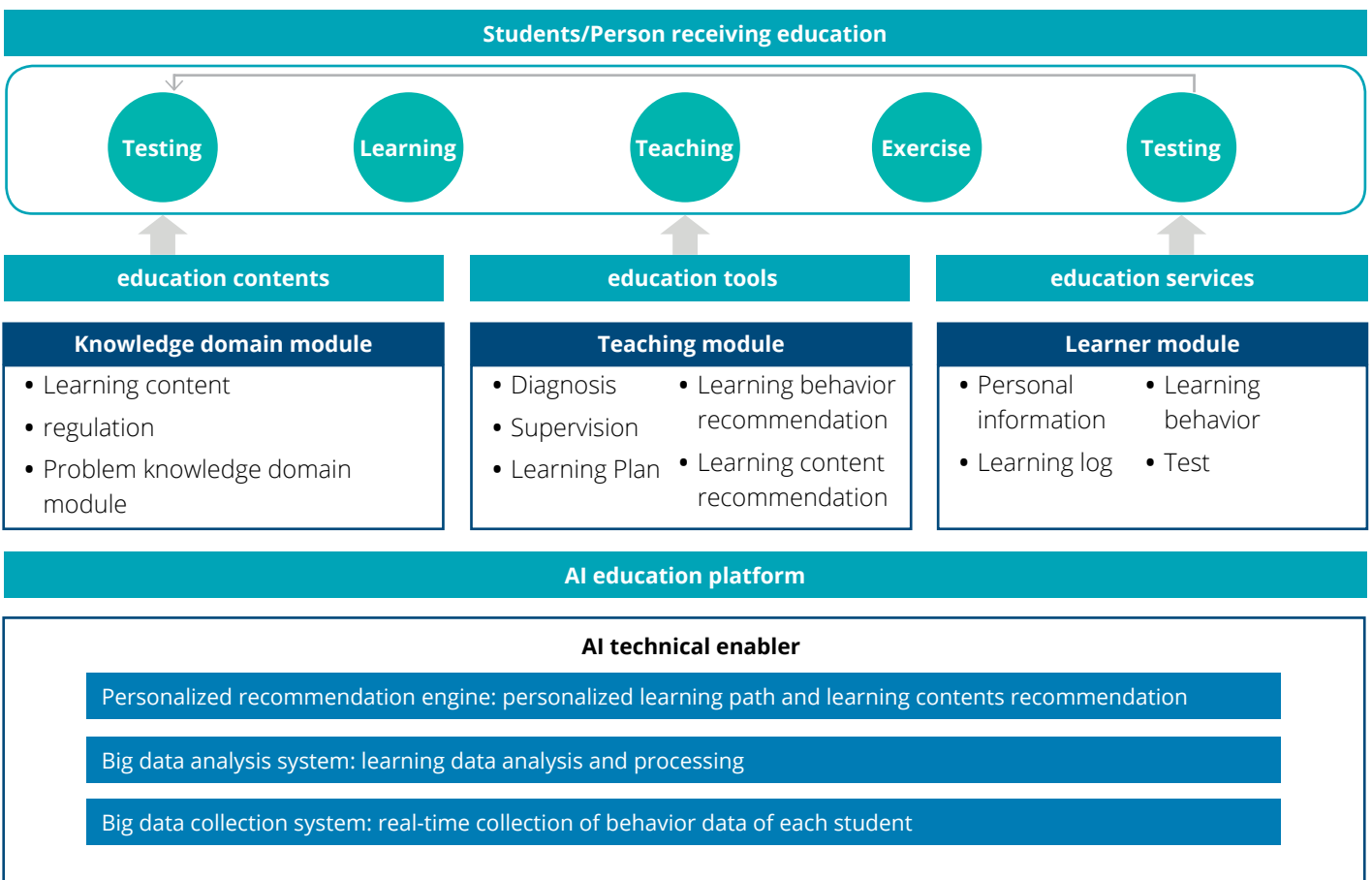
2.2.3 Intelligent adaptive teaching platform

Intelligent adaptive teaching platform can apply general testing, exercise, learning and teaching intelligently. Students can complete the closed-loop learning through the consistent application of intelligent adaptive algorithm system. Intelligent adaptive learning systems collect students' learning data to plan the best learning paths for students based on the understanding of students' present capabilities and push automatically online teaching videos to close the loop of learning. In contrast to intelligent test banks, the platform can record students' learning data in real time through consistent intelligent adaptive function and recommend teaching videos related to knowledge points through tests and exercises. The system applying personalized recommendation, big data analysis and collection can use algorithm technology to all teaching parts.

Figure 2-14: Intelligent adaptive teaching platform

Source: Deloitte Research

In domestic intelligent adaptive teaching segment, Yixue Education-Squirrel AI works with tutoring organizations to develop an intelligent education platform model integrating online intelligence and offline support. Yixue Education-Squirrel AI has started early in diving into AI-based education. It develops the first intelligent adaptive learning engine focused on advanced algorithms with complete independent intellectual property right in China. This engine breaks up knowledge points into nanoscale parts and detects students' understanding of these knowledge points more accurately.

The intelligent adaptive system it developed independently can simulate human teachers' teaching and apply AI technologies into teaching, learning, testing, assessment and exercise. Yixue Education-Squirrel AI uses the online-offline integrated product service model, i.e. a teaching model integrating online intelligent adaptive system with human teachers. On online side, Yixue Education-Squirrel AI leverages the intelligent adaptive learning system and class livestream to provide services for students. On offline side, it cooperates with other offline educational companies or

proprietary tutoring organizations to offer question answering services and students' psychological counseling. It mainly provides services mainly about Chinese, math, English, physics with the business model of setting up offline tutoring and training organizations and online intelligent adaptive course tutoring. Its system assesses students' understanding of knowledge graphs dynamically and pushes relevant explanation videos, exercises and test questions while teachers are responsible for controlling the learning pace, providing guidance and encouragement and answering questions.

Figure 2-15: Comparison of main intelligent adaptive teaching platform companies

	Yixue Education-Squirrel AI	ALEKS	RealizeIT	BYJUs
Main models	Online intelligent education combining with offline tutoring organizations	Offering contents	Customized courses and self-platform contents	Personalized platform-based learning + technical support
Partners	Offline tutoring organizations	Acquired by McGraw-Hill Education	Cooperation with schools, educational organizations, publishers	Invested by Tencent, Sequoia Capital, etc.
Technical performance	Independently develop intelligent adaptive system and simulate real teachers' teaching	Identify learners' knowledge learned and unlearned quickly and accurately based on knowledge space theory through adaptive questions and choose knowledge that is badly needed	Update knowledge points and analyze and update students' learning status through data collection and analysis	Adjust automatically based on students' learning habits and capabilities. Provide videos, exercises and tests
Business models	To B+ To C model combining online intelligent adaptive platform with offline teaching aid organizations	To B	To B	To C
Market segments	K-12 education	K-12 education	Meeting needs of B-end clients	C-end education at all levels
Subjects	Chinese, math, English	Math, physics and chemistry courses	No limitations on subjects	All subjects + professional exams+ exams for studying abroad

Source: Deloitte Research

ALEKS provides platforms and contents from its own platform. ALEKS PPL system includes three stages of positioning, preparation and learning while the procedures can reflect unique understanding of knowledge of each student and divide them into course-specific preparation and learning modules. Unlike traditional standard tests and written exams, ALEKS PPL focuses more on students' unique knowledge gaps and enables seamless transition from positioning and assessment to targeting learning modules to inspire students to gain higher scores.

RealizeIt helps educational organizations build customized platforms. RealizeIt is engaged in contents and systems with the ability to analyze and update students' learning status in real time and dynamically. It makes money by providing intelligent adaptive educational systems, course contents and services for schools, educational organizations and publishers. As the most popular learning APP in India, BYJU's provides contents covering

As the most popular learning APP in India, BYJU's provides contents covering K12, English for going abroad and higher learning, enjoying a high penetration rate in Indian market. By leveraging its platform, BYJU's integrates online teaching, exercise and testing to help users visualize all concepts via videos, delivering more understandable knowledge points and concepts to improve test scores. Exquisite videos are BYJU's most prominent feature, integrating

human teachers and animations to explain intricate science subject concepts and graphics clearly in a simple comprehensible way. It can recommend relevant courses based on students' capabilities and preferences to provide individualized learning paths. Its gaming designs and game level challenges make students feel they are playing games through such an edutainment model.

Comparing with Aleks, RealizeIT, BYJU's, the Chinese brand Yixue Education-Squirrel AI can meet international standards from the perspective of partners and subjects. In terms of partners, benchmarking with Knewton, Yixue Education-Squirrel AI cooperates educational publishers and online teaching platforms like MOOC to acquire more platform-based contents to provide more content tutoring services for C-end users and customized services for B-end users. In terms of subjects, Yixue Education-Squirrel AI is mainly engaged in Chinese, math and English while both testing and test bank platforms at home and abroad can offer platform-based tutoring services without limitations on subjects. Therefore, Yixue Education-Squirrel AI can develop all-subject services in the future.

The future of intelligent adaptive education platforms

Refinement will be the future trend of iteration. Generally, domestic AI-based intelligent adaptive learning products have several defects, including general data with fewer dimensions, incomplete

learning models and less intelligent dynamic adjustments. With the accumulation of effective student data, advanced AI algorithms and in-depth understanding of practitioners of teaching and research, genuine AI-based intelligent adaptive learning products will be iterated in the future.

