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Report on China Smart Education 2022

Digital Transformation of Chinese Education Towards Smart Education

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China National Academy of Educational Sciences (CNAES)

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Preface

As we enter the digital era, the education form of the industrial age can no longer adapt to social development. Countries worldwide are paying close attention to promoting the digital transformation of education and exploring smart education.

In 2022, China launched the Strategic Action Plan for Education Digitalization, built the public service platform called Smart Education of China platform, and established the largest library of education resources. The platform has received more than 6.7 billion views and covered users from over 200 countries and regions. It has played an imperative role in supporting online classes when offline classes are suspended during the prevention and control of COVID-19; narrowing the digital divide and setting an example for marching toward smart education.

As a national education think tank, China National Academy of Educational Sciences (CNAES) aims at smart education, brings together domestic and international practices and research results, extensively consults all parties, and builds consensus to form the China Smart Education Bluebook and the "1+3" development index report, which were presented to the people at home and abroad at the first World Digital Education Conference co-organized by the Ministry of Education and the National Commission of the People's Republic of China for UNESCO.

This book is compiled on top of extracting and summarizing the China Smart Education Bluebook and the "1+3" development index report. It is the first systematic summary of the progress of smart education in China and explains in depth the digital transformation of Chinese education toward smart education. With the interpretation of the connotation of smart education as the thread, the book presents 16 specific features from four dimensions: environment, teaching and learning, governance, and talent literacy, summarizes China's experience in the smart education development, and proposes the world seven issues and five initiatives that should be the future focus. Furthermore, based on the objective reality that the development of smart education is in a nascent stage, the book explores and establishes an index system consisting of four primary dimensions and 12 secondary dimensions. It attempts to quantitatively assess the development level of smart education in China and form three sub-reports in basic education, vocational education, and higher education fields to provide references for effectively promoting smart education.

Both theory and practice have proved that the development of smart education in China has a solid foundation and distinctive characteristics. In other words, it attaches great importance to upholding the values of putting people first and running education to the satisfaction of people. It puts much stress on the inheritance and development of traditional education philosophies, such as education for all without discrimination, aptitude-based teaching, and the unity of knowledge and practice. It also values the appropriate blending of a top-down approach to macro adoption of initiatives and a bottom-up approach to ecological construction.

China's mega-scale application practice of digital education will undoubtedly make historic contributions to the human quest for educational equity and the development of high-quality education, contributing China's wisdom and strength to the world's education development in the digital era.

Beijing, China

China National Academy of
Educational Sciences (CNAES)

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Conceptual Framework of Smart Education in China

The development course of human civilization is not only a history of scientific and technological innovation but also a history of educational advancement. The modern education system was created during industrialization, from which it inherits distinctive features such as large scale, standardization, and specialization. The advent of the digital era has challenged the classroom teaching mode built up during industrialization. Taking the initiative to promote the digital transformation in education and develop smart education is a strategic move to cope with contemporary changes and an integral part of education modernization.

1.1 Connotations and Characteristics of Smart Education

1.1.1 Connotations of Smart Education

As a new form of education in the digital era, smart education is essentially distinct from education forms in the industrial era.

Smart education is an important goal of the digital transformation of education and represents the future of education development. Based on learning and development patterns of learners and via modern technologies, smart education empowers and drives the learning sector. Smart education helps to reach the full alignment between individual development and societal development that makes it possible to provide suitable education for each learner and to prepare a systematic talent pipeline for societal development. Smart education is dedicated to quality and personalized lifelong learning that will be available for anyone anywhere anytime. Smart education reshapes learning content through nurturing learners' higher-order thinking skills, integrated innovation capacity and lifelong learning literacy to eventually contribute to quality education. Smart education will construct a new paradigm of

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teaching and learning by integrating physical, social, and digital spaces to create new learning scenarios and promote human-technology integration. Centered around data governance and driven by digital intelligence, smart education promotes the education process optimization and reengineering, and advances the modernization of system and capacity for education governance, to improve educational efficiency, effectiveness, and benefits.

Though in a nascent stage, smart education has already enabled learning resources sharing and teacher-student communication cross-time-and-space. Preliminary results have been observed in achieving regional education equality, enhancing the bottom line of education quality, and improving digital literacy and skills of teachers and students. In the future, more learning resources will be shared, teaching paradigms innovated, teacher-student relationship reshaped, education process reengineered, talent training quality improved, and intellectual capital of the society fully leveraged. Smart education will empower the transformation of education on all fronts, promote digital transformation of education in a holistic manner, disrupt outdated educational paradigms, and systematically construct a new relationship between education and society.

China has solid foundations and distinctive characteristics for the development of smart education. First, China attaches great importance to upholding the values of putting people first and running education to the satisfaction of people. Second, China put much stress on the inheritance and development of traditional education philosophies, such as education for all without discrimination, aptitude-based teaching, and the unity of knowledge and practice. Third, China values the appropriate blending of a top-down approach to macro adoption of initiatives and a bottom-up approach to ecological construction.

1.1.2 Characteristics of Smart Education

Buttressed by a digitalized education environment, personalized teaching and learning, and precise education governance (see Fig. 1.1), smart education builds a more open, flexible, and high-quality education system that is accessible and applicable to all to cultivate a new generation of talents that has stronger value belief, digital literacy, creativity, and lifelong learning skills.

i. Education environment: ubiquitous and intelligent learning space

Smart and agile facilities. Through the integration with cloud networking, an education infrastructure system that connects everything and combines reality with virtuality is built, thus constituting an online learning space featuring comprehensive perception, ubiquitous connection, and deep interaction. Smart campuses and teaching venues that are continuously strengthened and smart learning terminals that deploy across the board could help smart education meet diverse and personalized demands for teaching and learning.

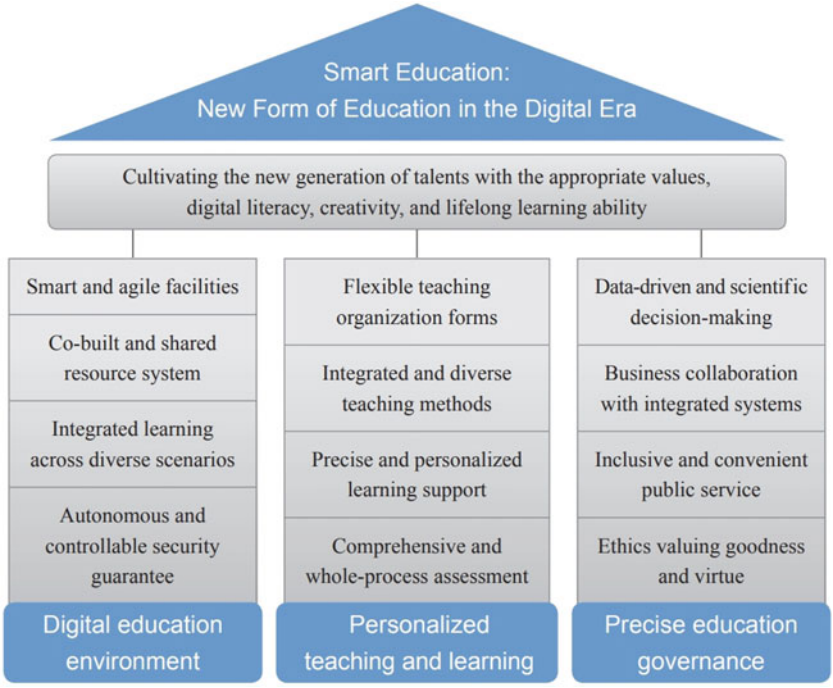

Fig. 1.1 Smart education: the conceptual framework

Co-built and shared resource system. Smart education integrates and develops various education platforms at all levels, on the basis of a united smart education platform with connectivity, complete applications and collaborative services. It improves the mechanism of resource development, dynamic upgrading, and societal consolidation to form a multi-type, systematic, and high-quality digital education resource system.

Integrated learning across diverse scenarios. Through combining school education with cyber learning and social practices, smart education nurtures a virtuous ecosystem characterized by online-offline and virtual-reality integration and connection inside and outside school. Smart education also builds a digital certification system to allow extensive mutual recognition and free conversion of learning achievements, and to support learners to carry out lifelong learning anytime, anywhere.

Autonomous and controllable security guarantee. Smart education establishes a long-term mechanism guarding education cybersecurity and the physical and mental well-being of students. It also forms a whole cycle of security management and classified precise protection for education data. Cybersecurity auditing measures are continuously bolstered, evaluation and daily supervision of new technologies and applications are carried out regularly, and the ability to prevent and mitigate major security risks is significantly enhanced.

ii. Education implementation: adapted to individual needs

Flexible teaching organization forms. Smart education employs digital technology to reshape instructional organization forms, flexibly sets course subjects and learning plans, and carries out cross-regional, cross-school, interdisciplinary and cross time and space teaching activities. It builds up communities for teachers and learners that transcend time and space limits, allows the online circulation and sharing of quality teaching resources, and enables schools to cooperate with other schools, businesses, and local governments to improve the quality of institutions-families-society collaborative education.

Integrated and diverse teaching and learning methods. Smart education comprehensively improves teachers' competencies, integrates online and offline learner-centered teaching, supports classroom innovations, and contributes to deep learning. It widely implements project-based, inquiry-oriented, experiential, and cooperative teaching, and reengineers the teaching process. It also supports the new type of dual-teacher classes led by a human teacher and a virtual teacher or an intelligent tutor.

Precise and personalized learning support. Smart education carries out data-driven learning analysis and accurate diagnosis, constructs knowledge graphs based on systematic logics of knowledge, sends targeted learning resources based on knowledge mapping, realizes learner-centered personalized learning while adopting a large-scale education approach, and meets learners' multi-tiered and diverse needs.

Comprehensive and whole-process assessments. Smart education leverages learning analysis and the adjoint data collection tools to achieve dynamic assessment, diagnosis, and feedback on learners' learning progress, supports all-round and whole-process assessment of moral, intellectual, physical, social, aesthetic, and labor education development, and makes education evaluation more science-based, professional and objective.

iii. Education governance: precise and intelligent management service

Data-driven and scientific decision-making. Smart education constructs and utilizes big data in education and reinforces data mining and analysis to dynamically follow the trends of education reform and development, enhances evidence-based decisions and diagnoses, and improves scientific decision-making of education. It builds a collective decision-making system with human–machine coordination and helps governments, schools, and society in collaborative governance on multiple facets.

Business collaboration with integrated systems. Smart education optimizes education processes with digital technology, integrates various education management systems, repurposes evaluation and supervision methods, and carries out online teaching and research to support the integrated management of education. It also improves data exchange and business collaboration across regions and departments at all levels to realize whole-process smart supervision.

Inclusive and convenient public services. Smart education adopts digital technology to build an integrated public education service system, implements the integrated processing of education services, forms a new mode of online smart service, and promotes the upgrading from an integrated net to an inclusive and convenient net so that the outcomes of education development can benefit all people more equitably.

Ethics valuing goodness and virtue. Upholding the principle of utilizing technology for the greater good, and developing digital applications that conform to the general laws of education and fit the physical and mental development of learners, smart education completes and improves education data governance mechanisms, respects teachers' and students' rights to privacy and information, enhances the transparency of algorithmic rules, builds a credible artificial intelligence system, and guarantees that teachers and students make decisions on their own.

iv. Talent cultivation: a new generation of talents willing to reform and innovate

Values rooted in the contemporary world. Smart education fosters talents who can tap the advantages of digital technology, adhere to the core socialist values, strive for the shared aspiration to achieve socialism with Chinese characteristics, and have the values and responsibilities to realize the great rejuvenation of the Chinese nation and build a community with a shared future for mankind. They respect cultural differences, actively promote the ability of cross-cultural understanding and communication, enrich the spiritual world, and build up mental strengths.

Digital literacy for the era. Smart education fosters talents who are proficient in using digital technology in their learning, actively participate in social practices, and have acute data awareness, a sharp mind for computing, collaborative learning ability, cybersecurity awareness, and good social-emotional literacy. They consciously abide by the ethics of the smart society, improve their digital competency, and can better adapt themselves to the digital era.

Creative mind to make changes. Smart education fosters talents with creative consciousness, scientific spirit and critical thinking, who are good at identifying and proposing problems, developing reasonable solutions, and solving problems creatively. They are adept at using digital technology to catalyze innovation and are able to either transform ideas into tangible results or make improvements to readily available solutions.

Ability to learn throughout a lifetime. Smart education fosters talents who have a strong will, always maintain learning motivation, make lifelong learning plans according to their needs, and can effectively manage their learning process. They can carry out continued self-evaluation and introspection, keep their knowledge and mindset up to date, improve themselves in practice, and lead an extraordinary life with pragmatic efforts.

1.2 Smart Education Development Index

1.2.1 Background

i. The connotations and characteristics of smart education

In the previous section, smart education was defined as a new form of education in the digital era, and as an important goal of the digital transformation of education, it represents the future direction of learning. Based on learning and development patterns of talents and via modern technologies, smart education empowers and drives the learning sector, which leads to full alignment between personal and social development. Each learner could access suitable education and a talent pipeline could be prepared for social development. Smart education is dedicated to quality and personalized lifelong learning which will be available for everyone everywhere all the time. It reshapes learning content. Aimed at quality education, smart education will nurture learners' advanced intellectual competence, integrated innovation capacity and lifelong learning trait. Smart education will build a new paradigm of teaching and learning by integrating physical, social, and digital space to create new learning scenarios and coordinate people and technology. Centered around data governance and driven by digital intelligence technology, smart education reinvents learning processes. As a result, governance system and governance capacity of education will be modernized, and efficiency, effectiveness and benefits of education improved. All the above theories are the cornerstones of Smart Education Development Index.

ii. Vivid practical experience of China's education informatization

Over the years, China has taken a series of powerful and significant measures to promote the construction of the basic application environment of education informatization as a whole, build a resource development and application system covering all levels and types of education, strengthen the construction of the teaching team that is compatible with the digital era, establish and improve the information system of education management, establish demonstration zones for education informatization and smart education in all forms of education at all levels, and vigorously implement *China's Strategic Action Plan for Education Digitalization.* The rich and vivid practical experience has been accumulated in China. The practices have become the realistic basis for building the Smart Education Development Index.

iii. International experience in digital monitoring and evaluation of education

The international community pays close attention to the digital monitoring and evaluation of education, and the corresponding achievements are increasingly fruitful. The databases of the World Bank, UNESCO, the Organisation for Economic Co-operation and Development (OECD), the International Telecommunication Union (ITU) and other international organizations document the data of relevant indicators. A series of influential international research reports, such as the *Global Competitiveness Report of the World Economic Forum*, the *Digital Economy and Social Index of*

the European Commission, the *Organisation for Economic Co-operation and Development's Education Overview,* as well as the Teaching and Learning International Survey (TALIS), the International Computer and Information Literacy Study (ICILS) Index of Readiness for Digital Lifelong Learning (IRDLL), *Worldwide Education for the Future Index (WEFFI)* and other research projects with high international appeal have developed and used corresponding indicators. In addition, the United States, Canada, Australia and other developed countries in education have developed a series of evaluation index systems for education informatization, which are also worthy of reference. A large number of international research results have greatly expanded the international vision of the design of the Smart Education Development Index.