Human-machine interaction will be a new teaching model in classrooms. In intelligent platforms, AI has great potential for growth, such as thinking from human perspective to assist teaching. As AI continues to develop, human-machine interaction in classrooms will be a new teaching model and the interaction will replace one-way course inputs. Besides, a learning style model can be built by using models to analyze learning styles and recommending courses based on the learning styles and features of different users. This will be another application of AI into intelligent platforms.

Parallel education and teaching platformsIn 2014, the State Key Laboratory of Management and Control for Complex Systems of the Chinese Academy of Sciences put forward the concept of parallel education based on parallel intelligence and ACP theories, attempting to provide personalized precision education services (see Figure 1). The upper part introduces the basic principles of parallel intelligence theory, and the lower part lists some parallel teaching platforms. Practical teaching systems and human teaching systems leverage data exchange and human-machine communication for interaction and iteration. This will help assess and visualise the teaching process, analyse

and predict the effectiveness of various teaching strategies, therefore helping learners obtain personalized learning experience that best suits their needs.

Technology roadmap for implementing parallel education and teaching platforms:

- Leverage emerging technologies such as big data, cloud computing, IoT, virtual and augmented reality to gain multi-sourced heterogeneous data, information and knowledge throughout the teaching and education administration process, and analyze the cognitive process of learning and teaching behaviors;

- Build knowledge graph covering different subjects, establish teacher (instructor) and learner model, and develop education robot and personalized knowledge recommendation mechanism;

- Establish human teaching system that corresponds to the practical teaching system based on parallel education theory, therefore developing the parallel teaching platform. Provide precise digital portrait and performance assessment of teaching process for administrators, teachers and students through interaction and parallel execution of practical and human education systems;

- Design various learning scenarios and education innovation solutions, and leverage computer experiments to predict, analyze and select the best solution, to effectively guide teaching and administration innovation with personalized intelligent adaptive services throughout the whole teaching process.

Some programs have been included in the 21st Century Education Grand Challenges of the US. Meanwhile, with the support of the Chinese Association of Automation, the research team has established CAA intelligent education committee, bringing together professionals at home and abroad, to advance the research on the integration of AI and education while driving the development of AI talents.

As the age of intelligence calls for qualified and well-trained emerging talents, the research team has put forward two core education concepts: iSTREAM and iCDIOS. Based on the two concepts, the research team will leverage existing scientific research achievements to integrate scientific technologies with education, develop AI–based education system for learners, and cultivate a new generation of AI talents.

Figure2-16. New paradigm of parallel education for personalized and accurate service
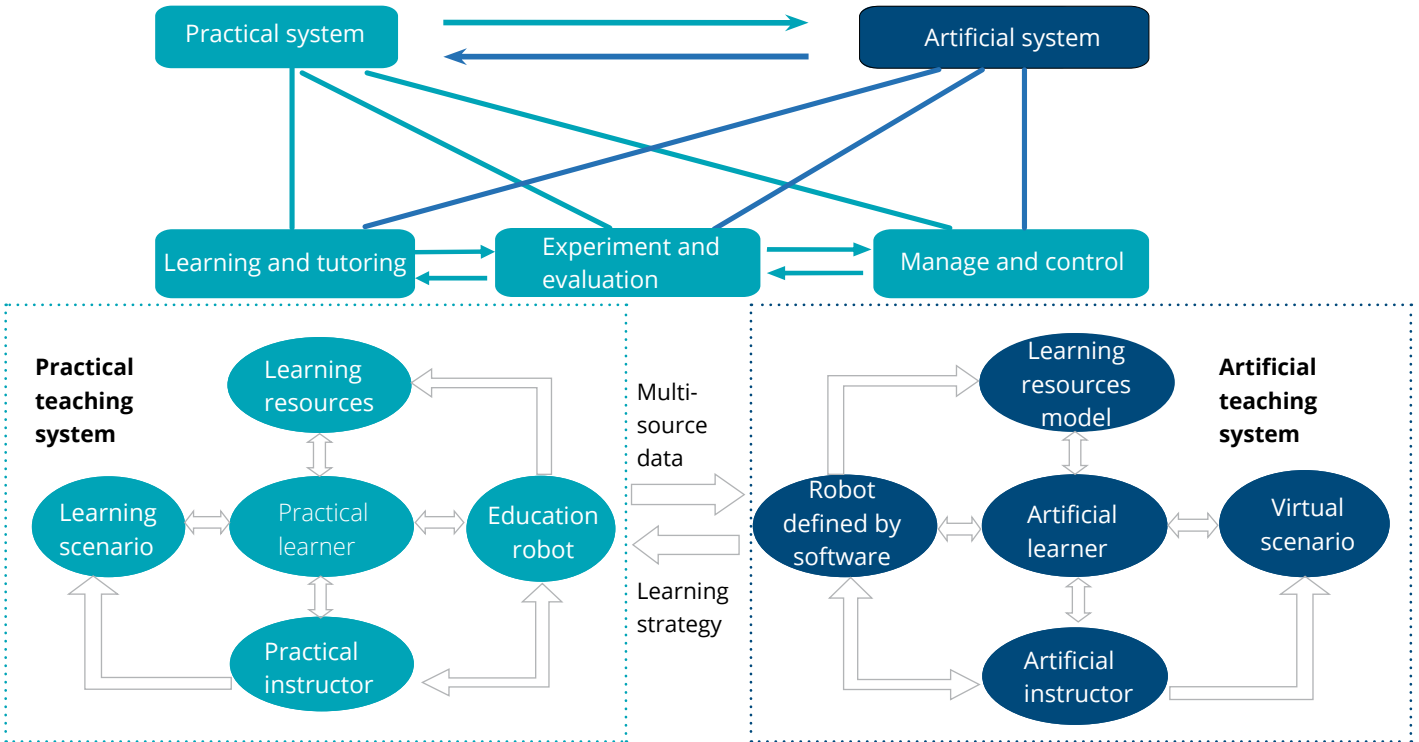
Source: Chinese Academy of Science

Figure2-17. iSTREAM AI education system
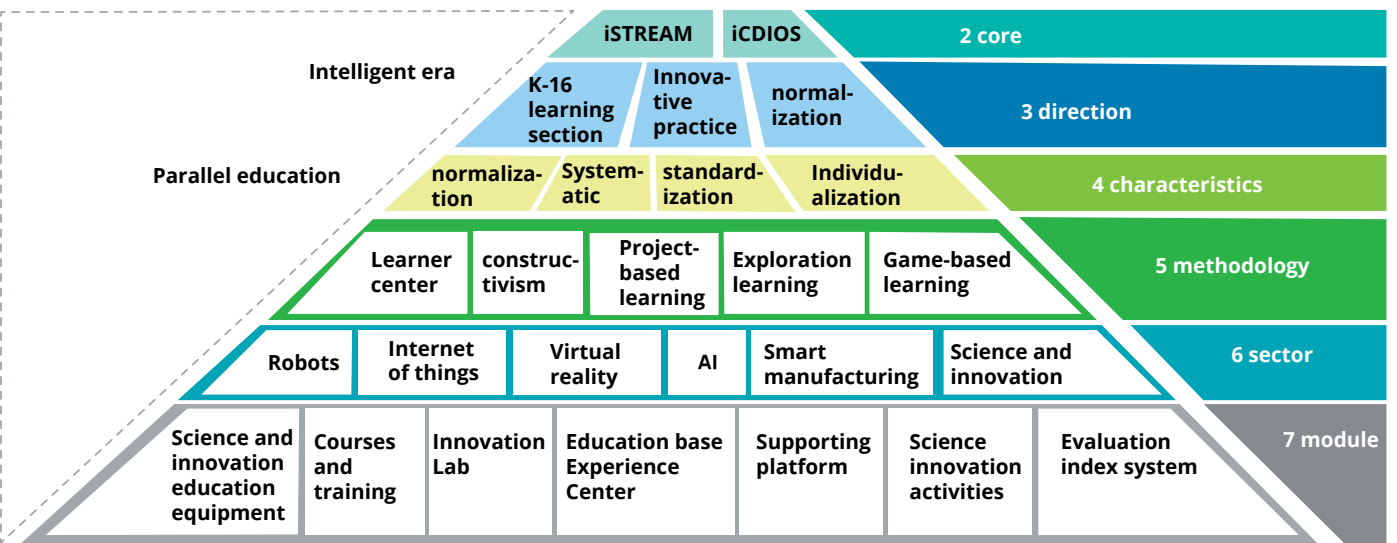
Source: Chinese Academy of Science

3. AI is transforming education industry

With its rapid development in the past 5 to 10 years, AI technology is changing the way participants interact with industry ecosystem. It has been put into commercial application, bringing varying impact to different parties. In this context, education giants are investing in or independently developing smart education products. Start-ups are trying to eliminate the pain points of education industry, provide more targeted solutions, expand to other market segments and increase user coverage.

3.1 AI drives the role change of ecosystem participants

Intelligent technologies redefine education ecosystem. Industries with mature AI technology application and those new sectors where AI application is still new have different pain points, but data collection, processing and analysis can help effectively resolve special industry problems. In the new sector of education, an intelligence trend is coming as AI constantly changes the ecosystem of education industry with data. Intelligence changes the way people study and the channel they access learning materials, understands diversified customer demands and provides customized services. Besides, education industry also face other trends: mobility, product diversification and online-offline integration.

Figure 3-1: Intelligence trend in China's education industry

Indispensable AI technology
AI technology has not been introduced into Chinese education industry until recent years. It develops rapidly, although still in the initial stage

Constant product improvement and upgrade
Diversified education products will help to satisfy individualize needs of users

Age of intelligence

Deepened mobility
The trend of mobile device-based learning will further grow. Many new technologies will emerge

Integration of online and offline education
Education companies constantly expand and integrate product chains. Offline and online education are likely

Source: Deloitte Research

AI will restructure the ecosystem of education industry. Based on AI technology, education companies can provide users with AI-based education content, tools and relevant services. They collect, analyze and give feedbacks on user data, then apply them into five processes: teaching, learning, assessing, testing and practicing, and finally develop customized solutions and effective feedbacks. AI will restructure the relationships between participants of the education industry ecosystem, improve the learning efficiency of students and redefine the education industry.

Intelligence trend helps transform the role and responsibility of ecosystem participants. In China, traditional education is organized in schools by teachers in the way of face-to-face class. With the rise of intelligence trend, traditional education transforms. New methods such as online teaching and intelligent adaptive education are gaining popularity. Therefore, participants of China's AI-based education ecosystem may have different roles and responsibilities, meanwhile, new entrants will flock in. Participants of China's AI-based education ecosystem include users, supporting organizations and AI-based education companies:

Users: Except students, intelligence-based education products began to attract organization users such as tutoring centers and schools. Most existing AI-based education products are designed for K12 students, aiming to support in-class learning and improve scores. As AI technology can mitigate uneven allocation of quality education resources to some degree, together with the support of education informationization policies, ToB market, especially public schools will become the focus.

Supporting organizations:
AI technology helps change the responsibilities of governmental and non-governmental education supporting organizations. They spare more efforts to build smart campus and upgrade hardware facilities and technologies for schools. To build smart campus, governments grant education budgets to help schools develop information-based management and teaching systems, establish official platforms, and advance human-machine coordination projects (for teachers). For example, tot optimize education management decisions and processes, Shanghai establishes a big data platform to deepen education data use based on technologies including data warehouse, data digging and big data analysis. Moreover, non-governmental organizations provide support through governmental policies. Taking Shanghai Wei Xiao as an example, it gathers internet education suppliers to build an integrated learning resource platform . [1]
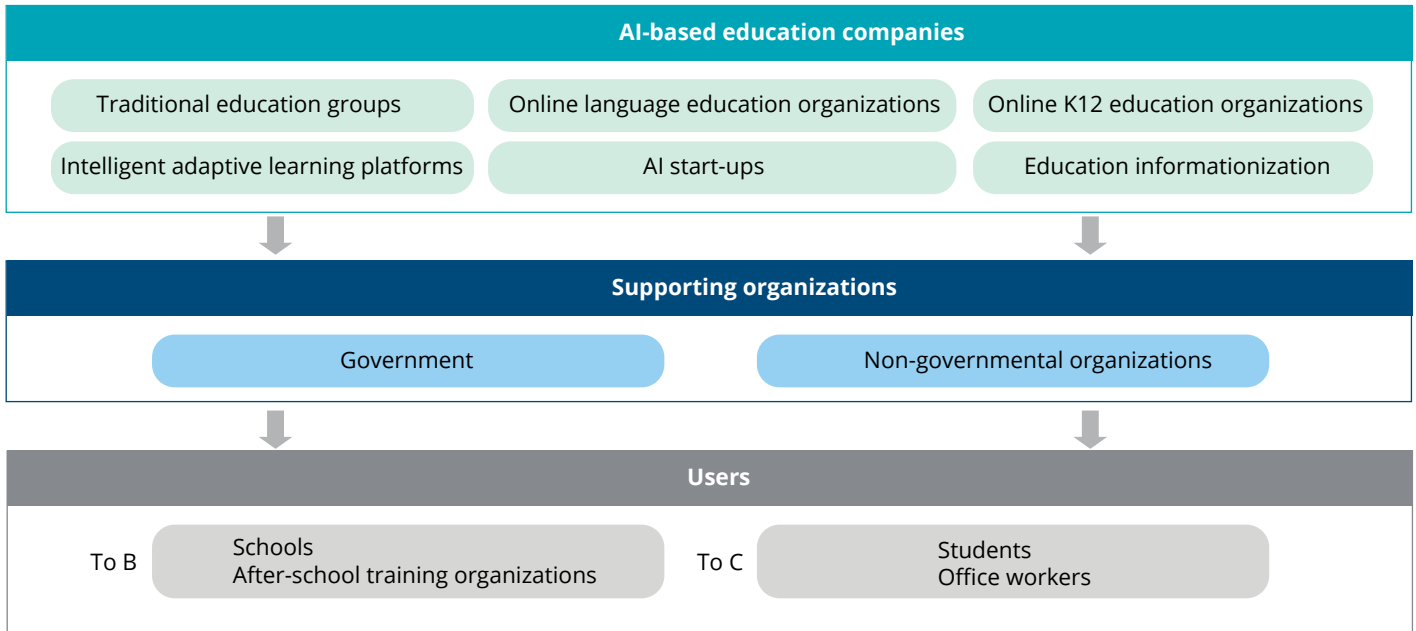
AI-based education companies:
Except for education organizations, more tech start-ups are transforming as AI-based education companies. Represented by New Oriental and Tomorrow Advancing Life, most traditional education organizations are comprehensive education groups. They overcome technology, resource, data and talent barriers to provide AI-based education products via investment, independent development and external cooperation. In 2017, New Oriental invested in 12 companies including ARIVOC POWERED, and rolled out an AI-based education product— RealSkill, through the joint venture established with iFLYTEK—Oriental iFly, helping students prepare for the oral and writing tests of TOEFL and IELTS, and develop home AI-education robot with ASUS as content provider. These companies will make AI-based education products cover wider areas and build a better ecosystem.

Moreover, AI-based education companies also include voice recognition-based online language education organizations, image recognition-based online K12 education platforms that enables picture-based question searching, adaptive learning platforms (e.g. Squirrel AI) and AI companies (e.g. iFLYTEK) are introducing intelligent products into schools.

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[1]Shanghai Education Informationization 2.0 Action Plan (2018-2022), Shanghai Municipal Education Commission

Figure3-2: China's AI-based education ecosystem

AI-based education companies		
Traditional education groups	Online language education organizations	Online K12 education organizations
Intelligent adaptive learning platforms	AI start-ups	Education informationization

Supporting organizations	
Government	Non-governmental organizations

Users	
To B — Schools / After-school training organizations	To C — Students / Office workers

Source: Deloitte Research

3.2 Intelligence becomes the prevailing trend of education industry

3.2.1 Chinese AI-based education companies will shift the focus from To C to To B

Compared with mature overseas markets, China doesn't have AI-based education until recent years, but it holds great promise. As China's AI-based education develops, Chinese companies will explore To B market like their overseas counterparts.

Foreign education companies applied AI technology much earlier. The adaptive technology can date back to 1990s. After nearly a decade, AI-based education products have been widely accepted by users of all age groups in western countries. They are mainly designed for extensive scenarios in To B market (such as examination bodies, schools and enterprises) and cover multiple subjects of different stages (including early childhood education, primary education, secondary education and vocational education). These companies can be divided into three categories: intelligent adaptive business units of education groups (e.g. Pearson provides computerized adaptive testing such as GMAT), intelligent adaptive education-based online education platforms, such as Coursera and Khan Academy, and intelligent adaptive platforms covering five learning processes, such as Knewton and Aleks. As an intelligent adaptive platform, Knewton provide adaptive learning solutions to publishers and education companies by digitalizing courses, and then begin to provide courses by collaborating with schools since 2016. It has raised over USD180 million of funds by 2019. [2]

Chinese companies began to apply AI technology mainly in To C market in recent years. It is still in the initial stage but develops rapidly. In 2018, the revenue of Squirrel AI exceeded RMB500 million and that of English liulishuo surpassed RMB600 million. Factors including large population, inadequate education resources and emphasis on education will greatly accelerate the development of adaptive learning systems. Many education companies are applying AI technologies. For example, New

Oriental and Tomorrow Advancing Life invest in or independently develop adaptive education products. Besides, there are three kinds of companies: intelligent adaptive platforms such as Squirrel AI, online intelligent adaptive education companies and AI-based intelligent adaptive education companies. With the unique characteristics of connecting all learning processes, intelligent adaptive learning becomes the most widely applied technology. As competition in To C market intensifies and government publishes policies to build information-based schools, To B market will become the new battlefield.

Figure 3-3: Comparison of AI-based education companies

	Overseas	Domestic
Business model	• To B focused • Clients including examination bodies, schools and companies	• To C-focused • Most clients are after-school tutoring organizations
Technological level	• The US and Europe have developed more sophisticated AI-based education with significant progress • To assist teaching, but can't replace teachers	• At initial stage • Core goal: to replace teachers
Representatives	• Online intelligent adaptive education platforms (i.e. Coursera, Khan Academy) • Intelligent adaptive business units of education groups (i.e. Pearson) • Intelligent adaptive learning companies (i.e. Knewton, Aleks)	• Online intelligent adaptive education platforms (i.e. zuoyebang, English liulishuo and 17zuoye) • Intelligent adaptive business units of education groups (i.e. New Oriental and Tomorrow Advancing Life) • Intelligent adaptive learning companies (i.e. Yixue-Squirrel AI,) • AI companies (i.e. iFLYTEK)
Prospect	• To have greater assistance to teaching • AI reshapes learning experience, new education system is coming into being	• Factors including large population, inadequate education resources and emphasis on education will greatly accelerate the development of adaptive learning systems. Chinese players are likely to surpass their overseas counterparts

Source: Deloitte Research

3.2.2 AI-based education companies to be the mainstream of education unicorns

AI technology is disrupting education industry. Customization is the biggest difference between "AI + education" and traditional education. With technology support, customized teaching can improve learning capability of students more effectively.