1.2.2 Principles

i. Purpose-oriented

The Smart Education Development Index aims to objectively describe the development status, evaluate the development level, diagnose practical problems, find solutions, identify future trends, offer developmental guidance, and provide strong support for the quality development of smart education.

ii. Scientific

The Smart Education Development Index must scientifically reflect the broadest conceptual consensus of the global smart education development, fully reflect the common requirements of the world's smart education development, and objectively reflect the concerns of various important plans and specific policies and measures of China's current education development, so as to provide an evaluation standard framework for comprehensively leading the healthy and orderly development of smart education. All evaluated dimensions and indicators strictly follow and strive to accurately reflect the connotations and characteristics of smart education.

iii. Systemic

Smart education is a complex system that includes educators, students, educational resources, school conditions, educational environments, educational policies and many other elements. The Indicator System of Smart Education Development should fully reflect the internal mechanism of smart education basing on the elements, consider the interdependence and interaction among the elements, and identify the relationship and level among the indicators appropriately, to reflect the development level of smart education comprehensively.

iv. Feasible

The Smart Education Development Index is an important tool for evaluating and analyzing the development status of smart education quantitatively, comparatively,

and objectively. The constructing of indicator system should be based on measurable and accessible data. All indicators should be determined by reliable, credible and available data.

v. Trend-setting

The Smart Education Development Index not only reflects the status of smart education, but also guides the future development. The design of indicator system should consider both making judgement of the actual level of smart education development, and developing leading indicators of smart education according to the development tendency of the field to promote the quality development of smart education.

1.2.3 Indicators

The Smart Education Development Index is calculated on the basis of Indicator System of Smart Education Development. The evaluation index system of smart education development is a bridge connecting the theory and practice of smart education, a yardstick to measure the development level of smart education, and an important tool to guide and lead the development of smart education.

The Indicator System of Smart Education Development takes the core index model as the design framework. Based on fully reflecting the connotations and characteristics of intelligent education, it consists of four primary dimensions: environment, teaching and learning, governance, and talent literacy, and 12 sub-dimensions, including facilities, equipment, and digital education resources, with a total of 32 indicators (see Table 1.1). For the specific data source of each indicator, see "Appendix A: Explanations for the Indicator System of Smart Education Development".

The Chinese Smart Education Development Index is calculated based on the composite indicator system, and the sector-specific smart education development indexes are based on the calculation of three sub-sector development indicator systems. As the indicators of each indicator system have certain differences, they are independent and not comparable with each other.

1.2.4 Data and Calculation

i. Data source

The measured data of China Smart Education Development Index is mainly from the departments of Ministry of Education, such as the Department of Development Planning, the Department of Science, Technology and Informatization, the Department of Basic Education, the Department of Vocational and Adult Education, the Department of Higher Education, the Department of Teacher Education. Data also comes

Table 1.1 Indicator System of Smart Education Development

Dimension	Sub-dimension	Indicator
Environment	ICT infrastructure	Percentage of educational institutions with a broadband connection, including both fixed and mobile (%)
		Percentage of educational institutions with WLANs network coverage (%)
		Percentage of classrooms with multimedia device(s) (%)
		Number of digital devices per teacher (device/person)
	Digital education resources	Average amount of digital educational resources by person (piece/person)
		Number of digital curricular resources per 100 students (class hours/100 people)
		Coverage rate of digital educational resources (%)
	Cyber learning space	Percentage of teachers with cyber learning space (%)
		Percentage of students with cyber learning space (%)
Teaching and learning	Digital literacy of teachers	Proportion of teachers with sufficient digital literacy (%)
	Utilization of resources	Effective utilization rate of digital educational resources (%)
		Effective utilization rate of curricular resources on the Smart Education of China platform (%)
		User activity indices of the Smart Education of China platform (time/person)
		Hit rate of resources recommended to users by the Smart Education of China platform (%)
	Transformation in teaching and learning practices	Coverage rate of hybrid education (%)
		Coverage rate of online teacher training (%)
		Coverage rate of online personalized learning (%)
		Percentage of users learning with online videos (%)
	Transformation in assessments	Coverage rate of ICT-based formative assessments (%)
		Coverage rate of AI-based assessments (%)
Governance	Data accessibility	Percentage of students, teachers and institutions in which the identity data was collected in (national) core database(s) (%)
		Percentage of region-level educational management system in which data is available to national Education Data Exchange Network (%)
	ICT-based management	Coverage rate of one-stop online educational affairs and services (%)
		Coverage rate of ICT engaged educational supervision (%)
		Percentage of educational institutions with ICT-related policy (%)

(continued)

Table 1.1 (continued)

Dimension	Sub-dimension	Indicator
		Percentage of educational institutions with data driven decision-making process (%)
	Cyber and data security	Percentage of schools with cybersecurity policy (%)
Talent literacy	Digital literacy of students	Proportion of students with sufficient digital literacy (%)
		Percentage of graduates from ICT-related majors (%)
		Indices of students' lifelong learning ability
	Laborer digital skills	Indices of average digital skills of population between ages 16 and 74
		Indices of digital skills among active population

from the Center for Scientific Research and Development in Higher Education Institutes, Ministry of Education, National Center for Educational Technology (National Resource Center for Basic Education, Ministry of Education), Higher Education Evaluation Center, Higher Education Press, Educational Informatization Strategy Research Base (Central China), Ministry of Education and other relevant departments, bureaus and units, as well as some data in Digital Economy and Social Index, 2019 Global Competitiveness Report, 2022 Global Digital Overview Report.

ii. Indicator normalization

To facilitate a more scientific comparison of different indicators and avoid the impact of different units and ranges among different indicators, before calculating the China Smart Education Development Index, the data of the indicators are normalized using the extremum method. The formula is:

$$Y = \frac{X - X_{\min}}{X_{\max} - X_{\min}}$$

In this formula, Y represents the normalized value of indicators. X is the original value of the indicator, $X_{\min}$ represents the minimum value of the indicator, $X_{\max}$ represents the maximum value of the indicator. The maximum and minimum values are determined by theoretical values, as well as the descriptive statistics of collected data. As a result, the normalized values of all indicators locate in the interval [0, 1].

iii. Weights

When aggregating the normalized values of indicators to produce the indexes, it is necessary to consider the weights of all indicators and dimensions. For setting the weight of all indicators and dimensions, referring to the calculation scheme of relevant international indexes, we use equal weight.

iv. Aggregating the normalized values

The formulas of China Smart Education Development Index (*SEDI*) and dimensional indexes (DDI_i) are:

$$SEDI = \sum_{i=1}^{4} w \cdot DDI_i$$

$$DDI_i = \sum_{j=1}^{n_i} \frac{1}{n_i} \cdot Z_{ij}$$

Where, w is the weight of the dimensions, and $w = \frac{1}{4}$. The number of sub-dimensions within dimension i in the Indicator System of China Smart Education Development is n_i. The value of sub-dimension j in dimension i is Z_{ij}.

The indexes of sub-dimensions are calculated by referencing the same formula as dimensional indexes.

v. Missing data

In the data collection and calculation process of China Smart Education Development Index, the missing data is processed according to different situations. For indicators that data cannot be collected but have alternative indicator with available data, the alternative indicator data is used in the calculation. For indicators that both its data and alternative indicator data are not available temporarily, the indicators are not used in calculation. The indicators of which data cannot be normalized due to no theoretical optimal value are not included in the index calculation. For indicators with available but insufficient data, existing data is used to calculate the index.

Chapter 2
Transformation and Practices of Smart Education in China

Since the twenty-first century, China has been keeping its finger on the pulse of the times and its national realities, attaching great importance to the role of information technology in education reform, and working to promote education modernization by developing infrastructure, upgrading technology, integrating technology into classrooms, and deepening educational awareness. Through the digital transformation of education, China has been practicing smart education with an innovative approach.

2.1 The Evolution from Education Informatization to Smart Education

In the recent two decades, China has gone through two stages known as Education Informatization 1.0 and Education Informatization 2.0, laying a solid foundation for smart education development. Marked by China's Strategic Action Plan for Education Digitalization in January 2022, the development of smart education in China opened a new chapter.

2.1.1 Education Informatization 1.0

China began its education informatization by using audio-visual aids in the late 1970s and this process accelerated from the beginning of twenty-first century to 2017, during which IT played a greater role in education and improved education philosophies and methods.

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China implemented a series of major policies and projects on education system to realize the integration of IT and education. To facilitate education informatization, China has also issued a slew of policy papers including the *Notice of* the *Ministry of Education on Providing Internet Access to All Primary and Secondary Schools,* the *Outline of China's National Plan for Medium and Long-term Education Reform and Development* (2010–2020), the *Ten-Year Development Plan of Education Informatization* (2011–2020), the *Guiding Opinions on Actively Promoting the "Internet Plus" Action Plan,* and the *Thirteenth Five-Year Plan of Education Informatization.*

In terms of infrastructure, China implemented initiatives such as "Full Internet Access in Schools",[1] "Modern Distance Education in Rural Primary and Secondary Schools", "Three Accesses and Two Platforms",[2] "Full Coverage of Digital Education Resources at All Teaching Venues", and "Digital Campus Construction". Educational institutions have accelerated to build broadband connection including both fixed and mobile and are gradually equipped with digital devices. The basic environment for informatization has been continuously improved.

In terms of applications in teaching, China launched campaigns, such as "One Course for Every Teacher, and One Teacher for Every Course" initiative,[3] teacher's IT proficiency enhancement program, the national high-quality course sharing program, the national high-quality public video course program, and the specialized teaching resource development program for higher vocational education. Such action plans substantially improved teachers' IT proficiency and the application of IT in education has gradually become popular.

2.1.2 Education Informatization 2.0

From 2018 to 2021, IT was innovatively integrated into education, paving the way for exploring smart education in China.

Following policy papers such as the *Education Informatization 2.0 Action Plan, China's Education Modernization 2035,* the *Guiding Opinions on Promoting the*

[1] "Full Internet Access in Schools" initiative: in November 2000, the Ministry of Education issued the *Notice of the Ministry of Education on Providing Internet Access to All Primary and Secondary* Schools, which proposed that in 5–10 years, about 90% of independent founded primary and secondary schools in China should have access to the internet to make sure that teachers and students in primary and secondary schools can share online education resources, improve the quality of education in all primary and secondary schools, and enable all teachers to receive continuing education aimed at improving their ability to implement quality education.

[2] "Three Accesses and Two Platforms" initiative: three "accesses" refer to broadband access to schools, quality resources access to every class, and online learning space access to everyone. "Two platforms" refer to public service platforms for education resources and education management platform.

[3] "One Course for Every Teacher, and One Teacher for Every Course" initiative: it aims to ensure that every primary and secondary school teacher could teach at least one course with IT tools and every course could be given by at least one teacher with IT tools.

Construction of New Education Infrastructure and Building a High-Quality Education Support System, and the *Action Plan of Artificial Intelligence Innovation for Institutions of Higher Education,* China has set several initiatives in motion to popularize digital resources and services, build digital campuses, expand the reach of online learning spaces, boost the capacity for education governance, and initiate the construction of smart education demonstration zones, which led to a basic digital ecosystem for Chinese education.

In terms of environments construction, the digital campus construction campaign is implemented in all schools. With the service mode of "platform plus education" introduced, public service platforms and support systems of various education resources at all levels are integrated to gradually connect the resource and management platforms. All provincial platforms are connected to the Smart Education of China platform, as a result, a big "internet plus education" platform is created.

In terms of application in teaching, China has made steady progress in the "Three Availabilities, Two Improvements, and One Big Platform" campaign[4] assuring that teaching applications are available to all teachers and learning applications are available to all school-age students, and that IT proficiency and information literacy of teachers and students are generally improved. China has systematically ramped up MOOC[5] and "MOOC in Western China" program, popularized the "Three Classrooms"[6] mode, and prioritized the "three regions and three prefectures"[7] when implementing the initiative of internet development as an intellectual booster. "Cloud classrooms" have been made available to fill the education gap in poor areas and improve their education quality. For example, Ningxia took the lead in building an "internet plus education" platform by creating the "cloud", connecting to the "network", and popularizing the "screen".[8] More than 500 schools in Ningxia have been virtually paired with prominent schools in Beijing, Fujian, etc., effectively addressing the inadequacy of teachers and teaching resources in low-performing schools and promoting high-quality development of education.

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[4] "Three Availabilities, Two Improvements, and One Big Platform" campaign: teaching applications are available to all teachers, learning applications are available to all school-age students, digital campuses are available in all schools, the IT proficiency and information literacy of teachers and students are improved, and the "internet + education" platform is built.

[5] MOOC: Massive Open Online Courses.

[6] "Three Classrooms": classrooms with featured topics, taught by famous teachers, and offered by renowned schools online.

[7] "Three regions and three prefectures": poverty-stricken areas at the national level. The "three regions" refer to Tibet Autonomous Region, Tibetan areas in Qinghai, Sichuan, Gansu, and Yunnan provinces, Hotan, Aksu, Kashgar, and Kizilsu Kirgiz Autonomous Prefecture in southern Xinjiang. "Three prefectures" refers to Liangshan Prefecture in Sichuan, Nujiang Prefecture in Yunnan, and Linxia Prefecture in Gansu.

[8] "Cloud" refers to the construction of a cloud platform for education at all levels and of all forms; "Network" refers to an education network that increases the school network and the bandwidth and constructs an efficient and connected education network; "Screen" refers to the program of ensuring full coverage of quality resources in every class and providing digital blackboards for all primary and secondary schools in those regions, especially rural schools.

2.1.3 China's Strategic Action Plan for Education Digitalization

In 2022, China launched the Strategic Action Plan for Education Digitalization, built the public service platform called Smart Education of China platform, and leveraged resources and data to explore a new approach to providing teachers and students with convenient and efficient services in learning, teaching, management, research, and governance, opening up a new chapter of smart education development in China.

i. Rationale

Guided by the "3C" strategy of Connection, Content, and Cooperation, China's Strategic Action Plan for Education Digitalization aims to build the Smart Education of China platform in scientific methods, comprehensively improve the supply capacity of high-quality resources and services, strengthen the technical support of Smart Education of China platform, actively promote international exchanges and cooperation in digital education, transform the untapped potential of digital resources into the powerful energy of education reform, and explore new ideas, theories, paths and practices of smart education to realize fairer and higher-quality education.

China's Strategic Action Plan for Education Digitalization follows three principles. First, it is nationally planned to serve the public. Adhering to national guidance, the Action Plan is coordinated by multiple parties and planned, standardized, managed, and evaluated with uniform criteria. It adopts an open, public welfare-oriented, and inclusive mode to digitalize education resources and governance. Second, it is demand- and application-driven. Platform integration and upgrading, resource development and utilization, etc. should be driven by the demand for digital applications to serve teachers, students, schools, and society to tap the supportive role of digital education in the high-quality development of education. Third, it integrates systems for scaled-up practice. The Action Plan strengthens the integration of functions, data, business and the development of common key content. It focuses on scaling up resource construction and application and harnesses data to popularize the student-specific teaching approach and smart education governance to make digital transformation more thorough and extensive.