Therefore, AI-based education has become one of the major concerns among industry players. Except education groups, many tech companies are developing AI-based education products. For example, New Oriental overcomes technology, resource, data and talent barriers to provide AI-based education products via investment, independent

development and external cooperation. Tencent establishes an education branch to tighten the bonds with education companies and organizations, and provide intelligent education products to individuals, schools, education organizations as well as education authorities.

Figure 3-4: Major education companies

Company	Category	AI products
Tomorrow Advancing Life	K12 training	Intelligent adaptive
Yixue Education- Squirrel AI	K12 training	Intelligent adaptive
VIPKID	Online language learning	Oral language practicing
Koolearn	Online education	Comprehensive
English liulihsuo	Online language learning	Oral language practicing
Yuanfudao	K12 training	Photo-based question searching
Zhangmen.com	K12 training	Intelligent adaptive
Zuoyebang	K12 training	Photo-based question searching
Onion Math	K12 training	Intelligent adaptive
iFLTEK Education	Vocational education	Intelligent adaptive
Tencent Education	K12 training	Intelligent adaptive
Toutiao AI learning	K12 training	Intelligent adaptive
Fclassroom	K12 training	Intelligent adaptive
iTutorGroup	Online language learning	-
Changingedu.com	K12 home tutoring O2O	-
17Edtech	K12 training	-

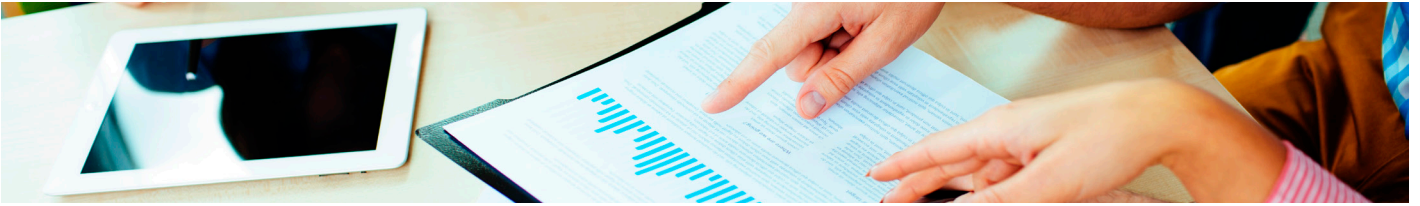Source: Startuplab, itjuzi.com, public materials, Deloitte

3.2.3AI-based intelligent adaptive education products gaining popularity

In education industry, AI technology is penetrating into different learning processes with noticeable speed. Those education products that use data to restructure education industry are unprecedentedly revolutionary. Different from traditional education approaches, intelligent education products collect data generated in five learning processes: teaching, learning, practicing, assessing and testing, apply image and voice recognition technologies to analyse problems and develop customized solutions and effective feedbacks through deep learning, adaptation and calculation.

Figure3-5: The application of AI products in five learning processes

Five learning processes	Application of AI	Major technologies	Difficulties
Teaching	• Collect preference data in advance, add feedback process • Analyse original data and feedback data to optimize online teaching systems	• Intelligent adaptive learning system • Human-machine interaction system	• Low data frequency makes it difficult to quantify • AI technology is less smart than teachers
Learning	• Deeply analyse learners' learning patterns • Provide targeted suggestions for learners on adjusting learning patterns based on scientific methodologies	• Intelligent adaptive learning system • Voice recognition	• Low data frequency makes it difficult to quantify • Complicated learning patterns lead to analysis difficulty
Assessing	• Apply recognition technologies to recognize testing results submitted by learners • Deepen learning and evaluate results according to preset standards	• Intelligent adaptive learning system	• Low machine recognition accuracy • Numerous and complicated testing data
Testing	• Predict based on learners' behaviour data • Use testing data to make learning plans	• Intelligent adaptive learning system • Image recognition product • Voice recognition product	• Large data volume • Simple and explicit feedback data • Low analysis difficulty
Practicing	• Use big data to design algorithm and analyse learner behaviours • Design customized question portfolios to strengthen weak points • Analyse question data to generate targeted evaluation report	• Intelligent adaptive learning system	• Large data volume • The most direct feedback data • The lowest analysis difficulty

Technical difficulty (vertical axis)

Source: Deloitte Research

Existing AI-based education products can be divided into three categories: intelligent adaptive learning products, photo-based searching products and voice assessment products. Among them, intelligent adaptive learning product is the most widely applied category for it can connect all learning processes.

Intelligent adaptive learning systems can provide real-time and customized learning solutions based on students' learning status, including knowledge reserve diagnosis, competence assessment and content recommendation. In the processes of teaching and learning, learners vary from each other in learning status and competence. With AI technology, intelligent adaptive course systems can use big data and algorithm to develop a set of effective and standardized courses according to important and difficult teaching points, offering the most suitable courses for learners of different levels. Computing power improvement, massive data and the application of Bayesian network algorithm have greatly accelerated the development of adaptive learning systems since 2010. Several research has been proven that AI technology can significantly improve scores. In 2018, the thesis research during a renewed international academic conference found that the intelligent adaptive system—ALEKS improves the pass rate of math by 15%. Another paper published by a top international

academic journal says that intelligent adaptive systems can help improve chemistry scores for middle and lower middle level students.

Companies engaged in intelligent adaptive education are constantly increasing globally. The number of emerging intelligent adaptive companies are growing, so do the valuation of and funds raised by them. Traditional internet education companies are shifting to or investing in intelligent adaptive education including Khan Academy, Coursera, duolingo, 17zuoye, English Liulishuo, Tencent, and Toutiao etc. Education giants like New Oriental and Tomorrow Advancing Life are also investing in or acquiring intelligent adaptive education companies.

Intelligent adaptive learning technologies and products in home and abroad have their unique characteristics. In the US and Europe, intelligent adaptive companies mainly serve To B users, represented by Knewton, ALEKS, RealizeIt and DreamBox. Chinese intelligent adaptive companies are in still in the initial stage and mainly serve To C users. However, they develop faster in China and can surpass overseas counterparts.

The integration of AI technology and learning information management system is an integral part of intelligent adaptive education products. By applying cloud computing and

deep learning function of AI, they can customize homework, testing and courses and conduct scientific assessment. AI technology has been introduced into schools and education companies to track learning status, record learning data, assess capability, management learning progress and connect parents with schools. By using open big data, it can challenge traditional teaching systems, make teaching more targeted, quantify and visualize learning progress, and improve teaching and learning quality. Currently, inadequate user coverage limits the application of learning information management system in K12 sector. However, as Chinese universities have high mobile terminal coverage and inefficient interaction between teachers and students, this system can be widely applied to reshape the interaction among universities, teachers and students based on AI technology.

Data opening is very important. With open big data, education tech companies can use AI technology to make analysis and give feedbacks, which could help companies and schools improve teaching plans and education quality. Moreover, companies can provide technical support for offline education entities with their technical strength and data reserve. Now, education companies and IT companies mainly provide open data in vocational and K12 education sectors.
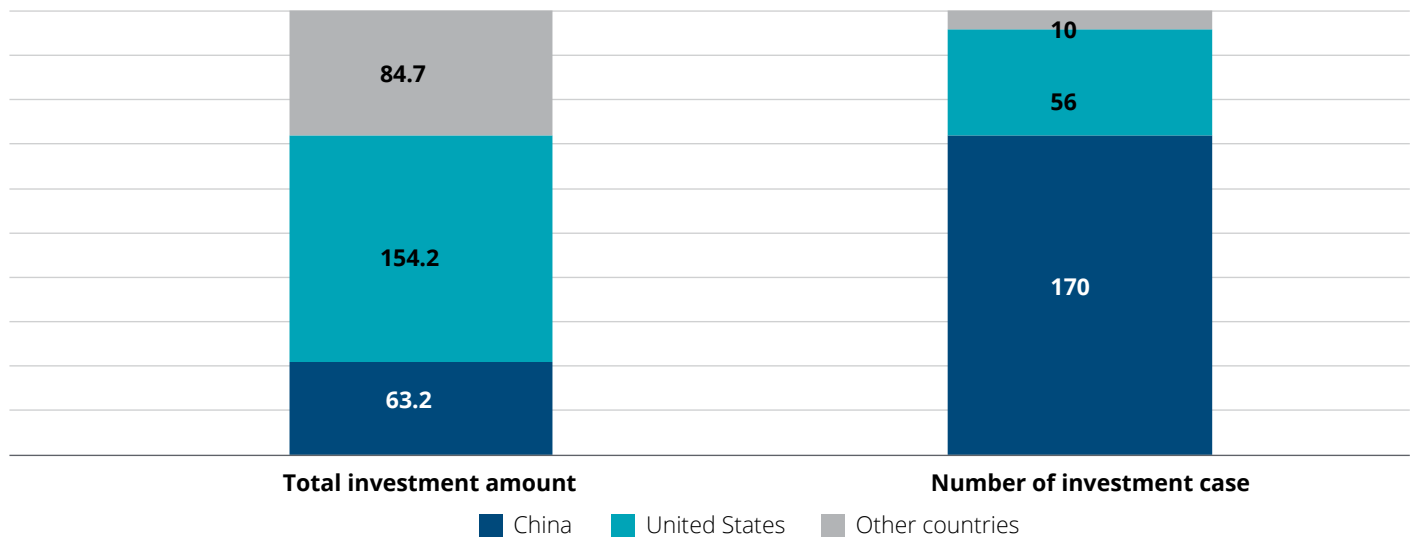
4. Trends of investment in AI-based education

Scientific and technological advances are accelerating development in the education sector. Since internet is being used in education, learning boundaries have begun to vanish. The rise of AI is significantly enhancing users' learning efficiency. Currently, the wave of "AI + education" is becoming more intense. Players in the technology-based education segment including VIPKID, Onion Math and Squirrel AI are quickly staking out their turf. The AI-enabled education sector is bringing about a revolution in the traditional education system.