China's Strategic Action Plan for Education Digitalization highlights the critical role of Smart Education of China platform. Focusing on the construction of Smart Education of China platform, it gathers all kinds of digital education resources at all levels, provides learning and job-seeking services for learners and course preparation and education research services for teachers, helps schools in school management, cooperation, and exchanges, and assists the government in governance and decision-making. Smart Education of China platform plays the role of organizing the creation and distribution of education resources underpinned by the advantages in data consolidation and analysis, which has emerged as a key infrastructure for the digital transformation of education.

China's Strategic Action Plan for Education Digitalization aims at creating a new era for education. Through digital transformation in education, China aims

to change the conventional teaching practices, promote the balanced development of high-quality education, realize China's millennial dream of "education without distinction", serve the reform of "Double Deduction"[9] and "eliminating five obsessions",[10] and strive to run a satisfactory education system for the people. By digitalizing education on a super-large scale, China implements innovative education philosophies, methods and modes to lead the paradigm shift of global education. Aided by digital technology, China accelerates the overall improvement of education quality, addresses weaknesses and imbalances in education development, supports the construction of an "always-on" learning society and country, and opens up a new era of education.

ii. Construction of Smart Education of China platform

Smart Education of China platform represents a milestone throughout the implementation of China's Strategic Action Plan for Education Digitalization and lays the cornerstones for bringing smart education to a higher level. Following the principles of "prioritizing application, putting service first, keeping simple and efficient, and achieving safe operation", the platform will be built on three phases: pilot and demonstration projects as the first phase, platform support and application integration as the second phase, and comprehensive coverage and overall demonstration as the third phase. During implementation, the existing infrastructure should be sufficiently used to strengthen integration and the development of common key content while making optimizations. Platform construction and application should satisfy the growing aspirations of learners in China for better education, and provide multilingual, international, and high-quality education resources for learners from across the world.

It creates a complete system through platform construction. Smart Education of China platform adopts a "five-tier" structure[11] covering the national, provincial, municipal, county, and school levels. The platform integrates three resource platforms including Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE), Smart Education of China, Platform for Vocational Education (SEC-PVE) and Smart Education of China, Platform for Higher Education (SEC-PHE), along with a service center for job-seeking, examination, academic degrees, and overseas study services (see Fig. 2.1). It also incorporates digital resources for moral,

[9] "Double Deduction": it refers to the reduction of the burden of excessive homework and off-campus tutoring for students undergoing compulsory education.

[10] "Eliminating five obsessions": it refers to the elimination of obsessions in education evaluation with grades, college entrance, diplomas, papers, and titles.

[11] "Five-tier" structure refers to Smart Education of China platform on national, provincial, municipal, county, and school levels.

Fig. 2.1 Homepage of smart education of China platform. *Source* https://www.smartedu.cn/

intellectual, physical, aesthetic, and labor education, and creates a pattern with three horizontal and three vertical dimensions[12] based on the "3 + 1" model.[13]

It gathers high-quality resources. By the end of December 2022, SEC-PPSE has provided 44,000 items of education resources; SEC-PVE offered 32,000 online courses, 1,317 teaching resource libraries, 6,844 high-quality online courses, 2,217

[12] "Three horizontal and three vertical dimensions": three horizontal dimensions include basic, vocational, and higher education, and three vertical dimensions include moral education, intellectual education and physical, aesthetic, and labor education, so that education is available to all grades and all people throughout all phases.

[13] "3 + 1" model: "3" refers to "Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE)", "Smart Education of China, Platform for Vocational Education (SEC-PVE) "and "Smart Education of China, Platform for Higher Education (SEC-PHE)", and "1" refers to the service center that integrates employment, examination, academic degrees, and overseas study services.

public course videos; SEC-PHE collected 27,000 high-quality MOOCs, and over 65,000 textbooks, course materials and case studies. Smart Education of China platform attracted over 912 million visitors contributing to approximately 5.49 billion platform views.

iii. The Smart Education of China Platform Applications

With a mission to serve the actual needs of learners, Smart Education of China platform provides high-quality and personalized education service for different groups of learners.

It serves students' development. The platform gathers a considerable amount of high-quality education resources for students of all grades and allows for redevelopment. For example, Qinghai, Henan, and other provinces integrate the high-quality resources on Smart Education of China platform into the daily curriculum of all primary and secondary schools. SEC-PVE amasses 19,000 virtual simulation training materials and serves more than 5,000 vocational schools to carry out field training, skill assessment, contests, and examinations; SEC-PHE not just gathers plentiful courses, but offers service throughout the whole process of teaching and learning, such as MOOC homework, online discussion, Q&A sessions and online examination; as of September 2022, the National Service Platform for College Student Employment–24,365 Campus Recruitment Service Platform attracted 5.47 million registered graduates, shared 13.25 million jobs, and pushed 21.92 million job information messages to graduates.

It serves teachers' development. A "Teachers' Training" sector has been made available for teachers of all grades to help teachers in teaching, pedagogical research, course preparation and professional development. In July 2022, the platform launched the "Summer Vacation Training for Teachers" program, which provides resources on teacher ethics, mental health education and home-school co-education. It offers 2,300 high-quality resource items and provides customized training to kindergarten, primary, lower secondary, junior high school and university teachers. This program had a total of 1.3 billion visits by more than 13 million teachers during its 42-day training period.

It serves school management. The platform allows external system access to help schools carry out digital management and reform school governance. For example, utilizing this platform, Qingdao Lanting Primary School mobilized all campuses to develop courses taught by different teachers and encourage collaborative teaching and learning, which created a new education and teaching mode where every child can access high-quality teaching resources simultaneously. Hunan Automotive Engineering Vocational College used SEC-PVE in simulation instruction, collected and analyzed data throughout the lessons without disturbing teachers and students, and made a timely adjustment to the college's internal control, quality management, teaching evaluation, and teacher and student service, effectively advanced precision of school management. Zhejiang University built "Online Zhejiang University 2.0" to explore a path of smart governance and established a whole-process teaching management system incorporating digital and smart technologies, an open, integrated

scientific research management system, and a unified modern school governance system to shore up school operation and governance.

It serves comprehensive research. The platform dynamically monitors resource development and application data to serve the research on platform construction and talent cultivation. For example, Beijing utilized the employment data of the National Service Platform for College Student Employment to identify the underlying pattern of talent development, school operation, and social demand changes, and give feedback in school enrollment, talent training and management to build an employment system with tailor-made services. Minhang District of Shanghai made explorative attempts in "smart homework", so that teachers could adjust teaching strategies and carry out personalized teaching and counseling according to the feedback, and monitor teaching quality through indicators such as homework validity, information content, differentiation, and capability.

It serves governance. Education administrative authorities at all levels use the platform to grasp in the latest trends in education development and make decisions scientifically. For example, Shaanxi, Anhui, and other provinces connect themselves thoroughly to the national platform to monitor the real-time development of education in the whole provinces. Chengdu is connected to the national platform to build a "smart brain of education", which realizes the integration, sharing and processing of regional education big data and serves education development monitoring, academic degree prediction, equipment management, and supervisory model innovation.

2.2 Experience and Implications

In retrospect of China's progress in education informatization, governments, education administrative authorities, schools, and teachers have made innovative attempts, enriched and developed theories, facilitated education digitalization, and created enabling conditions for smart education development.

2.2.1 Keep the Focus on China and Tap the Institutional Advantages

China incorporates education informatization, education digitalization, and smart education into the national strategy, makes overarching plans to promote smart education, and transforms the institutional advantages of socialism with Chinese characteristics into inexhaustible momentum for education development. China concentrates its efforts on making great changes, strengthens top-level design and overall deployment, and promotes education modernization via informatized tools to realize high-quality education development. It adopts a systemic approach by establishing a mechanism in which government at all levels are linked and each school works closely

together and gathers all forces to build the world's biggest digital center and service platform for education resources. China also integrates institutional advantages and advanced digital technologies, explores the philosophies, methods, and modes of smart education with Chinese characteristics, and forms a development pattern of "strong government coordination, active exploration of schools, and extensive social collaboration".

2.2.2 Benefit all People and Serve Education Equity

China regards education informatization as an important tool for education equity and constantly expands the coverage of quality education resources. It builds internet infrastructure covering all schools, grades, and subjects, and realizes "single-point access to be shared in the whole system". It builds "three classrooms" and MOOC, etc., to tap the leadership role of famous schools and teachers in order that low-performing schools can have adequate access to learning national curriculum. In this way, all students can share quality education, achieving a historic leap from receiving "education" to receiving "quality education". Smart Education of China platform benefits all people and enables more people to achieve lifelong learning and sustainable development.

2.2.3 Prioritize Application to Improve Education Quality

China attaches great attention to the integration of IT into education and teaching, which promotes education reform and innovation, and supports the construction of a high-quality education system. China sufficiently taps the multiplication and spillover effect of digital resources, adopts an application-driven approach in development of teaching content, serves the needs of teachers and students, and popularizes informatized teaching. China works to improve teachers' IT proficiency and leverages cyberspace to carry out multi-form and multi-channel teacher training so that teachers' professional expertise can keep abreast with the requirements of the digital age. Moreover, China promotes innovations across all application scenarios, explores new teaching and learning modes, and seeks to integrate large-scale education and personalized cultivation.

2.2.4 Popularize Pilot Projects and Ensure Scientific Development

Guided by the general principle of "following the lead of pilot projects, bringing mature service online first, implementing step by step, and making continuous improvement", China accumulates experience through pilot projects, which serves as the guide for subsequent work to push forward education informatization in a scientific, orderly manner. China carries out pilot projects such as "internet plus education" and smart education initiatives, explores a new path of empowering education with science and technology, and lays a solid foundation for science-based development of smart education. China also makes continuous improvements in the course of construction and application, sets up demonstration cases, and works to popularize its experience gained from the pilot projects.

2.2.5 Promote Openness and Cooperation, and Aim for Shared Prosperity

China considers shared development, shared benefits, and win–win outcomes the means and ends of opening up on a higher level, promotes high-quality international cooperation in education, and strives for the sharing of high-quality education resources globally. China carries out close exchanges with other countries by drawing comparisons and learning from their best practices, deepens cooperation through communication, scales up the scope of education informatization and digitalization, and makes joint efforts to promote education reform and progress. Collaborating with UNESCO, China has held important international conferences, such as the International Conference on Education Informatization, and the International Conference on Artificial Intelligence and Education, and delivered landmark documents such as the *Qingdao Declaration* and the *Beijing Consensus*, which builds a global platform for the informatized, digital, and smart development of education. China also strengthens connectivity, focuses on building an international platform for online education, gathers, integrates, and shares resources to promote the establishment of credit and degree recognition standards, and shares diverse learning fruits.

Chapter 3
Achievements and Challenges of Smart Education Development in China

3.1 Achievements of China Smart Education Development

To promote the sustainable development of smart education, the first step is to analyze the status and identify the strengths, weakness, and future directions of smart education. Based on the China Smart Education Development Index calculated by China National Academy of Educational Sciences (CNAES) in 2022, this chapter analyzes the overall development of smart education in four dimensions, as well as in the subsectors, that is, basic education, vocational education, and higher education, and then presents the challenges.

In 2022, the Smart Education Development Index in China is 0.74. For the four dimensions, index of governance is 0.84, reported the highest level among the four dimensions. The teaching and learning index is 0.68, reported the lowest level among the dimensions. The indexes of environment and talent literacy are 0.73 and 0.72 respectively, standing in the middle range (See Fig. 3.1).

3.1.1 Taking Shape in a Digital Education Environment

The environment index for smart education in China is 0.73. China has created an environment that can support the implementation of smart education effectively. In terms of ICT infrastructure, institutions of all forms of education at all levels basically have broadband connection to the internet. Nearly three in four schools report coverage of WLANs network. The percentage of classrooms with multimedia device(s) is above 71%, and almost every teacher is equipped with a digital device. The results indicated the equipment of ICT infrastructures have been put in place to

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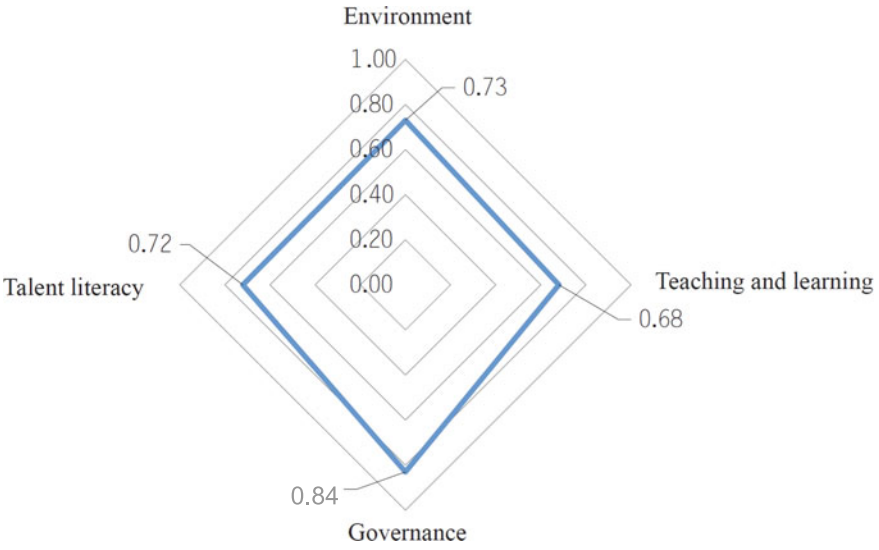

Fig. 3.1 China smart education development index on the four dimensions in 2022

support the development of smart education. In terms of cyber learning space, nearly two in three teachers and more than half of students have registered to their own cyber learning space.

By the end of 2021, 99.5% of primary and secondary schools reported having multimedia classrooms. The total number of multimedia classrooms reached more than 4 million. Among which, 87.2% of schools have achieved full coverage of multimedia teaching devices. More than 70% of vocational institutions and schools covered with wireless network, more than 60% of classrooms are equipped with multimedia devices. The infrastructure and facilities supporting smart education have gradually been adopted, creating a smart, personalized, open, and interactive learning environment for learners. All Chinese universities have internet access and nearly 80% of them have full wireless network coverage. Multimedia classrooms with internet access account for more than 60% of the total number of classrooms in Chinese universities, and nearly 90% of classrooms are equipped with next-generation IT in the construction of smart campuses.

Digital education resources are constantly enriched. As of December 2022, the total number of digital resources on the platform reached 44,000, including 25,900 course resources. The daily visits of platform reaches 64.32 million. It offers all kinds of resources including but not limiting with moral, intellectual, physical, aesthetic, and labor education. In March 2022, the Smart Education of China, Platform for Vocational Education (SEC-PVE) launched online. By the end of December 2022, the platform provided 32,000 online courses and 1317 resource libraries covering nearly 600 majors of vocational education. There are plentiful digital resources for higher education, including 318,700 digital courses shared by universities in the

form of MOOCs, resource sharing courses, and public course videos. By the end of December 2022, there are over 64,500 MOOCs accessed 1,088 million person-times. The platform is also connected to xuetangX and iCourse, both being international online teaching platforms. The Smart Education of China, Platform for Higher Education (SEC-PHE) has reached out to 166 countries and regions. 4.28% of MOOCs developed by Chinese universities are made available on overseas platforms. The percentage of higher education institutions with online learning space has reached 85%.