4.1 China is becoming one of the most active regions for investment around the globe

New AI companies continue to emerge around the world. By 2019, the number of AI adaptive learning companies, being the mainstream of AI-based education, exceeded 100, of which 52 were from the United States, accounting for half of the total number of the world. In addition to China, AI companies are largely located in countries or regions with advantages

in AI technology including Ireland, Canada, Australia, Israel and India. In terms of frequency of investment and funds raised, the amount of investment obtained by US companies exceeded USD2.3 billion. Although China is a late-comer in AI-based education, its unique advantages in application and implementation make it one of the most popular regions for investment in AI-based education globally.

Figure 4-1: Global AI-based education investment between 2016 and Q1 2019 (incomplete statistics)

Total investment amount: China 63.2, United States 154.2, Other countries 84.7

Number of investment case: China 170, United States 56, Other countries 10

Legend: China, United States, Other countries

Source: Crunchbase, Deloitte Research

In terms of phase of development, foreign AI-based education companies are early-comers. In 2015, M&As of foreign AI-based education companies already began when China was only in the initial phase of development of AI-based education. Between 2013 and 2019, the early adaptive learning company ALEKS, learning assessment company LearnBop, online test platform Grokit, Danish adaptive learning company Grockit, and K12 education company Waggle Practice were successively acquired by or merged with large international education groups including Kaplan, K12 and McGraw Hill.

In terms of the form of financing, foreign AI-based education companies may adopt various forms of financing including the conventional venture capital investment, as well as private equity investment, debt financing, and crowd-funding. The flexibility in the choice of financing channels offers more development opportunities for foreign AI-based companies.

Compared to developed countries, China is a late-comer in AI-based education. With technology lagging behind the United States and other developed countries in the past,

Chinese players started entering the field in 2012 and the government began to roll out various policies. In 2015, AI-based education financing saw rapid growth year-on-year, heralding the arrival of the "AI + education" era in China. In 2016 and 2017, AI-based education accounted for 4% and 7% of the total number of education deals in China respectively. In 2018, the figure rose significantly to 19% with a total of 97 deals.

Figure 4-2: Percentage of financing deals of China's AI-based education sector over the total number of financing deals of the past years
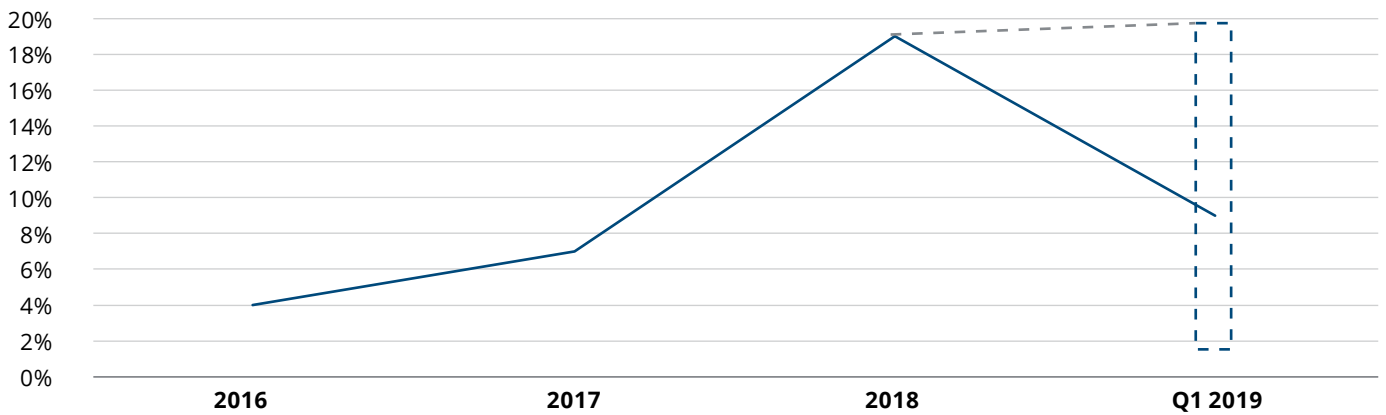
Source: itjuzi.com, Deloitte Research

The development of China's AI-based education can be examined from three aspects. First, from a geographical perspective, AI-based education companies located in Beijing, Shanghai and Guangzhou, the developed tier-one municipalities/cities, have obtained the most investment leveraging the leading technological strength and highly developed education industry in China. From 2016 to Q1 2019, 88 deals were completed in Beijing, making it the municipality with the most frequent financing deals of AI-based education companies, followed by Shanghai and Guangdong, with 32 and 8 deals respectively. In addition, AI-based education companies also emerged in the Yangtze River Delta region, Fujian, and central and western regions. Although the financing in these areas is less frequent, it reflects that the AI-based education sector is reaching out to tier-two and tier-three cities.

Figure 4-3: AI investment in China in 2018 (by geography)
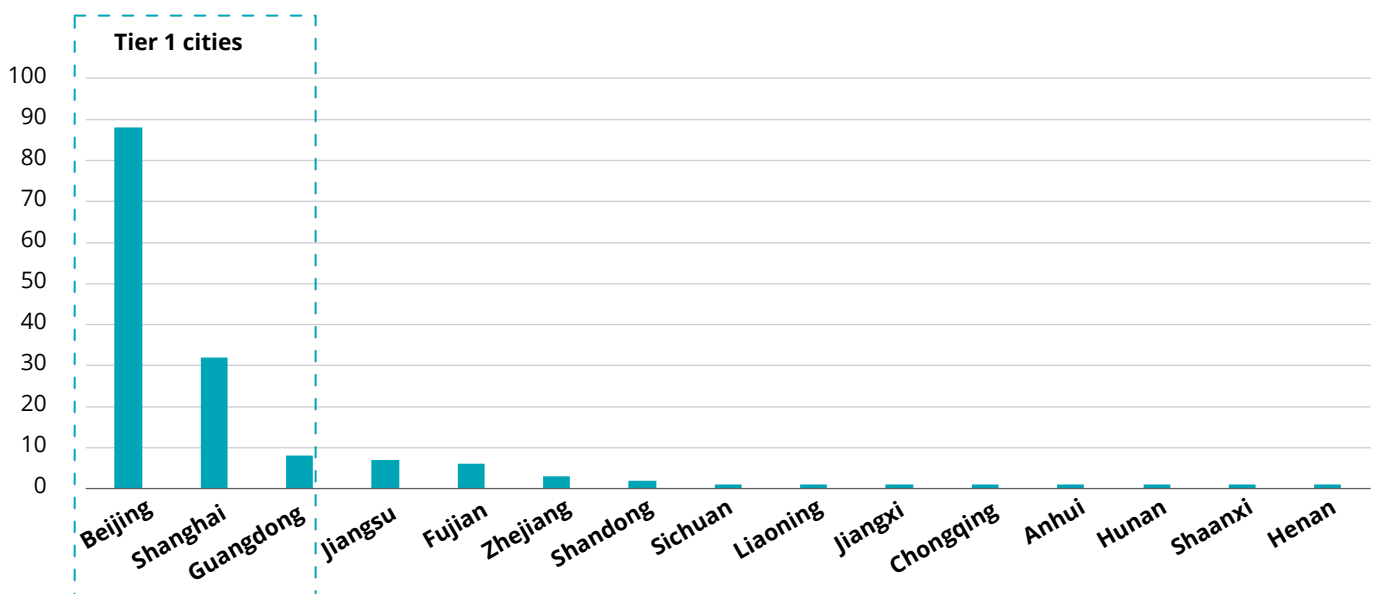
Source: itjuzi.com, Deloitte Research

Secondly, in terms of segment, AI has already penetrated a number of segments including K12, language, education informationization, and quality education. In 2018, K12, education informationization, language, and quality education including STEAM became the most popular segments for investment in AI-based education, with 24, 17, 14 and 13 deals respectively. In addition, some early childhood education and vocational education companies adopting AI have also raised certain amount of funds.

Figure 4-4: Financing in "AI + education" in China in 2018 (by segment)
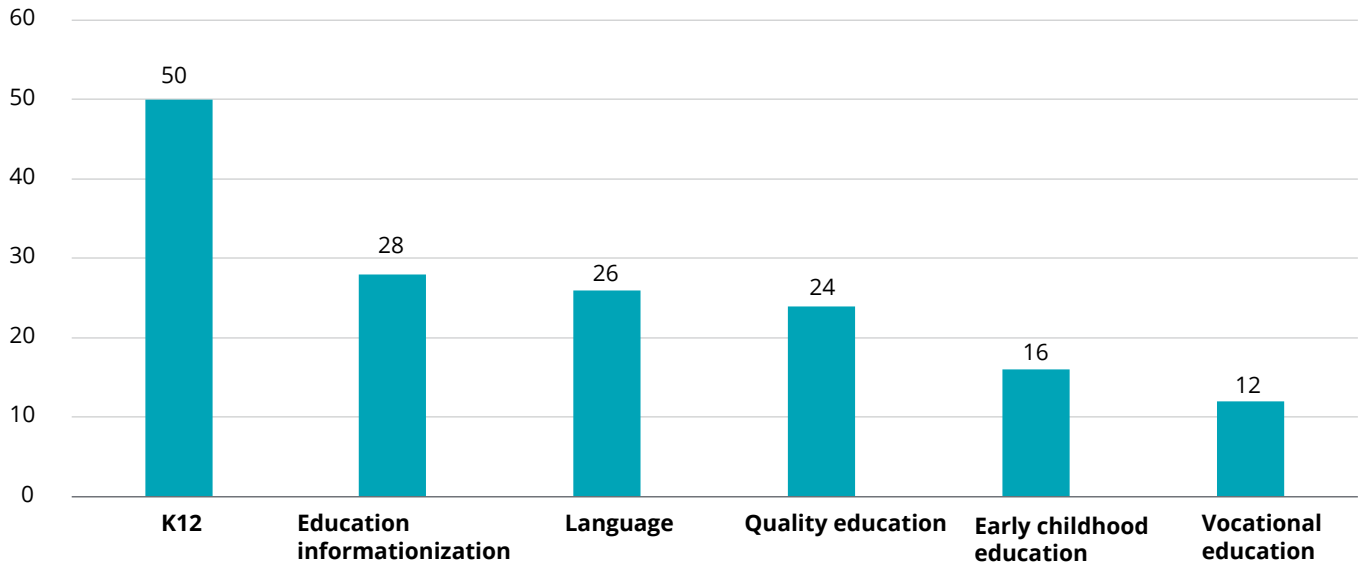
Source: itjuzi.com, Deloitte Research

Thirdly, in terms of rounds of financing, China's AI-based education sector exhibits the following features:

- First, AI-based education start-ups obtaining **early-round (before round A)** financing the most frequently. For example, AI-based education companies obtained early-round financing for 79 times from 2016 to Q1 2019.

- As competition in the industry grows, the frequency of AI-based education and the education sector as a whole obtaining financing **in the transitional round stage (rounds A and A+)** will drop rapidly, but the amount of financing will increase accordingly. It is worth noting that the key to the transition stage is companies need to establish a growth mechanism. Therefore, the state of development of a company during the transitional round is the key to whether the company can survive or become the next unicorn.For example, the frequency of AI-based education companies obtaining round A financing dropped by half (41 times) of those obtaining early-round financing from 2016 to Q1 2019.

- The number of education companies entering the **expansion stage (round B and subsequent rounds)** further decreases. The education sector is faced with more intense competition in this mature stageFrom 2016 to Q1 2019, the number of companies obtaining financing in the AI growth stage was 50, surpassing the number of companies obtaining financing in the transition stage.

Figure 4-5: Financing stages of AI-based education vs the education sector between 2016 to 2019 Q1
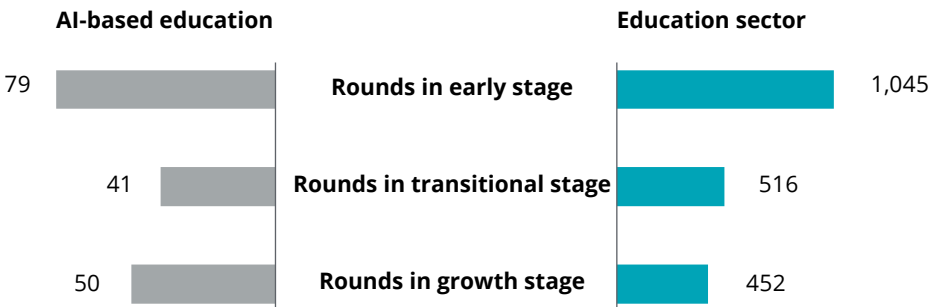
AI-based education		Education sector
79	**Rounds in early stage**	1,045
41	**Rounds in transitional stage**	516
50	**Rounds in growth stage**	452

Source: Public materials, Deloitte Research
*Note: Rounds in early stage (seed, angel, Pre-A); rounds in transition stage (A, A+); rounds in growth stage (round B and subsequent rounds)

From 2016 to Q1 2019, the frequency of AI-based education companies and the entire education sector obtaining round A financing dropped to 41 times and 516 times respectively. Furthermore, the number of education companies entering the expansion stage continued to decrease. From 2016 to Q1 2019, only 452 companies in the education sector obtained round B (or above) financing. 50 of them obtained financing in the AI growth stage, which surpassed the number of companies obtaining financing in the transition stage. The AI-based education sector in China is faced with more intense competition in the mature stage.

4.2 Investment in the AI-based education segment remains fragmented

Currently, the combination of AI and education is predominant in the following four segments: K12, education informationization, quality education, and foreign language training. Their use of AI can be classified into the following main areas: academic affairs administration including intelligent class scheduling, attendance, and test; online education with intelligent emotion recognition system enabled by deep learning facial recognition technology; photo-based question answering platform for K12 homework supported by image recognition technology; and education start-ups entering the market directly with adaptive learning platforms.

Among the four segments, education informationization, English language training, and K12 have all obtained post-round C financing. While the education informationization segment is backed by policy, its development prospect is limited by the saturating market. AI-based education companies in the quality education segment are mostly in the round A stage, but their financing amount basically exceeds RMB100 million. In the English language training segment, English Liulishuo was successfully listed in the United States, Hujiang Education has passed the listing hearing of the HKEx, and VIPKID, an online English teaching company for young people, obtained USD500 million of round D+ financing. Among the K12 homework platforms, 17Edtech and Yuanfudao

obtained USD250 million of round E financing and USD300 million of round F financing respectively in 2018. The adaptive learning company Squirrel AI has raised more than RMB1 billion over the past three years. Therefore, in addition to the development of business of these companies, certain industry barrier has also been set up in terms of financing amount.

AI-based K12 education investment has entered mature stage: The application of AI in K12 education is one of the most popular application scenarios at present, and is the AI segment obtaining the most investment. In terms of rounds of investment, post-round A investment accounted for the highest proportion, meaning that this

portion of companies have already established growth mechanism. Therefore, competition among AI companies in the K12 segment is increasingly fierce. From 2016 to Q1 2019, the total number of investment deals in the K12 education segment

was 51, of which 18 were early investment deals, 10 were round A investment deals and 23 were post-round A deals. Geographically, Beijing remains the region with the largest number of K12 education companies obtaining investment. Currently, K12

is still a more popular segment for AI investment compared to other segments. Companies including internet giants, renowned VC/PE and education giants are establishing their presence in the K12 segment.

Figure 4-6: Distribution of AI-based K12 education between 2016 and Q1 2019 by round of financing

Legend:
- Seed
- Angel
- Pre-A
- A
- B
- C
- D
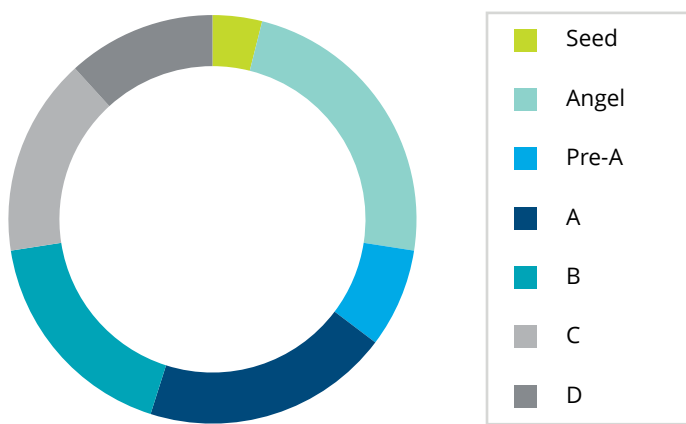
Source: itjuzi.com, Deloitte Research

Figure 4-7: Investment in AI-based education informationization (by number of deals)
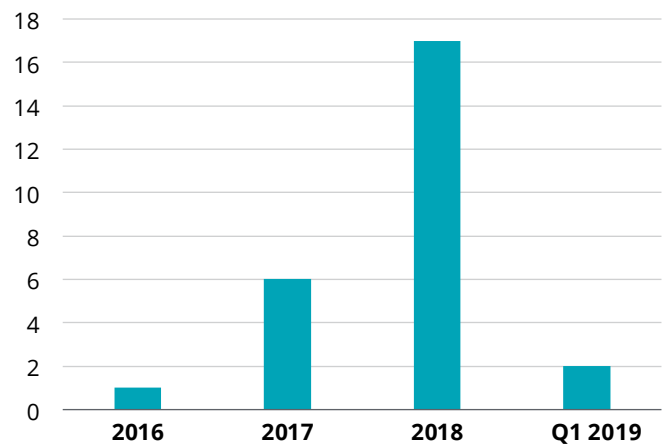
Source: itjuzi.com, Deloitte Research

Investment in AI-based education informationization is huge: The launch of the Education Informationization 2.0 Action Plan officially kicked off the phase transition and upgrade of education informationization. Meanwhile, this favorable policy will help the education informationization segment become the target of capital pursuit. From 2016 to Q1 2019, a total of 26 investment deals were completed in AI-based education informationization. In 2018, investment and financing in education informationization increased substantially, accounting for 65% of the total investment deals for the four years. In terms of rounds of investment, 57.7% of investment during the four

years were mainly made in early stage such as the seed round and the angel round. In the AI related education informationization segment, education giants and VC including TAL Education and Xinrong Qihang are beginning to show interest in the segment. Although most of the investment is of the early stage, the investment amount reached RMB10 million.