3.1.2 Applying Digital Teaching and Learning Innovatively

The teaching and learning index is 0.68. Progress has been made in integrating digital technology into education continually, and more contextual innovative applications are developed. In terms of the digital literacy of teachers, more than 86% of primary and secondary school teachers have qualified digital literacy, laying a good foundation for implementing and developing smart education. In terms of the utilization of resources, the effective utilization rates of curricular resources on the SEC-PPSE, SEC-PVE and SEC-PHE have reached 40%, 64% and 77%, denoting a trend of large-scale application of digital education resources. In terms of the transformation in teaching and learning practice, the coverage rates of hybrid teaching in basic education, vocational education and higher education increased to 83%, 54% and 100%, and more than 40% of users have report learning with online videos. The hybrid form of learning has gradually become the new norm for people to enhance their skills.

In the subsector of basic education, continuous progress is made in empowering education reforms with digital technology. Primary and secondary schools teaching with resources from SEC-PPSE extensively, and form of a new norm of digital teaching in which digital resources are "used in class, used frequently, and used extensively". Innovative teaching modes such as ICT-based personalized learning and adaptive learning effectively powered the education reform and high-quality development of basic education.

In the subsector of vocational education, innovative tryouts have been made in smart and personalized teaching. As the next-generation technologies are increasingly integrated into educational contexts, Chinese vocational education has transformed its teaching and learning practices, and more innovative practice modes with smart education characteristics are fostered. Digital technologies such as Internet of Things, cloud computing, big data, 5G technology, are being applied to personalized teaching, learning and assessments in vocational education preliminarily. The digital transformation of internships and practicums effectively support the training of tech-savvy, high-caliber talents. At the end of September 2022, the SEC-PVE provided more than 200 virtual simulations courses, serving teaching based on simulation in multiple contexts including both in and out of classroom. With the SEC-PVE, nearly 80% of the course resources assess students with ICT-based assessments.

In the subsector of higher education, new technologies promote continuous innovation and transformation in teaching and learning. Teaching and learning are available in more diverse and personalized forms, and technology-enabled teaching evaluation began to exhibit more process-oriented and systematic features. MOOCs and SPOCs flourished, making online teaching become a "new normal". The "MOOC in Western China" program provides 183,900 MOOCs and customized services to all the western universities, and helped the western area to carry out hybrid teaching and learning activities 3.78 million times. More than 60% of Chinese universities use their big data centers to support classroom teaching, about one third of the universities incorporate artificial intelligence in their classrooms, more than half of the universities adopt artificial intelligence and big data in the student learning analysis, student development prediction, and classroom analysis, and about 72% of the universities can carry out credit recognition for online courses. China has initiated the Global MOOC and Online Education Alliance, hosted more than 50 global online education seminars, launched global open classes, and achieved mutual recognition of credits with 13 renowned universities from 11 countries.

3.1.3 Creating a Digital Governance Framework

The governance index is 0.84. A systemic architecture for data management, application, and protection for digital education governance has been established. In terms of data accessibility, the percentage of students, teachers, and institutions in which the identity data was collected in (national) core database(s) has reached 100%, realizing the collection and management of basic information for every student, teacher, and educational institution nationwide. In terms of ICT-based management, most educational institutions are well prepared for the practical application for digital management. More than 82% of educational institutions report establishing ICT-related policies. The percentage of institutions integrating general functions into a single card in basic, vocational and higher education increased to 14, 67 and 90%. In terms of cyber and data security, nearly 85% of educational institutions have at least one cybersecurity policy in place, establishing an institutional "fence" for secure digital management.

In the subsector of basic education, the National Management Service Platform for Primary and Secondary Schools was officially commissioned in June 2022, which could address the demands of education administrative departments, schools, teachers, parents, and students. As of December 2022, the platform was connected to all provincial, municipal, and district and county-level education administrative departments, along with 220,000 primary and secondary schools. The percentage of region-level learning management systems join in national Education Data Exchange Network reached 100%. According to a survey in 2021, 82.78% of primary and secondary schools applied data driven decision-making process.

In the subsector of vocational education, China has built a nationwide information management system, and has made significant progress in applying management

systems and building digital campuses. The vocational education in China is realizing the transition from "personnel-based management and electronic control" to intelligent approaches.

In the subsector of higher education, the data base has been established and increasingly completed. Over 70% of universities have created university-level data centers. The information systems of 99% of universities realize integrated data management and phase out the information silos. The basic data of 1,238 universities and 32 vocational schools have been incorporated into the National Data Platform of Higher Education Quality Monitoring. Close to 60% of universities provide one-stop school management services, and more than 80% of them offer digital scientific research services.

3.1.4 Exerting Influence on Talent Cultivation

The talent literacy index is 0.72. The digital literacy of students is improved dramatically, and laborer digital skills is gradually raised to meet societal requirements. In terms of the digital literacy of students, most primary and secondary school students has reached the qualified level or above, and the structure of talent training in ICT-related disciplines is constantly optimized, providing intellectual support for the development of China's digital economy. In terms of laborer digital skills, the normalized value of this index, based on laborers self-report, is 0.47, while the index assessed by employers is 0.62, indicating that workers are equipped with basic digital skills.

China attaches great importance to improving the capacity of applying digital technologies in teaching for primary and secondary school teachers. The Ministry of Education formulated the *Action Plan of Education Informatization 2.0*, the *Information and Technology Curriculum Standards for General High Schools (2017 Edition Amended in 2020)* and *Information and Technology Curriculum Standards for Compulsory Education (2022 Edition)* to improve students' digital literacy. The curriculum aiming at enhancing digital literacy is gradually improved, as well as the supporting resources. The survey in 2021 showed that 78.79% of primary and secondary school students had qualified digital literacy.

China has continued to strengthen talent cultivation in ICT-related majors, providing strong intellectual support for industrial progression and technological transformation. In 2021, the Ministry of Education released a new catalog of vocational majors, in which it optimized the structure of ICT-related majors. According to the catalog for 2021, students in ICT-related majors counts for about 34% of the total number of vocational students, and more than 70% of graduates working on ICT-related professions. These students contribute to the development of digital economy remarkably.

Given its disciplinary structure and capacity for talent training, China's higher education system has been ready to meet the development needs of the digital economy. In 2021, 40.77% of Chinese university students graduated from ICT-related

majors, a large proportion even compared globally. University teachers and students can apply new technologies to teaching and learning activities. Since the COVID-19 pandemic, Chinese universities have rolled out online teaching across the board, manifesting high information literacy of university teachers and students. Higher education in China has been adequately prepared to embrace the era of the digital economy.

3.2 Challenges to Smart Education Development in China

Smart education in China has developed rapidly, achieving remarkable results in digital environment creation, teaching implementation, education governance, and talent cultivation. Yet practical issues and challenges still abound.

3.2.1 Digital Resources Should be Enriched and Optimized

Smart Education of China platform gathers a large number of high-quality resources, providing effective support for promoting education equity and quality. However, there is still a gap between the supply of digital resources and the societal demand for high-quality education. Firstly, the content and types of resources are not rich enough. There is a lack of personalized high-quality resources for different learners, teaching supplements for specific disciplines, and application resources such as tools and software. Secondly, the use of resources is not easy and convenient enough. Practical functions such as searching contents by knowledge points, editing contents and personalizing push notifications are lacking. Thirdly, the mechanism of resource library construction needs to be improved. The rational incentive mechanism, selection mechanism and withdrawal mechanism of resource supply have not been formed.

3.2.2 Integration and Innovation of Education and Teaching Should be Deepened

The integration of new technologies and education has yet to be deepened. Firstly, high-quality digital education resources are not sufficiently utilized. The user activity on Smart Education of China platform should be further motivated. Secondly, the interactive functions of the platform are inadequate. The existing static resources only play a supportive role in many important teaching activities and have their limits in boosting teaching and learning innovations. Thirdly, teachers' digital literacy is still need to be improved. New technologies can provide greater support for cultivating

students' higher-order thinking. However, many teachers are unable to tap the full potential of technology to serve their classes, because they are still in the stage of mastering basic digital skills, and the relatively lower level of innovative application.

3.2.3 Education Governance Should be More Intelligent

After years of committed efforts, China's data infrastructures have been mostly completed, yet there are still many obstacles in the development of intelligent education governance. First, the data-sharing mechanism is yet to be improved. The existing education governance system has not yet tackled the problems such as the "digital silos" and insufficient use of data elements and information. Second, the information systems, infrastructure, and technical architecture are poorly planned. The new and old technologies and systems are not seamlessly connected, and the regional and urban–rural digital divide still exists, which should be addressed by better planning, coordination, and optimized infrastructure layout. Third, online learning, examination, learning certification, and other systems are incomplete, raising an urgent demand for a new quality assurance mechanism.

3.2.4 Digital Literacy of Talents Should be Strengthened

In recent years, the rapid evolvement of digital industrialization and industrial digitization has posed new challenges to the labor force. First, the digital literacy cultivating system should be improved. Second, digital talents are in short supply in the market. There is also a shortage of digital skill training for front-line workers. Third, the training of digital talents should be better planned and coordinated and the training system for all people should be ramped up.

Chapter 4
Outlooks on Smart Education in China

Making smart education sustainable is a task of our time with a lasting impact on our nation as a whole. Therefore, it has raised increasing concerns and discussions among education professions and beyond, and given rise to diverse research in this area. Going forward, it is important to note that the challenges smart education in China faces are both global and unique. In this light, this chapter presents the following issues in the development of smart education based on extensive stakeholder consultation. These problems require our attention and need to be addressed.

4.1 Key Issues Associated with the Development of Smart Education

Improved ICT infrastructure, along with the creation and expansion of cyber space, has created fertile ground for smart education. Future efforts should focus on exploring the following practices and theories.

4.1.1 Improving Smart Learning Environment to Effectively Support Learning

Smart learning environments must be open, interactive, and customized. To improve it, we should pay attention to the following aspects.

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First, integrating new technologies seamlessly into teaching to meet the needs of learners. The use of technologies, facilities, and devices should not be the sole focus in our efforts to create a smart learning environment. Improving teaching methods and practices is also important. We should follow an application-driven approach while prioritizing teaching and learning needs.

Second, creating and sharing high-quality digital resources. Priority should be given to common key content creation, resource optimization and integration, standard development, and content protection. It is also crucial to launch a supply-side reform of digital education resources, bolster industry-university-research collaborative innovation, engage more people in the process of digital resources development, and make quality education resources more accessible.

Third, transforming the learning environment. Smart classrooms, adaptive learning, intelligent learning status analysis, and intelligent class evaluation will be key subjects of AI-powered education. With digital technologies, it is possible to facilitate the combination of online and offline learning, implement a diversity of learning scenarios, and ensure a smooth transition from school to work.

4.1.2 Reconstructing Teaching and Learning to Shift Education Paradigm

By reconstructing teaching and learning, smart education will iterate education models to better meet the diverse needs of learners. This involves:

First, human–machine collaborative education, which liberates teachers from repetitive work, diversifies the delivery of teaching while encouraging in-depth learning, and empowers teachers to be more creative, devoted, and inspiring.

Second, adaptive learning. Big data collection and analysis technologies will be used to produce real-time learning data, and on that basis, provide instructions precisely according to students' characteristics. This ensures every learner gets a personalized, diverse, and differentiated learning experience.

Third, immersive learning. Virtual reality technologies will be leveraged to create a hybrid learning environment. Game-based, simulated and 3D scenarios can help students to conduct immersive and interactive learning, and guide them toward better learning outcomes.

4.1.3 Cultivating "Smart Teachers" for Future Talents

The integration of digital technologies in education results in a fundamental shift in teachers' roles and functions. Efforts to cultivate smart teachers should focus on reshaping their ideas, awareness, and competency.

First, updating the teaching philosophy. Teachers, faculties and staffs need to clearly understand the principles of education and students' physical and psychological development, and take new approaches in teaching. The new approaches are supposed to integrate digital technologies into the whole process of education. Teachers also need to redirect their teaching ideologies and methodologies towards smart education.

Second, strengthening the digital literacy of teachers. Teachers, faculties and staffs are expected to be familiar with the fundamental rationales of digital technologies, along with the potentials and risks of applying these technologies in education, and be capable of appropriately carrying out teaching activities powered by digital technologies in compliance with regulations.

Third, becoming more competent in guiding students' development. Teachers, faculties, and staffs need to be good at using digital technologies to help students transform knowledge to competency. Also, they are supposed to take a more human-centered approach to teaching while staying wary of the pan-technology tendency.

4.1.4 Making Education Governance More Intelligent to Improve Decision-Making and Services

Digital technologies add new substance to the structure, component, and function of education governance, shining a new path forward toward a modern education governance system.

First, intelligent education governance demands the re-engineering of processes. As new technologies are implemented, the education governance system will gradually shift away from the traditional hierarchical structure to one that is decentralized, flat, open, and holistic. In this way, the silos within the education sector will be broken down, making way for a top-to-toe optimization of the education process.

Second, intelligent education governance looks for data and algorithm-driven public services. Collecting, pooling, and sharing data across the board makes possible real-time, multi-dimensional analysis of and targeted guidance for teaching. Data, instead of experience, drives education decisions as education services go from passive to active. As a result, education governance becomes more targeted, with improvements in service provision.

Third, intelligent education governance needs to create a multi-agent collaborative model. Platform, collaboration, and sharing mindsets will guide the reengineering of the organizational system and functions of education governance. It is also vital to pool education resources and stimulate innovations in the education governance model through collaborative governance across regions, levels, and departments and transition to a new public–private partnership.

4.1.5 Transforming Education Assessments to Include the Entire Process

The adoption of artificial intelligence and big data technologies points the way for education evaluation and its implementation.

First, innovations in the content and tools of assessments. New technologies should be applied in adaptability tests, situational assessments, and simulation tests. This will make it possible to access the competencies that are unmeasurable using traditional standardized tests. At the same time, AI-based assessments and intelligent graders will ensure fair and efficient assessments are administrated.

Second, improving assessment process and methods. Collecting data throughout the process supports multi-modal analysis and comprehensive assessment. It is also vital to record students' progress over different periods, across places, and from multiple dimensions. This enables real-time, comprehensive feedback and modification, helps fine-tune teaching and learning, and better supports customized learning.

Third, adequate use of assessment results. Blockchain technologies and micro-credentials make it possible to recognize informal learning outcomes. Actions should be taken to establish a certification and transfer system for open, customized, and lifelong learning. This gives the nod to ubiquitous learning and stimulates learners' development and mobility.

4.1.6 Bridging Digital Divide to Promote Education Equality

Digital technologies contribute to equality, but for smart education to take root, digital divide must be breached. This means:

First, to close the opportunity divide. According to the UN Transforming Education Summit, more than two-thirds of the school-age population (1.3 billion) have no internet access. This means many girls and young women are stripped of opportunities to learn. It is, therefore, essential to prioritize the construction of digital education infrastructure in rural, remote, impoverished, and ethnic regions, so that disadvantaged groups can also benefit from quality education resources. However, this remains a daunting task.

Second, to narrow the skills gap. To this end, digital skills training should be incorporated into the education system as a way to improve the digital literacy of the entire population, especially students. One of the key issues pending solutions in the future will be how to realize digital equality through the development of digital skills.

Third, to bridge the digital use divide. The digital use divide refers to the difference in how various groups of people use technology, primarily reflected in duration, frequency, and the number and types of applications being used. It is important to allocate education resources equally, to provide targeted instructions on how to apply

digital technologies in teaching for teachers, faculties, staffs and students, to increase the independence and engagement of special groups, and to allow most of them to access quality education.

4.1.7 Conforming to Technology Ethics and Protecting Data Security to Ensure the Healthy Growth of Smart Education

Widely-adopted digital technologies are strong support for smart education. However, risks are also mounting in areas such as digital ethics, individual privacy, and data security, which require urgent attention.

First, data security should be guarded. To give full play to the role of data and technologies in education, the generating, recording, and sharing of data must comply with ethical principles of no harm and probable cause. Efforts should also be taken to guard against risks, including privacy infringement, unclear digital asset ownership, and data leakage and abuse.

Second, algorithms should be used properly. It is vital to define the boundary for AI applications in education, accommodate the diverse needs of teachers, faculties, staff and students, and protect user privacy in reorganizing, analyzing, and interpreting education data. There should also be measures to avoid information cocoons and algorithmic discrimination resulting from the misuse of algorithms.

Third, technology ethics should be established. Setting rules for the application of technologies will ensure that technologies are developed and applied in a reliable, controllable, and predictable way and for the greater good. The development of technologies must be guided by the right set of values. This is key to enabling reliable innovation and safe use of technologies.

Fourth, the goodness of education should be valued. The application of technologies should take a human-centered approach and focus on the right to education, education responsibilities and equality and the ethical pursuit of education values to better promote educational growth and the all-rounded development of students.

4.2 Suggestions for the Future Development of Smart Education

Implementing China's Strategic Action Plan for Education Digitalization and making education smarter are not only the demands of high-quality education, but also the cornerstone of a smart society. The following is where to start in moving toward the future of smart education.

4.2.1 Improving the Strategic Planning of Smart Education

First, there should be holistic planning for smart education. It is crucial to improve top-level design to include smart education in the broader agenda of China's transition to a digital and smart society and ensure that smart education features prominently in the endeavor to achieve quality growth of education. Attention should also be given to policy consistency and coordination.

Second, interdisciplinary studies should be conducted. Advancing smart education is a complicated and systematic task. Therefore, actions should be taken to add infrastructure, develop common technologies and improve ethics. It is also necessary to carry out frontier research in smart education across disciplines and agents.

Third, multi-agent collaboration should be promoted systematically. This requires constant improvements in the multi-agent collaborative innovation mechanism for smart education, a coordination mechanism for decision-making and inter-departmental synchronization, and a booster mechanism for smart education which is coordinated by administrative authorities, pushed forward by business departments, supported by technical divisions, and served by social organizations.

4.2.2 Facilitating Reforms in the Digital Education Model

First, integrated innovation in digital technology and teaching process should be deepened. Digital technologies can give rise to a new mode of nurturing next-generation talents. Efforts should be made to implement student-centered teaching practices, explore differentiated learning, collaborative learning, interactive learning, etc., allow teachers to teach multiple classes, students to choose courses from other schools, and different regions to coordinate teaching and learning, and create a new type of class.

Second, efforts should be made to facilitate the sharing of quality digital educational resources and strengthen the connectivity between digital education platforms. To this end, it is necessary to develop quality education resources, create new types of resources, build integrated platforms and promote resource exchanges. This will make educational resources more decentralized, dynamic, diverse, interdisciplinary, and comprehensive.

Third, a full upgrade of education evaluation should be explored. Big data analysis can help expand the dimensions of education evaluation and make such evaluation more scientific. It is vital to enable an integrated education analysis that covers all elements, processes, and dimensions, establish a mechanism and method to collect evaluation data on a regular and consistent basis and innovate evaluation feedback to better inform teaching.

Fourth, the transition to smart education governance should be accelerated. This calls for better-designed data standards and the removal of barriers up and

down and across the system. Data should be used to make education decisions wiser, education governance more targeted, and education service more accessible.

4.2.3 Building the Smart Lifelong Learning System

This entails, first, to upgrade the supporting platforms of smart education. The national public service platform like Smart Education of China platform should play a central role in enabling lifelong learning for all. Meanwhile, it is important to engage the private sector in smart education, increase the connectivity between different platforms, provide easily available, plural, digital, and smart resources for lifelong learning, and develop more applications in this area.

Second, to step up the building of online learning standards and certification systems. The fast-evolving need of future talents makes it necessary to develop standards for measuring the learning outcomes of online courses at different levels and of various categories, build a digital certification or micro-credential system according to learning hours, and explore credit transfer between online and school education.

Third, to provide employers with unfettered access to individual learning records. Blockchain and other technologies can be used to ensure the safe and permanent storage of personal learning records. Connectivity between online learning and employment platforms is also vital to effectively matching supply and demand in the job market and enabling a positive interaction between schools and employers.

4.2.4 Carrying Out Data-Empowered Innovations in Education

This entails, first, to perfect education data standards. The purpose of improving education data standards is to better serve practices in this area. Teaching, management, and evaluation data should be managed and applied differently according to different entities, such as students, teachers, and schools.

Second, to mine valuable education data. In this light, it is necessary to improve the flow of big data between regional, national, and social platforms through institutional innovations. Moreover, these platforms should be more interoperable and better managed, with increased data retrievability. Focus should also be placed on the mining and analysis of big data on education to improve applications, reveal education patterns and foster new education philosophies and models.

Third, to ramp up support for practical innovations. Data is central to empowering innovations in supporting systems. Furthermore, it is necessary to improve the

data facility support system, digital property trading protection system, and multi-dimensional digital governance system. Innovation should also be made in funding mechanisms to diversify funding channels.

4.2.5 Deepening International Communication and Cooperation on Smart Education

This entails, first, to improve the influence of smart education in academia. More steps should be taken to promote smart education and build it into a brand through various channels, such as international conferences and academic journals. Encouraging experts at home and abroad to share their insights in online and in-person discussions is vital to building a broader consensus on smart education.

Second, to help the education technology industry go global. A critical step toward this end is encouraging education technology products and services to reach Belt and Road countries and beyond for shared prosperity. There should also be measures to support enterprises and education institutions playing a greater role in the building of international smart education facilities and digital education resources, as well as the innovation of digital technology applications. This could contribute China's share of ideas, plans, and models to the growth of smart education worldwide.

Third, to build an international collaborative research network for smart education. High echelons of universities, research institutions, and professional agencies should work together to perform research related to smart education, develop digital learning resources and courses, propose policy and standard initiatives and contribute to global smart education governance.

Part II
Monitoring and Evaluation

Chapter 5
Report on China Smart Education Development Index 2022 (Composite Index)

The digital transformation in education has become an important topic of common concern of the international community. In September 2022, the 2022 United Nations Transforming Education Summit launched an initiative, hoping that the international community can focus on digital learning and its transformation, jointly promote the construction of digital learning platforms, and make education more inclusive, equitable, effective and sustainable.

Right now, changes of the world, of our times and of history are unfolding in education. China follows the trend, firmly promotes the digitalization in education, explores the form of intelligent education, and lays a solid foundation for building a society and country of learning where lifelong learning is pursued by all.

In order to gather consensus, evaluate progress, and effectively promote the vivid practice of smart education, CNAES have explored and constructed China Smart Education Development Index and China Smart Education Development Index for three sub-sectors (basic education, vocational education, and higher education), named as the "1 + 3" China Smart Education Development Index. The Index is based on the reality and characteristics of China's smart education development, on the basis of absorbing relevant research results and work experience at home and abroad, and committed to objectively reflecting the development level of China's smart education. The Index provides China's solutions for the vigorous development of global smart education.

The indicator system of China Smart Education Development and three sub-sector indicator systems are consistent in the dimensions and sub-dimensions. The third level indicators are different among three subfields according to the characteristics of education development in each field. Each index is independent and incomparable. See Chaps. 6–8 for the development index of smart education in each subfield.

Chapter 1 focuses on the construction process and measurement methods of China Smart Education Development Index. The current chapter and the following chapters

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intend to present the results of the measurement, analyze the main achievements and deficiencies of China's smart education development in combination with Chinese context, and look forward to the important trend of China's smart education development in the future. Part II as a whole provides indicator analysis and data support for the overall understanding of China's smart education development.

5.1 Indicators

The Smart Education Development Index is calculated based on the Indicator System of Smart Education Development. The evaluation index system of smart education development is a bridge connecting the theory and practice of smart education, a yardstick to measure the development level of smart education, and an important tool to guide and lead the development of smart education.

The Indicator System of Smart Education Development takes the core index model as the design framework. Based on fully reflecting the connotations and characteristics of intelligent education, it consists of four primary dimensions: environment, teaching and learning, governance, and talent literacy, and 12 sub-dimensions, including facilities, equipment, and digital education resources, with a total of 32 indicators (see Table 5.1). For the specific data source of each indicator, see "Appendix A: Explanations for the Indicator System of Smart Education Development".

The measured data of China Smart Education Development Index is mainly from the departments of Ministry of Education, such as the Department of Development Planning, the Department of Science, Technology and Informatization, the Department of Basic Education, the Department of Vocational and Adult Education, the Department of Higher Education, the Department of Teacher Education. Data also comes from the Center for Scientific Research and Development in Higher Education Institutes, Ministry of Education, National Center for Educational Technology (National Resource Center for Basic Education, Ministry of Education), Higher Education Evaluation Center, Higher Education Press, Educational Informatization Strategy Research Base (Central China), Ministry of Education and other relevant departments, bureaus and units, as well as some data in Digital Economy and Social Index, 2019 Global Competitiveness Report, 2022 Global Digital Overview Report.

In the data collection and calculation process of China Smart Education Development Index, the missing data is processed according to different situations. For indicators that data cannot be collected but have alternative indicator with available data, the alternative indicator data is used in the calculation. For indicators that both its data and alternative indicator data are not available temporarily, the indicators are not used in calculation. The indicators of which data cannot be normalized due to no theoretical optimal value are not included in the index calculation. For indicators with available but insufficient data, existing data is used to calculate the index. As a result, 20 out of the 32 indicators engage in the calculation of China Smart Education Development Index.

Table 5.1 Indicator system of smart education development

Dimension	Sub-dimension	Indicator
Environment	ICT infrastructure	Percentage of educational institutions with a broadband connection, including both fixed and mobile (%)
		Percentage of educational institutions with WLANs network coverage (%)
		Percentage of classrooms with multimedia device(s) (%)
		Number of digital devices per teacher (device/person)
	Digital educational resources	Average amount of digital educational resources by person (piece/person)
		Number of digital curricular resources per 100 students (class hours/100 people)
		Coverage rate of digital educational resources (%) ★
	Cyber learning space	Percentage of teachers with cyber learning space (%)
		Percentage of students with cyber learning space (%)
Teaching and learning	Digital literacy of teachers	Proportion of teachers with sufficient digital literacy (%)
	Utilization of resources	Effective utilization rate of public digital educational resources (%) ★
		Effective utilization rate of curricular resources on the Smart Education of China platform (%)
		User activity indices of the Smart Education of China platform (time/person)
		Hit rate of resources recommended to users by the Smart Education of China platform (%) ★
	Transformation in teaching and learning practices	Coverage rate of hybrid education (%)
		Coverage rate of online teacher training (%)
		Coverage rate of online personalized learning (%) ★
		Percentage of users learning with online videos (%)
	Transformation in assessments	Coverage rate of ICT-based formative assessments (%) ★
		Coverage rate of AI-based assessments (%) ★
Governance	Data accessibility	Percentage of students, teachers and institutions in which the identity data was collected in (national) core database(s) (%)
		Percentage of region-level educational management system in which data is available to national Education Data Exchange Network (%) ★
	ICT-based management	Coverage rate of one-stop online educational affairs and services (%)
		Coverage rate of ICT engaged educational supervision (%) ★
		Percentage of educational institutions with ICT-related policy (%)

(continued)

Table 5.1 (continued)

Dimension	Sub-dimension	Indicator
		Percentage of educational institutions with data-driven decision-making process (%)
	Cyber and data security	Percentage of schools with cybersecurity policy (%)
Talent literacy	Digital literacy of students	Proportion of students with sufficient digital literacy (%)
		Percentage of graduates from ICT-related majors (%)
		Indices of students' lifelong learning ability ★
	Laborer digital skills	Indices of average digital skills of population between ages 16 and 74
		Indices of digital skills among active population

Note ★ indicates that data is temporarily unavailable, and the rest is the same

5.2 Calculation Results

5.2.1 General Description

The China Smart Education Development Index 2022 is 0.74. Among them, the Environment index is 0.73, the Teaching and learning index is 0.68, the Governance index is 0.84, and the Talent literacy index is 0.72 (see Fig. 5.1).

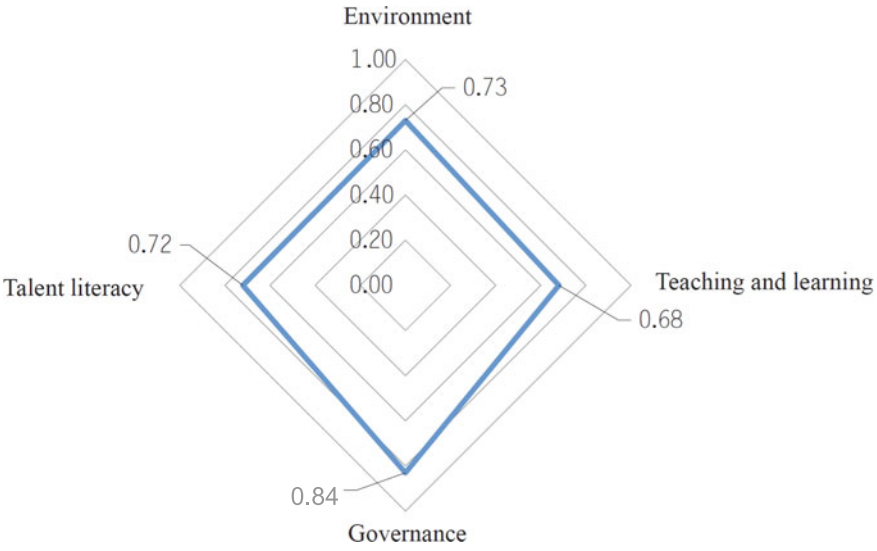

Fig. 5.1 The result of China smart education development index 2022

Table 5.2 Index values of environment dimension

Sub-dimension	Indicator	Value
ICT infrastructure	Percentage of educational institutions with a broadband connection, including both fixed and mobile (%)	98.85
	Percentage of educational institutions with WLANs network coverage (%)	75.52
	Percentage of classrooms with multimedia device(s) (%)	71.82
	Number of digital devices per teacher (device/person)	0.98
Digital educational resources	Average amount of digital educational resources by person (piece/person)[1]	—
	Number of digital curricular resources per 100 students (class hours/100 people)[2]	—
	Coverage rate of digital educational resources (%) ★	—
Cyber learning space	Percentage of teachers with cyber learning space (%)	65.21
	Percentage of students with cyber learning space (%)	53.08

Note If there is no specific description, "—" in the table indicates that there is no data for this indicator, and the rest is the same

5.2.2 Results of Each Dimension

i. Environment index

The Environment index is 0.73. Among them, the ICT infrastructure index is 0.86, and the Cyber learning space index is 0.59. See Table 5.2 for the index values.

ii. Teaching and learning index

The Teaching and learning index is 0.68. Among them, the Digital literacy of teachers index is 0.87, the Utilization of resources index is 0.60, and the Transformation in teaching and learning practices index is 0.58. See Table 5.3 for the index values.

iii. Governance index

The governance index is 0.84. Among them, the Data accessibility index is 1.00, the ICT-based management is 0.66, and the Cyber and data security index is 0.85. See Table 5.4 for the index values.

iv. Talent literacy index

The Talent literacy index is 0.72. Among them, Digital literacy of students index is 0.89, and Laborer digital skills index is 0.54. See Table 5.5 for the index values.