AI-based foreign language training has entered rapid expansion stage: the popularity of foreign language training in the education sector has extended to the "AI + education" sector. With the rapid development of voice recognition and machine vision application in China, the teaching

of speaking and reading English learning has become one of the most popular application scenario of AI in education. From 2016 to Q1 2019, there were 25 investment deals in "AI + education" in foreign language training, of which over 65% of the companies have entered round A or subsequent rounds. This shows that start-up projects in the foreign language training segment have entered the rapid expansion stage. Leveraging technological advances and continuous aggregation of user data, companies will rapidly expand the market with large-scale financing and build up brand advantages, gradually forming an industry barrier.

Figure 4-8: Distribution of AI-based foreign language training between 2016 and Q1 2019 by round of financing
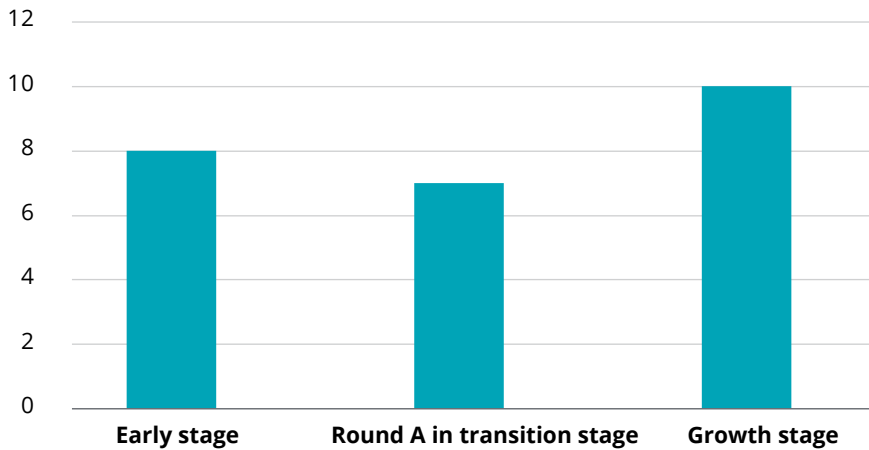
Source: Public materials, Deloitte Research
*Note: Rounds in early stage (seed, angel, Pre-A); rounds in transition stage (A, A+); rounds in growth stage (round B and subsequent rounds)

AI-based quality education is becoming the blue ocean for investment: Following the launch of a series of policies, rules and regulations in the second half of 2018, investors have become relatively cautious about their investment in AI-based education. Quality education related segments have begun to grow. Since AI-based education emerged in 2016, the quality education segment represented by STEAM from Europe and the United States has already completed 23 financing deals. The development of the quality education segment was supported by the state's efforts in promoting quality education. In addition, segments focusing on K12 and English language teaching have already entered the red oceans. Leveraging new education philosophies, rapid development in digital technology, and strong support from relevant policies, quality education has become the new blue ocean for the education sector. The

"AI + quality education" segment saw an upsurge in 2018. The number of financing deals completed in 2018 alone already accounted for 78.2% of the total financing deals completed by the sector since 2016. In terms of development stage, most financing projects of "AI + quality education" are still of rounds in early stage and transition stage.

4.3 AI-based education investment and integration trends for the next step
During 2018, China's AI-based education sector attracted investments from leading players in AI technology, VC/PE and education giants, including K12 giants like New Oriental and TAL Education, internet enterprises like Tencent, as well as renowned capital firms like Sequoia Capital, Matrix Partners China, ZhenFund and Blue Elephant Capital. At present, AI-based education companies are not fully opened up

to technology and the sector. Their application remains focused on relatively vertical fields. Over time, the vertical market segments of companies would further deepen. In 2019, companies will achieve multi-dimensional technological penetration, and segments will integrate together on a large scale.

Investors of education companies are divided into three main types. The first type is leading companies and institutions in AI technology such as Tencent, iFlytek and Chinese Academy of Sciences Venture Capital Management Company. The second type is renowned VC/PE such as ZhenFund and Sinovation Ventures. The third type is education giants such as TAL education, New Oriental and Net Dragon.

The investment of leading players in AI technology is inclining towards more mature start-up projects

The investment made by AI technology companies such as Tencent and iFlytek as well as technology investment funds supported by Ministry of Science and Technology has penetrated in all segments in AI. In terms of investment areas, projects chosen by investors are in various stages of their future industrial strategic plan. In terms of rounds of investment, rounds in the growth stage (post-round B) have absolute dominance over other rounds. Among Tencent's nine investment deals in AI-based education between 2016 and Q1 2019, round C, round D, round E, round F and strategic investment accounted for 30%,

30%, 10%, 10% and 20% respectively. With abundant technologies and funds, leading players in AI technology also focus on overseas "AI + education" market. In 2017 and 2019, Tencent invested in Indian AI-based education company Byju's. In contrast to Tencent, AI technology company iFlytek focused their investment on the early stage. Among iFlytek's investment in education between 2016 and Q1 2019, almost all companies were "AI + education" companies. In terms of segment, their investment mainly focused on education informationization and quality education. In addition, projects iFlytek invested in were mostly start-up projects incubated under the company.

Figure 4-9: Percentage of rounds of investment in "AI + education" by Tencent between 2016 and Q1 2019

Round C
Round D
Round E
Round F
Strategic investment
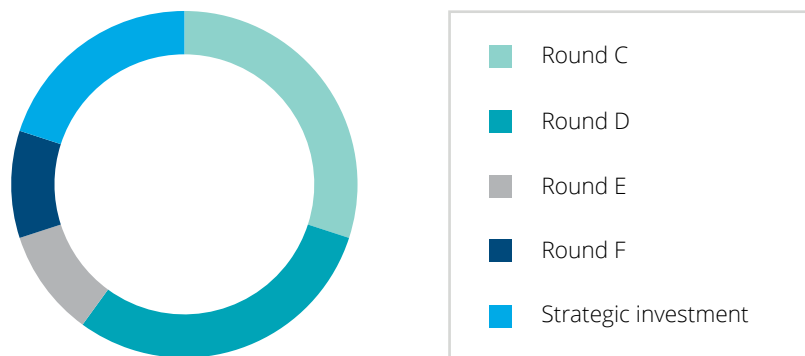
Source: Public materials, Deloitte Research

VC/PE investment became more rational with a focus on projects with strong technology and implementation

2018 marked a different year for venture capital and private equity investment. Compared to the previous investment landscape of AI projects, VC/PE investment has become more rational. According to incomplete statistics, among the investment in education made by renowned VC/PE between 2016 and 2018, the percentage of investment in "AI + education" varied between 5% and 50%. The percentages of investment in "AI + education" made by investment firms including Sequoia Capital, Fortune Capital and Sinovation Ventures were 47%, 38%, 21% and 25% respectively. In terms of investment amount, the amount of investment made in round A and subsequent rounds by VC/PE exceeded RMB10 million. In the future, as the market gradually turns rational, companies with advantages in technology, data and business model are more likely to attract to VC/PE.

Figure 4-10: Statistics of frequency of investment in education made by major VC/PE between 2016 and 2018

Number of deals of investment in education — Percentage of investment in "AI + education"
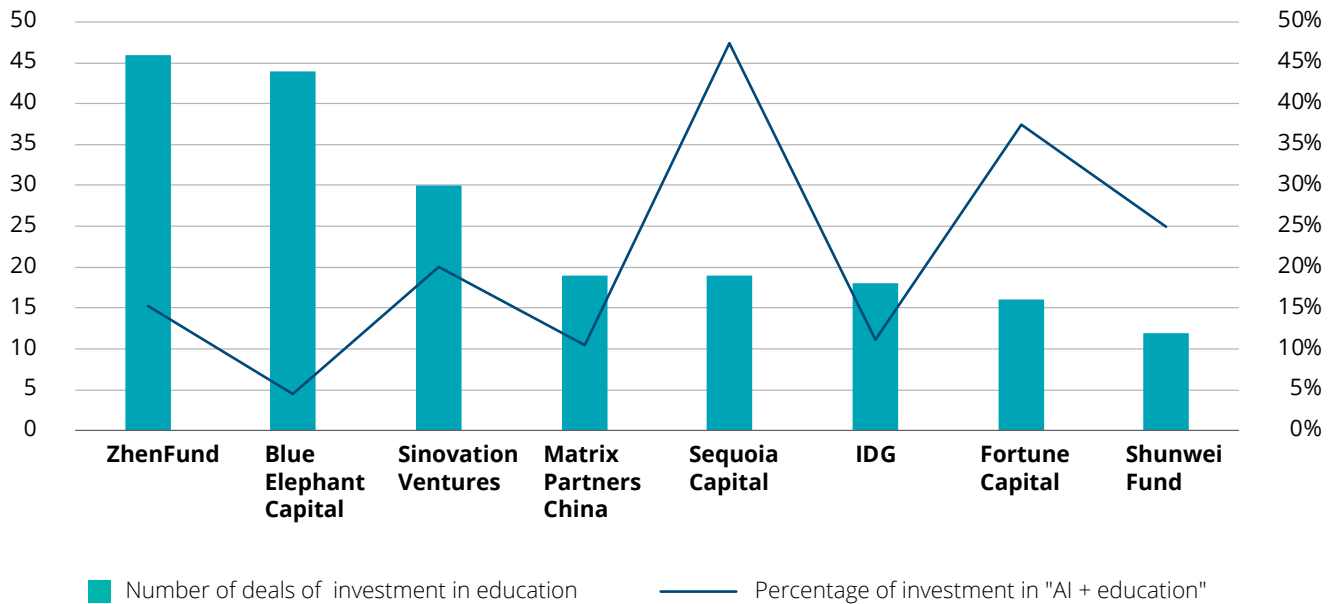
Source: itjuzi.com, Deloitte Research