[1] The theoretical maximum and minimum values of the index data cannot be determined temporarily, and will not be included in the index calculation in 2022.

[2] Same as above.

Table 5.3 Index values of teaching and learning dimension

Sub-dimension	Indicator	Value
Digital literacy of teachers	Proportion of teachers with sufficient digital literacy (%)	86.50
Utilization of resources	Effective utilization rate of public digital educational resources (%) ★	—
	Effective utilization rate of curricular resources on the Smart Education of China platform(%)	59.99
	User activity indices of the Smart Education of China platform (time/person)[3]	—
	Hit rate of resources recommended to users by the Smart Education of China platform (%) ★	—
Transformation in teaching and learning practices	Coverage rate of hybrid education (%)	78.97
	Coverage rate of online teacher training (%)	54.62
	Coverage rate of online personalized learning (%) ★	—
	Percentage of users learning with online videos (%)	40.90
Transformation in assessments	Coverage rate of ICT-based formative assessments (%) ★	—
	Coverage rate of AI-based assessments (%) ★	—

Table 5.4 Index values of governance dimension

Sub-dimension	Indicator	Value
Data accessibility	Percentage of students, teachers and institutions in which the identity data was collected in (national) core database(s) (%)	100.00
	Percentage of region-level educational management system in which data is available to national Education Data Exchange Network (%) ★	—
ICT-based management	Coverage rate of one-stop online educational affairs and services (%)	57.31
	Coverage rate of ICT engaged educational supervision (%) ★	—
	Percentage of educational institutions with ICT-related policy (%)	82.32
	Percentage of educational institutions with data-driven decision-making process (%)	58.74
Cyber and data security	Percentage of schools with cybersecurity policy (%)	84.90

[3] The theoretical maximum and minimum values of the index data cannot be determined temporarily, and will not be included in the index calculation in 2022.

Table 5.5 Index values of talent literacy dimension

Sub-dimension	Indicator	Value
Digital literacy of students	Proportion of students with sufficient digital literacy (%)	78.79
	Percentage of graduates from ICT-related majors (%)	40.77
	Indices of students' lifelong learning ability ★	—
Laborer digital skills	Indices of average digital skills of population between ages 16 and 74[4]	47.00
	Indices of digital skills among active population[5]	4.70

5.3 Achievements and Deficiencies

5.3.1 Achievements

i. Intelligent infrastructure, equipment and environment in education have been basically completed

Since the twenty-first century, especially since the 18th CPC National Congress in 2012, China has issued policies such as the *Ten Year Plan for the Development of Education Informatization (2011–2020), the 13th Five Year Plan for Education Informatization, and the 2.0 Action Plan for Education Informatization*, to implement China's Strategic Action Plan for Education Digitalization, promote the construction of new educational infrastructure, and increase financial investment in infrastructure equipment for Education Informatization. After years of development, the proportion of schools connected to the internet in China has reached nearly 100%, more than three quarters of schools have been fully covered by wireless networks, more than 70% of classrooms are network multimedia classrooms, and digital terminals for teachers' teaching are popularized. The digital facilities of school has been significantly improved. It has laid a solid foundation for smart education from the "network" and "equipment" aspects of the digital environment.

ii. Digital literacy of primary and secondary school teachers has been improved comprehensively

China has successively implemented training programs such as the National Training Program, educational technology capability training, and national information technology application capability improvement project for primary and secondary school teachers, and formulated relevant standards such as the Standards for Information Technology Application Competence of Primary and Secondary School Teachers (Trial), and the Curriculum Standards for Information Technology Application

[4] The index data adopts the measurement results in the series of reports of the European Commission's Digital Economy and Society Index, and the numerical range is [0,100].

[5] The index data adopts the measurement results in the Global Competitiveness Report 2019 of the World Economic Forum, and the numerical range is [1,7].

Competence Training for Primary and Secondary School Teachers (Trial). At present, China has completed the training for more than 10 million primary and secondary school teachers, more than 100,000 primary and secondary school principals, and more than 200,000 vocational college teachers to improve their ICT application ability. In this process, China has gradually accumulated a teacher training practice model that combines the whole school promotion, application orientation, and regular evaluation. The survey of teachers' digital literacy conducted by the Educational Informatization Strategy Research Base (Central China), Ministry of Education shows that more than 86% of teachers have the ability to apply information technology, laying a good human resource foundation for the implementation and development of smart education.

iii. Hybrid teaching and learning is increasingly popular

China actively promotes "internet plus education", constantly optimizes the supply of high-quality education resources, and provides effective support for promoting education fairness, quality improvement, and bridge the digital divide. In the field of basic education, China has strengthened the construction and application of "courier class", "famous teacher class" and "famous school network class", and selected and promoted the application of national online quality courses in the field of higher education and vocational education. At present, the number of MOOCs launched in China has exceeded 64,500, with 402 million registered users, 1,088 million learners. Especially during the prevention and control of the COVID-19, China's smart education has rapidly accumulated and effectively integrated, supporting the world's largest online teaching. Hybrid teaching in higher education has been fully popularized, while hybrid teaching in basic education has been popularized.

iv. The data base of education governance is basically established

China pays attention to establishing and improving the standard system of education management informatization, strives to build an education public management service platform, issues the Notice on Strengthening the Education Informatization Management in the New Era and other specific documents, and promotes the modernization of education governance. At present, the basic data of China's smart education governance is well established. Three major education basic databases of schools, teachers and students have been built, and the basic data collection and management of schools, teachers and students nationwide have been completed. "One school, one code" and "one person, one number" have become a reality, which has established a data base for education governance.

v. The policy of schools' management informatization and cybersecurity is relatively complete

Driven by the Platform for Action to Promote the Development of Big Data, the Guiding Opinions on Strengthening the Construction of Digital Government, the Notice on Strengthening the Informatization of Education Management in the New Era, and the construction norms of various digital campuses at all levels, over 80% of schools have established policy of information-based operation and management,

which has made full institutional preparations for promoting the practice of digital governance. China has also successively promulgated the Cybersecurity Law of the People's Republic of China, the Data Security Law of the People's Republic of China, the Personal Information Protection Law of the People's Republic of China and other laws. China has been vigorously promoting the construction of school cybersecurity. Nearly 85% of schools have adopted cybersecurity management systems, which firmly established the system for schools to carry out safe digital governance "Fence".

vi. Nearly 80% of primary and secondary school students have sufficient digital literacy

In order to cultivate citizens who meet the requirements of the development of the digital era and enable students to have the necessary quality and ability to study, work and live in the digital society, the Ministry of Education has issued a number of policy documents in recent years, deployed and implemented the comprehensive improvement action of students' information literacy, formulated the curriculum standards related to information literacy training, incorporated the evaluation of students' information literacy into the comprehensive quality evaluation, and strengthened the cultivation of students' information literacy. The result of the students' information literacy survey in the Educational Informatization Strategy Research Base (Central China), Ministry of Education shows that nearly 80% of the primary and secondary school students' digital literacy has reached the qualified level or above.

vii. The proportion of ict related professionals is relatively high in the world

In order to cultivate digital professionals and ensure the innovative development of China's digital economy and science and technology, planning documents such as the New Generation Artificial Intelligence Development Plan, the Fourteenth Five Year Digital Economy Development Plan, and Several Opinions on Deeply Promoting the Construction of World-class Universities and Disciplines require strengthening the training of digital technology skilled talents, and strengthening the training of science, industry, agriculture, medicine and interdisciplinary talents. The proportion of graduates in ICT-related disciplines in China is more than 40%. The professional structure is stable and at a high level internationally, which provides intellectual support for the development of economic industries in the digital era.

5.3.2 Deficiencies

i. The supply and service capacity of digital educational resources still needs to be improved

In March 2022, the Smart Education of China platform was put into operation, the supply of various high-quality digital resources continued to expand, and the number of registered users of the platform grew rapidly.

However, from the perspective of the coverage of registered users of the public digital education resource platform in the population, and the amount of digital education resources per capita and per student, as a comprehensive integrated platform of national education public services, the Smart Education of China platform still needs to continue to gather more diverse types, more complete subjects and better quality education resources, and strive to expand the coverage among teachers, students, parents and the public to benefit more people.

ii. The cyber learning spaces are not coverage to all student and teachers

In order to accelerate the construction of a learning society that "everyone can learn, everywhere can learn, and always can learn", and realize the normalized applications of space-based teaching and learning, teaching management, and education governance, China has strengthened the construction and application of cyber learning spaces, and carried out the popularization of cyber learning space applications for many years in a row. At present, the number of teachers' cyber learning spaces and students' cyber learning spaces are 9,737,600 and 115,388,000, respectively. The development goal of "one person, one space, and everyone uses space" has not been achieved. The awareness of teachers and students to open and use cyber learning spaces needs further improvement. The construction and application of "cloud" space in the basic environment of smart education still need to be continued.

iii. Smart teaching has not yet formed deep-level, regular and full-process application and reform

China's smart education is still lacking in reform and innovation at the teaching level, which is mainly reflected in the following aspects: the application level of smart teaching is not deep, only about half of primary and secondary school teachers and vocational school teachers carry out online research with the advantage of information technology such as the internet, and the popularity of students' online personalized learning needs to be improved; the interactive application of educational resources is not enough, especially the accuracy of interactive services is not high; the personalized, intelligent and accurate push services for users need to be improved and deepened; the reform of intelligent evaluation has not achieved obvious results. It is urgent to strengthen the popularization and application of digital teaching process evaluation and intelligent evaluation.

iv. The popularity of school data application needs to be improved

The construction of basic education data is to serve digital education governance. In order to effectively solve the prominent problems such as insufficient integration of educational management information system, poor data sharing, poor service experience, and repeated construction of facilities, the Ministry of Education requires the use of new generation information technology to improve the digital, networked, and intelligent level of educational management, and to promote the transformation of educational decision-making from experience-driven to data-driven. At present, less than 60% of schools apply all kinds of educational management information

system data to daily decision-making and management services, and the application rate of educational management data needs to be improved.

v. There is much room to improve the development of digital literacy of the whole nation

It is a necessary measure to promote workers to better adapt to digital production and lifestyle by focusing on the training of digital literacy for workers and improving their digital literacy and skills. The Fourteenth Five Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of the Long term Goals for 2035 emphasized "strengthening digital skills education and training for all, and popularizing and improving citizens' digital literacy". In 2022, the Cyberspace Administration of China (CAC) issued the Action Outline for Upgrading Digital Literacy and Skills of the General Public, proposing the goal of "By 2025, the digital adaptability, competence and creativity of the general public …are expected to be on par with that of developed countries". Due to the short starting time of this action, China has not yet fully established a lifelong digital literacy learning system for all, especially for workers. The improvement of workers' digital literacy requires a long period of time.

The positive role of school education, continuing education and lifelong learning in improving workers' digital literacy needs to be accumulated in the later period.

5.4 Development Recommendations

5.4.1 Enhancing the Level of Data Connection Through Platform Optimization

i. Build a high-quality, fair and efficient public service platform for smart education

We are supposed to give priority to application and services, upgrade and improve the Smart Education of China platform. A learner-centered personalized learning and lifelong learning environment can be built based on extensively gathering high-quality educational resources, seamlessly integrating efficient learning tools, comprehensively tracking the learning process, proactively offering customized services. Dedicated to education equity, we will provide everyone with higher quality education resources and more convenient and reliable public services.

ii. Create a smart education ecosystem integrating the Internet of Things, big data and intelligent technology

We suggest to revitalize the existing resources of digital education and optimize the new resources, give full play to the role of data as a new factor of production, build an integrated infrastructure of "cloud-network-edge-device" based on the new

generation of information technology, speed up the deployment of IoT perception infrastructure in universities, promote the construction of smart campuses and smart laboratories, and build a new education ecosystem that integrates virtual and real scenes online and offline, and bridges activities on and off campus.

5.4.2 Transforming to a New Teaching and Learning Paradigm Around Deep Application of Technologies

i. Actively explore the innovative application of the new generation of information technology in education

We suggest to actively promote immersive and experiential teaching based on augmented reality and virtual reality, remote multi-location collaborative teaching based on 5G technology, inquiry and personalized learning based on artificial intelligence, to promote inter-disciplinary teaching, and remodel teaching processes and teaching modes. We supposed to encourage education institutions of all kinds at all levels to innovate management models and education methods based on the new generation of information technology, improve teachers' digital literacy, and promote deep changes in teaching and learning through collaboration between schools, families and society.

ii. Building a smart education evaluation system driven by big data

We recommend to innovate education evaluation methods by employing smart evaluation and big data analysis, and reform the evaluation methods and mechanisms in education development, talent training and selection through data collection, mining and analysis that cover all elements, the whole process and all dimensions. Blockchain and other technologies should be used to accelerate the construction of a credit certification and skills certification system for lifelong learning, and explore a common mechanism for recognizing different types of learning achievements and online and offline learning qualifications.

5.4.3 Developing Intelligent Governance in Education Powered by Big Data

i. Build a new mechanism of data-empowered collaborative education governance

We suggest to improve the functions of the government service platform for education integration, accelerate the data flow and collaborative application across departments, regions and government levels, and improve the overall effectiveness of digital education governance. A decision-making support platform for educational development

can be built to optimize the allocation of educational resources and factors, enable scientific management and trend prediction through comprehensive collection and analysis of educational, economic, social, and demographic data, so as to provide scientific and reliable evidence for educational decision-making.

ii. Improve standards for smart education development

We are supposed to improve governance systems such as information networks, platform systems, digital resources, smart campuses, innovative applications, and digital certification, establish and improve education platforms and data security assurance networks, and harmonize processes and standards for the collection, transmission and use of teacher and student information, as well as ethical codes on the application of artificial intelligence in education, so as to build an institutionalized, scientific, and standardized governance system for smart education.

5.4.4 Establishing an Innovative Pattern of Talent Cultivating Aiming at Nationwide Digital Literacy Improvement

i. Accelerate enhancing digital literacy of students

We recommend establishing digital literacy standards for teachers and students, incorporate digital literacy cultivation into the integrated education program for universities, middle schools and primary schools, and evaluate the progress of digital talent training system on a regular basis. According to the needs of social development, we suggest to promptly optimize the discipline design of vocational education and higher education, dynamically adjust the programs offered, and enhance the training of digital related professionals. With a focus on lifelong learning awareness, self-management, quality of thinking and adaptability, we suggest to innovate the training model for students' lifelong learning ability under the smart education environment, and cultivate talents capable of sustained learning and self-development.

ii. Improve nationwide digital literacy

We suppose to integrate resources in community education, elderly education network and various public learning service platforms, and expand the supply channels of high-quality resources for lifelong learning for all. Whole-life-cycle learning support should be provided for all people through digital means, so that everyone has access to learning resources anywhere and anytime. We also suggest to establish digital literacy standards for all people, regularly monitor lifelong learning needs and capabilities of the whole population, accelerate lifelong learning for all through digital education, and lay a solid foundation for building a learning society and a learning country.

Chapter 6
Report on China Smart Education Development Index 2022 (Basic Education)

A new round of accelerating technology revolution has important and far-reaching impacts on social development. As the Digital China continues to advance, the education sector has also rolled out China's Strategic Action Plan for Education Digitalization to leverage and incorporate existing and emerging information technologies such as the internet, big data, cloud computing and artificial intelligent. Basic education is also undergoing a transformation to smart education. Aiming at quality development, technologies can be applied in a wide range of scenarios in basic education: enhanced learning environment, teaching method renewals, campus governance and digital literacy for teachers /students, all contributing to goals of going smart. To reflect the level of smart education in China's basic education, this chapter constructs the Indicator System of Smart Education Development (Basic Education) as well as provides a set of recommendations based on a future vision of digital education.

6.1 Indicators

The Indicator System of Smart Education Development (Basic Education) has 4 dimensions (environment, teaching and learning, governance, and talent literacy). In total, 13 sub-dimensions (ICT infrastructure, digital educational resources, cyber learning space, digital literacy of teachers, utilization of resources, transformation in teaching and learning practices, transformation in assessments, pedagogical research, data accessibility, ICT-based management, cyber and data security, digital literacy of students, and digitalized learning experiences) with 35 indicators included in the indicator system (see Table 6.1).

The measured data of Index is mainly from the departments of Ministry of Education, such as Department of Development Planning, Department of Science,

China National Academy of Educational Sciences (CNAES), *Report on China Smart Education 2022*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-99-6109-2_6

Table 6.1 Indicator system of smart education development (basic education)

Dimension	Sub-dimension	Indicator
Environment	ICT infrastructure	Percentage of schools with a broadband connection, includes both fixed and mobile (%)
		Percentage of schools with WLANs network coverage (%)
		Percentage of classrooms with multimedia device(s) (%)
		Number of digital devices per 100 students (device / 100 people)
Environment	Digital educational resources	Number of open digital curricular resources for primary and secondary education (class hours)
		Number of open digital resources for pedagogical research for primary and secondary education (pieces)
	Cyber learning space	Percentage of teachers with cyber learning space (%)
		Percentage of students with cyber learning space (%)
Teaching and learning	Digital literacy of teachers	Number of ICT professionals in education per 100 students (people / 100 people)
		Number of ICT-related training per 100 teachers (times / 100 people)
		Proportion of teachers with sufficient digital literacy (%)
	Utilization of resources	Annual user activity indices of the Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE)
		Effective utilization rate of resources on the SEC-PPSE (%)
		Hit rate of resources recommended to users by the SEC-PPSE (%)
		Effective utilization of moral, physical, aesthetic, and labor education related resources on the SEC-PPSE (%)
	Transformation in teaching and learning practices	Coverage rate of hybrid education (%)
		Coverage rate of online personalized teaching (%)
		Coverage rate of ICT engaged classroom lessons (%)
		Coverage rate of ICT engaged homework assignments (%)
	Transformation in assessments	Number of ICT-based assessment patterns
		Coverage rate of ICT-based assessments (%)
	Pedagogical research	Average hours of teachers participating in online professional training per year (hours)
		Coverage rate of online pedagogical research (%)

(continued)

Table 6.1 (continued)

Dimension	Sub-dimension	Indicator
Governance	Data accessibility	Percentage of students, teachers, and schools in which the identity data was collected in (national) core database(s) (%)
		Percentage of region-level learning management systems join in national Education Data Exchange Network (%)
	ICT-based management	Coverage rate of one-stop online educational affairs and services (%)
		Coverage rate of ICT engaged educational supervision (%)
		Coverage rate of after-school service management system (%)
		Percentage of schools with ICT-related policy (%)
	ICT-based management	Percentage of schools with data driven decision-making process (%)
		Financial expenditure on ICT in education (%)
	Cyber and data security	Percentage of schools with cybersecurity policy (%)
Talent literacy	Digital literacy of students	percentage of students with satisfactory digital literacy (%)
		Indices of students' life-long learning ability among primary and secondary schools
	Digitalized learning experience	Indices of learning experience of users on SEC-PPSE

Note ★ indicates that data is temporarily unavailable

Technology and Informatization, Department of Basic Education, Department of Teacher Education. Data also comes from National Center for Educational Technology (National Resource Center for Basic Education, Ministry of Education), Educational Informatization Strategy Research Base (Central China), Ministry of Education and other relevant departments, bureaus, and units.

For indicator "Number of digital devices per 100 students", in view of common practices in China and internationally, the index opts for one device for every 7 students as the criterion, that is, 14.3 devices for every 100 students as the maximum value.[1] For indicator "Number of ICT professionals in education per 100 students", considering the average levels in developed countries, we decides to go with one

[1] Internationally, the average OECD countries for student-device ratio released in 2012 was 4.7:1, and it was 5.9:1 for South Korea in the same year. According to the UNESCO Institute for Statistics (UIS), in 2012, device-student ratio was 7:1 in Japan, 9:1 in Hong Kong, China. In the mainland of China, the ratio varied across regions between 30:1 and 6:1. Zhejiang Province in its 2011 "School Benchmarks for Compulsory Education Standardization" required a 7: 1. Jiangsu Provinces in its 2019 "Interim Indicators for Standardized Compulsory Education Schools" required 10:1 and 8:1 for primary and secondary schools respectively. After considering practices from various countries

ICT worker per 100 students as the maximum value. For indicators measured in standardized scores, we linearly transformed the original scores into a normalized value in the range of [0, 1] for further calculation.

In the data collection and calculation process of China Smart Education Development Index, the missing data is processed according to different situation. For indicators that data cannot be collected, but have alternative indicator with available data, the alternative indicator data is used in the calculation. For indicators that neither its data nor alternative indicator data are available temporarily, they are not used in calculation. The indicators of which theoretical data range cannot be identified would not be normalized. These indicators are not included in the index calculation. For indicators with available but insufficient data, existing data is used to calculate the index. As a result, 26 out of the 35 indicators report available data, 20 of the 35 indicators engage in the calculation of China Smart Education Development Index (Basic Education).

6.2 Calculation Results

It is estimated that China Smart Education Development Index (basic education) is 0.74. As shown in Fig. 6.1, among the dimensions, the value of environment dimension is 0.72; the value of teaching and learning dimension is 0.62; the value of governance dimension is 0.81; and the value of talent literacy governance is 0.79. The results indicate teaching and learning is a weak link in the development of smart education in China, in the area of basic education.

6.2.1 Environment

The overall value of environment dimension is 0.72. For the sub-dimensions, the value of ICT Infrastructure is 0.82 and the value of cyber learning space is 0.62, showing the level of ICT infrastructure construction performs better than cyber learning space. As of September 2022, the Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE) offers 19,505 class hours of curricular resources; and the pedagogical research platform offers 10,507 class hours or entries.

For all provinces, the maximum value of environment dimension is 0.95. Fifteen provinces report values of environment dimension higher than 0.72. The results suggest the overall environment in most Chinese provinces are adequate for meeting the essential demands of smart education, and the material basis for educational transformation is already in place.

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and different regions in China and consulting domain experts, the index settled on 7:1 or 14.3 per hundred students as its standard value.

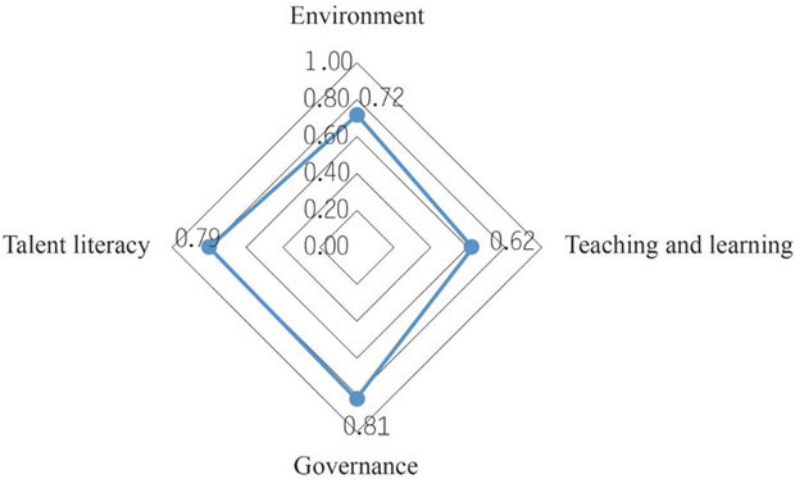

Fig. 6.1 China smart education development index (basic education) by dimension

ICT infrastructure. The average value of ICT infrastructure is 0.82. All provinces have 100% of their schools with a broadband connection. Nationwide, 75.59% of schools are covered by WLANs network, and 73.92% of all classrooms are equipped with multimedia device(s). The average number of digital teaching devices available for every 100 students is 11.29, or 0.79 in index. As shown in Fig. 6.2, for the value of ICT infrastructure for all provinces, the maximum value is 0.97. The values of most provinces locate in the range between 0.70 and 0.90. There are 14 provinces report values higher than the national average level. The standard deviation is 0.08, suggesting a narrow regional gap in ICT infrastructure.

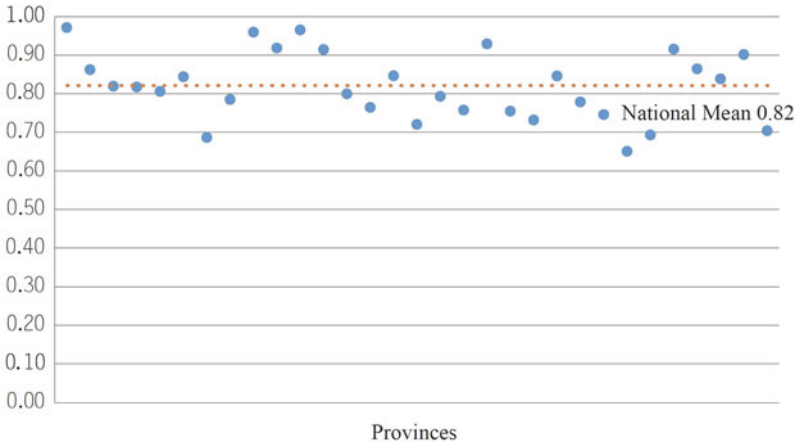

Fig. 6.2 Value of ICT infrastructure by province

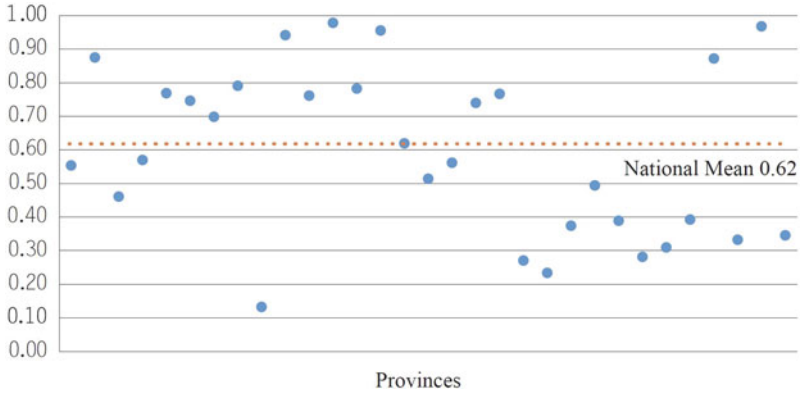

Fig. 6.3 Value of cyber learning space by province

Cyber learning space. The national average value of the sub-dimension cyber learning space is 0.62 with standard deviation of 0.25, suggesting significant regional disparity among the provinces. 69.35% of the students and 54.24% of teachers have registered personal accounts to access cyber learning space. As shown in Fig. 6.3, differences between provinces are quite large with 14 of them report values higher than 0.62, and 17 provinces report values lower than the national average level.

6.2.2 Teaching and Learning

The value of teaching and learning dimension is 0.62. For its sub-dimensions, the national average values are 0.53 for the digital literacy of teachers, 0.70 for the utilization of resources, 0.69 for transformation in teaching and learning practices, and 0.55 for pedagogical research.

Digital literacy of teachers. The national average of digital literacy of teachers is 0.53. There are 0.19 ICT professionals in education for every 100 students, and 86.50% of the teachers report sufficient digital literacy (passing the digital literacy test). As shown in Fig. 6.4, there are 16 provinces in which the number of ICT professionals in education per 100 students exceeds the national average. The number is between 0.15 and 0.19 for 12 provinces.

Utilization of resources. The national average for the utilization of resources is 0.70, with a high level of annual user annual activity on the SEC-PPSE.[2] Data show that the effective utilization rate of resources on the platform is 39.86%. It suggests

[2] The annual user activity of SEC-PPSE is calculated as the ratio of page view over the unique visitors of the platform. The national average value of this ratio is 65.67. Referring to related data from Baidu, Taobao, Amazon, and JD, we identify the user activity level of SEC-PPSE stay at high level. As a result, all provinces report full score at this indicator.

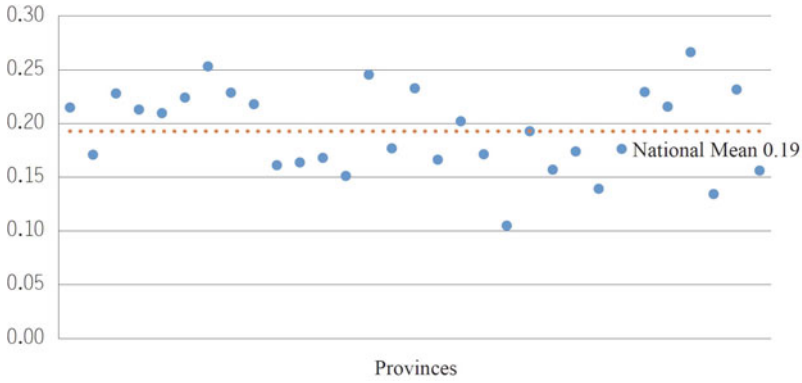

Fig. 6.4 Number of ICT professionals in education per 100 students by province

space for improving the utilization despite the large amount of available resources on the platform.

Under COVID-19, as an effort to keep teaching and learning amid class suspension, all primary and secondary schools register as users of the SEC-PPSE and begin the exploration of hybrid education. Surveys show 82.66% of offline courses nationwide are engaging with ICT technologies, and the coverage rate of online personalized teaching for teachers is 54.61%, indicating where improvement should be made.

Pedagogical research. The average value of pedagogical research is 0.55. The coverage rate of online teacher training is 55.49% with standard deviation of 0.22, suggesting the space for improvement for this indicator in some provinces. As shown in Fig. 6.5, teacher online training is above national average level in 14 provinces. The maximum value of this indicator is 91.98%.

6.2.3 Governance

The value of governance dimension is 0.81. For the sub-dimensions, data accessibility reaches 100% in all provinces; the national average of ICT-based management is 0.59; and the national average of cyber and data security is 0.85.