Education giants accelerate their plans in the white space, bringing about the era of extensive investment and M&As of education giants in the "AI + education" sector

From 2004 to 2018, a number of iconic adaptive learning start-ups worldwide have been acquired by large international education groups. Such trend has reached a peak in 2018. In particular, the investment and financing trends of adaptive learning pioneering countries around the world also have certain indicative effect on the future development trends of China's AI-based education sector. In the future, as competition of AI in education in China enters the red oceans, China's education sector may continue to scale up investment while carrying out M&As on companies in certain segments, just as what education giants in Europe and the United States did.

Figure 4-11: Major acquisitions of overseas adaptive learning companies between 2013 and Q1 2019 (incomplete statistics)

Intelligent Adaptive learning company	Location	Year of acquisition	Acquirer
Lexia Learning System	United States	2013	Rosetta Stone
Grockit	United States	2013	Kaplan
ALEKS	United States	2013	McGraw-Hill Education
Area9	Denmark	2014	McGraw-Hill Education
LearnBop	United States	2014	K12
Think Through Learning	United States	2016	Imagine Learning
Gradescope	United States	2018	Turnitin
Fishtree	United States	2018	Follett Corporation
Knowre	United States	2018	Daekyo Investment
Grovo	United States	2018	Cornerstone OnDemand
Carnegie Learning	United States	2018	CIP Capital
StudyBlue	United States	2018	Chegg
Waggle Practice	United States	2019	Houghton Mifflin Harcourt
Knewton	United States	2019	John Wiley&Sons

Source: Crunchbase, Deloitte Research

Among investment in "AI + education", investment of traditional education giants has played an important part. According to statistics, investment of New Oriental and TAL Education in AI-based education accounted for 11% and 21% respectively of investment in the education sector as a whole. "AI + Educatioin" segments that New Oriental are gaining footholds in include informationization, early childhood education, language and K12. In contrast, TAL Education has focused their investment on education informationization. In addition, New Oriental also have invested in the K12 and language related segments. In terms of rounds of investment, post-round B projects in the growth stage are more likely to attract education giants. Overall, before making investment, both New Oriental and TAL Education have taken into consideration of whether the investment will expand the market for other participants and enable synergistic collaboration with the traditional business of the company. In the future, as competition of AI in education in China enters the red oceans, China's education sector may continue to scale up investment while carrying out M&As on companies in certain segments, just as what education giants in Europe and the United States did.

Figure 4-12: Percentage of investment in "AI + education" by education giants between 2016 and Q1 2019
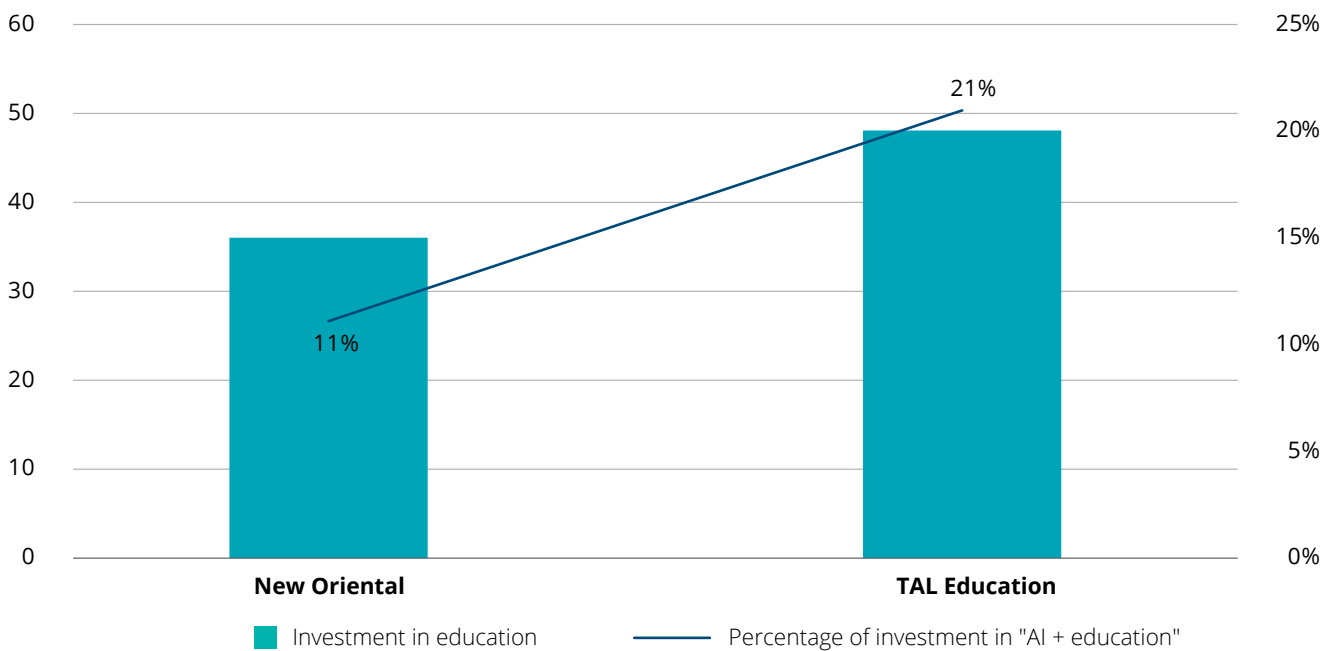
Source: crunchbase, itjuzi.com, Deloitte Research

5. Future challenges, prospect and thinking of AI-based education

With learning experience being reshaped by AI and the gradual formation of a new education system, the development of China's education sector is approaching towards an intelligent era. Nevertheless, AI-based education is still faced with various issues in the course of its development. For "AI + education" to be fully implemented, there remains a number of challenges:

First, there is insufficient data in AI-based education. Data and algorithms are the core of AI-based education. Currently, the gap in core algorithms technology among AI-based education companies is not significant except individual teams. Data is the major issue encountered by the vast majority of education companies at present. AI requires massive precise and labeled data. However, AI-based education companies cutting in from different education segments all encounter different degrees of data insufficiency. In addition, data is not effectively assessed. The key obstacle of "AI+education" is the absence of a closed loop of learning data in the education sector. Certain important parts such as learning process data and knowledge mastery data are still missing. Therefore, at this stage, AI cannot be

used to form effective assessment to drive learning improvement. The acceptance of implementation of education scenarios by the traditional education system will become a tough issue for "AI + education". For example, in the K12 segment, students spend most of their time learning at school. Schools under the traditional education system are sticking to the traditional learning model. Therefore, implementing "AI + education" requires schools, teachers, parents and students to work together.

The development of AI in education is still seeing bright prospects. To better implement AI-based education and make it the future of education, we need to rethink the role of AI and education in society:

Educators and decision-makers have to understand AI in a broader learning context. From the perspective of educators, AI-based education brings challenges to teachers' development mechanism and changes in their future roles. Of the teaching aspect of education in the future, teachers are likely to be completely replaced by AI. However, in terms of educating people, it is not possible for AI to replace teachers. By then, the role of teachers is likely to change from

"teaching" to "educating" as well as communicating on an emotional level. From the perspective of people's livelihood, the development of AI-based education will facilitate the fair allocation of education resources, an insight already perceived by the government and education decision-makers. From 2016, a series of new education policies on intelligentization and informationization are driving the development of AI in education.

The data required for machine learning is usually highly customized. When used for assessing students' performance, data security may become the key bottleneck of the use of AI. The development of AI-based education in China has been relatively lagged behind partly due to the high requirements on algorithms and the huge R&D investment required in the early stage. However, the "marginal cost" is not high in actual implementation. Once the issue on algorithms is solved, precision data will become a key factor of whether AI can be practically implemented. With the support of advanced algorithms and data in the future, AI-based education will achieve the level of the special-grade teacher, and the efficiency of knowledge acceptance by users will be significantly enhanced.

In the future, the role of AI in supporting human development will be increasingly important, bringing fundamental changes. Like every scientific and technological progress that was made, legal issues around such technology would emerge accordingly. The issue on formulating laws, rules and regulations in the development process of AI is also a challenge faced by the industry. Gartner predicted that by 2020, AI and machine learning would create 2.3 million jobs while eliminating 1.8 million. In this case, whether job will be eliminated or created largely depends on the industry. For example, healthcare, education and the public sector would be benefited. To maximize value, we should focus on the AI industry to enrich the industries of the future, and reset existing rules and policies to create new industries. Changing our own culture will allow us to quickly adapt to opportunities brought by the AI science and technology.

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