Data accessibility. Data accessibility reaches 100% in basic education, suggesting a solid foundation to roll out digital transformation on.

ICT-based management. The value of ICT-based management is 0.59. The "National after-school service management system" for primary and secondary schools covers more than 29,000 schools, suggesting ICT, as a "fast variable", is already beginning to empower policies such as "double reduction". As shown in Fig. 6.6, there are 82.78% of the schools conducting data driven decision-making

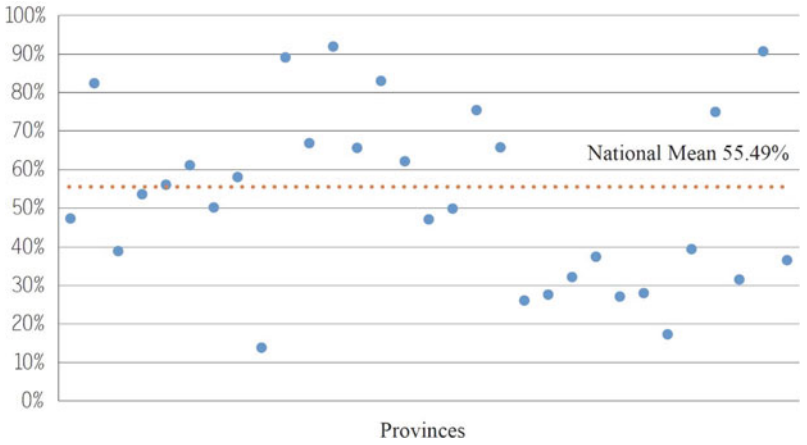

Fig. 6.5 Teacher online training by province

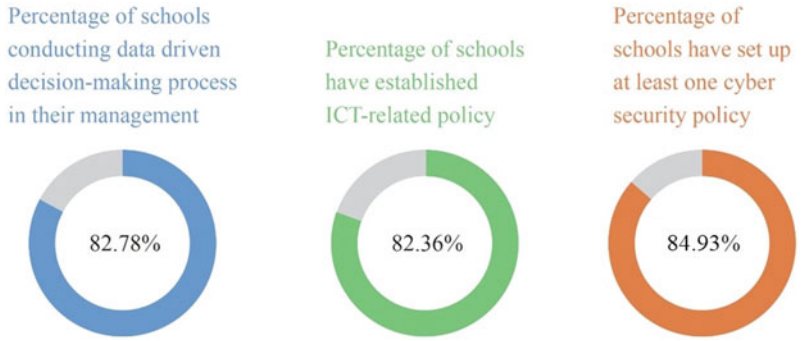

Fig. 6.6 Selected indicators from governance dimension

process in their management, showing a strong national consensus. In total, 82.36% of the schools have established ICT-related policy.

Cyber and data security. 84.93% of the schools have set up at least one cybersecurity policy. From the provincial perspective, 17 provinces report percentage more than the national average.

6.2.4 Talent Literacy

The value of talent literacy dimension is 0.79. There are 78.79% of student meeting the criterion of sufficient digital literacy, suggesting students in basic education have solid digital skills.

6.3 Achievements and Deficiencies

6.3.1 Achievements

Digital transformation of basic education in China is in good shape with well-developed infrastructure and strong policy and public service support. The teaching and learning process is enriched by extensive digital content and diverse applications with rapid improvement in digital management and teacher/student's digital literacy. A large set of experiences have been developed on digital transformation in education encompassing theories and practices with Chinese characteristics. Under China's Strategic Action Plan for Education Digitalization, primary and secondary schools have embarked on a new stage of the digital journey to embrace transformative changes in all educational aspects leading to a new ecosystem.

i. Fundamental improvement is achieved of digital environment across the country

Educational ICT infrastructure has improved rapidly, offering ubiquitous access to smart learning environment with complete network coverage and integrated multimedia for both offline and online settings. By the end of 2020, primary and secondary schools were 100% connected to the internet. By the end of 2021, the number of multimedia classrooms at primary and secondary schools exceeded 4 million, and 73.92% of classrooms were equipped with multimedia with internet access. 99.50% of the primary and secondary schools had multimedia classrooms. ICT infrastructural development is quite quality and fairly even across China.

ii. The national public service system of sharing digital content for basic education has made remarkable breakthrough

To ensure every child enjoy fair and quality education through rapid modernization and public accountability, the SEC-PPSE and other resource centers were developed as a public service to expand access to premium content. As of December 2022, the total number of digital resources on the platform reached 44,000 with 69.98 million registered users. The total number of visits of SEC-PPSE reached 19.6 billion, with daily visits reaching 64.32 million. During COVID-19, the platform keeping learning amid class suspension during the pandemic. It also expands equal access to education by supporting the national policy such as "double deduction" to prohibit overloading students with campus and extracurricular academic duties.

iii. ICT's deep integration with education paves the way for new teaching formats to emerge

ICT's role as an instrumental enabler to education reform is becoming evident through demonstration sites, case studies and hands-on training. By the end of 2021, more than 80% of offline teaching sessions were supported by ICT. Schools across the country are leveraging the SEC-PPSE and resources centers to carry out hybrid education. ICT is frequently and extensively used in the teaching process. Personalized learning,

adaptive learning and "courier class" enabled by ICT keep emerging, effectively promoting education quality and equity.

iv. The level of digital management in education has improved steadily

Digital public service platforms, such as the National Management Service Platform for Primary and Secondary Schools, have developed rapidly, with significant improvement in data-driven governance, e-government and coordinated oversight. The platform was put into operation in June 2022 with three modules: student management, school management; and special purpose management, and two services: the work desk and the "Learning Through Excellent Teaching" App. It meets the daily needs of regulators, school administrators, teachers, parents, and students. As of December 2022, the platform has been connected with 220,000 primary and secondary schools in various provinces, cities and counties together with their corresponding regulators. Data on basic education are shared 100%. The registration system of primary and secondary school students has collected 303 million pieces of information, and the coverage rate of basic education data reached 100%. The after-school service management system has carried out two rounds of piloting. Nearly 30 thousand schools across China use the national platform while about one thousand schools use their locally developed systems with interfaces connecting to the national platform for data transfer. Digital enablement and standardization are improving fast as well as the cybersecurity is becoming more robust.

v. The talent development system gearing towards the digital age has taken shape

China attaches great importance to improving the capacity of applying digital technologies in teaching for primary and secondary school teachers. Between 2013 and 2017, the Ministry of Education initiated educational technology capability training, and information technology application capability improvement project for primary and secondary school teachers, offering training sessions to more than 10 million teachers nationwide. In 2019, the Ministry of Education implemented an upgraded version of this project to ensure continuous improvement of teachers' digital literacy. A survey in 2021 showed 86.5% of teachers qualified sufficient digital literacy. Meanwhile, China was intensifying efforts to cultivate the digital literacy of students. The Ministry of Education formulated the *Information and Technology Curriculum Standards for General High Schools (2017 Edition Amended in 2020)* and *Information and Technology Curriculum Standards for Compulsory Education (2022 Edition)* to improve students' digital literacy. The survey in 2021 showed that more than three quarters of primary and secondary school students had qualified digital literacy.

6.3.2 Deficiencies

i. Infrastructure deficiency

There is still room for further improving the configuration of digital equipment and facilities. For example, most of the digital devices at schools are desktop computers, which are not portable. Some equipment is sitting idle with minimum usage. Bandwidth at some schools is too low to support the "pair-teacher class" and "courier class" formats. At the same time, data show the ratio of registering on network teaching space as users can be further raised. The integration of cloud and on-premise functions is not fully achieved to support online and offline hybrid teaching, so it needs to be updated with new iterations.

ii. Digital content is not learner specific

At present, digital content in basic education is not evenly distributed, and its presentation form lacks diversity. For example, content on the SEC-PPSE is mostly related to subject-centered curriculum, with very little available on moral, physical and artistic development, coordination between home and school, after-school services and interdisciplinary learning. Digital content is presented primarily as MOOC or video recordings of classroom sessions. E-textbooks, digital toolkit, virtual simulation are not commonly used.

iii. Use of digital technologies not yet routine

At present, teachers at primary and secondary schools are not fully harnessing the potential of ICT to flexibly implement teaching with innovate tools suited for different needs. Administrative staff and school management are not open-minded enough, and some of them are using new technologies to cement legacy education systems. Many schools don't have enough ICT expertise to back up digital teaching in a sustainable way. Full-time IT staff is less and not specialized. At most schools, the IT administrator is not an independent job position, and someone teaching ICT often assumes the role, leaving huge gaps in maintenance work.

iv. Insufficient public service support

There are still a number of shortcomings ranging from data integration, to service coordination and diversification. For example, various platforms and data sources are not fully integrated; data under different statistical measurements are not standardized and difficult to exchange; access to data still faces barriers; collaborative governance and decision-making based on full data flow is still hindered. Digital supervision, after-school services, home-school-society coordination and other diverse needs have not been met.

6.4 Development Recommendations

6.4.1 Make Utilization Routine and Improve the Digital Infrastructure

First, provide guidelines for schools on using their existing digital facilities to make utilization a daily routine. Second, update and renew mission critical equipment, add mobile digital devises, enhance the campus local area network, raise the bandwidth and build multimedia classrooms with internet access and interoperability. Third, strengthen the conditions at rural schools to deliver "pair-teacher class", improve their connectivity, equip them with interactive tools over long distances, support their effort to offer the national mandatory curriculum in its entirety. Fourth, require proper maintenance of digital assets with increased staffing to ensure availability, reliability, and sustainability.

6.4.2 Produce Quality Digital Content in Larger Volumes to Support the Basic Education Reform Agenda

First, improve the SEC-PPSE with constant generation of new and innovative content to enrich teaching and learning on academic subjects as well as morality development, acquisition of practical skills and home-school-community engagement. Second, diversify the forms of presenting digital content to support a wide range of scenarios such as "blended learning", "self-managed learning", "project-based learning" and "virtual simulation experiment resources". Third, increase the precision and relevance of digital content through intelligently filtering, automatic classification, semantic retrieval, information recommendation and other big data and AI technologies to ensure efficient resource use. Fourth, develop an ecosystem for digital content creation, maintenance, updating, audit and supervision with multiple stakeholders. Fifth, refine the standards for evaluating digital content for quality education, build a full-chain mechanism for efficient supervision of massive content.

6.4.3 Create Innovative Use Scenarios and Deepen the Integration Between Digital Technologies and Education

First, develop a greater understanding of education's digital transformation, systematically design and innovate new use scenarios of in all aspects and processes, and regularly publish the list of application settings. Second, study the inherent requirements of quality basic education and develop key use scenarios on the SEC-PPSE, reflecting

learners' cognitive characteristics, teaching patterns and teacher student dynamics. Third, implement pilot projects such as the "smart education demonstration zone" and the "new teaching and learning model experimental zone based on teaching reform and IT integration", and develop benchmark scenarios that can be replicated. Fourth, open up the educational setting to interface with a wide range of players for collaboratively developing scenarios while maintaining schools' leading role as education providers. Fifth, raise teachers' digital literacy through ongoing training them to incorporate digital technologies in their day-to-day teaching activities, and refine the evaluation standards in this regard.

6.4.4 Develop a Well Functioning Public Service System for Digital Education Aiming at Universality, Quality and Efficiency

First, improve data governance and standards, facilitate cross-platform and cross-regional data convergence, offer big data service with open access, encourage efficient data sharing under relevant laws, and fully release the value of data assets. Second, strengthen the National Primary and Secondary School Management Platform, broaden public services and their channels of access, provide schools with easy-to-use digital management tools and communication solutions with parents, and transform towards data driven education intelligent governance. Third, build a system for enhancing student digital literacy aiming at their all-round development, and bridge the digital skill divided between student groups. Fourth, deploy digital supervision and monitoring, and conduct real time collection, evaluation and diagnosis of smart education indicators.

6.4.5 Enhance Technology Governance to Safeguard Digital Security

First, implement the Cybersecurity Law of China and other relevant regulation and policies, improve the safeguards of data and cybersecurity, timely update the systems and ensure the integrity of critical assets. Second, strengthen technology ethics, step up monitoring, early warning and regulatory responses, improve oversight over data and algorithms, and ensure the standardized and orderly integration of digital technologies into the education ecosystem. Third, conduct studies before implementing new technologies and processes in a large scale, and establish an evaluation framework to assess the readiness and feasibility of digital technologies.

Chapter 7
Report on China Smart Education Development Index 2022 (Vocational Education)

In recent years, as China makes continuous efforts to advance the construction of Digital China and the *China's Strategic Action Plan for Education Digitalization*, breakthrough progress has been made in the construction of software and hardware for smart education in the field of vocational education, increasingly highlighting the role of digital technology in facilitating teaching, learning, management, research and governance. Especially during the containment of the COVID-19 pandemic, China has built up broad consensus on the teaching of vocational education, internship and training, campus management and school-industry cooperation, in view of the concepts, approaches and methods of smart education, through which we have produced effective teaching practices under a diversified range of application scenarios. This chapter analyzes the status quo of China's smart education in the field of vocational education and suggests future development directions by constructing an indicator system and calculating development indexes.

7.1 Indicators

The Indicator System of Smart Education Development (Vocational Education) comprises 4 dimensions (environment, teaching and learning, governance and talent literacy), 12 sub-dimensions (ICT infrastructure, digital educational resources, cyber learning space, digital literacy of teachers, utilization of resources, transformation in teaching and learning practices, transformation in assessments, data accessibility, ICT-based management, cyber and data security, digital literacy of students and digital skills of laborer) and 27 indicators (see Table 7.1).

The data calculated for the China Smart Education Development Index (Vocational Education) in 2022 is mainly contributed by the relevant institutions, including

China National Academy of Educational Sciences (CNAES), *Report on China Smart Education 2022*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-99-6109-2_7

Table 7.1 Indicator system of smart education development (vocational education)

Dimension	Sub-dimension	Indicator
Environment	ICT infrastructure	Percentage of vocational schools with a broadband connection (%)
		Percentage of vocational schools with WLANs network coverage (%)
		Percentage of teachers and students with digital devices (%)
		Percentage of classrooms with multimedia device(s) (%)
	Digital educational resources	Coverage rate of majors with major-related resources provided by the Platform for Smart Education of China, Platform for Vocational Education (SEC-PVE) (%)
	Cyber learning space	Percentage of vocational schools with cyber learning spaces (%)
Teaching and learning	Digital literacy of teachers	Proportion of teachers with sufficient digital literacy (%) ★
	Utilization of resources	Percentage of active users in SEC-PVE (%)
		Effective utilization rate of resources on the SEC-PVE (%)
		Click-through rate of resources recommended to users by the SEC-PVE (%) ★
	Transformation in teaching and learning practices	Coverage rate of hybrid teaching among teachers (%)
		Coverage rate of virtual simulation resources by vocational education schools (%) ★
		Coverage rate of online personalized learning (%)
		Coverage rate of online teacher training (%)
	Transformation in assessments	Coverage rate of ICT-based assessments (%)
		Coverage rate of ICT engaged educational supervision (%)
Governance	Data accessibility	Percentage of students, teachers and schools in which the identity data was collected in (national) core database(s) (%)
		Percentage of schools in the national talent cultivation database (%)
	ICT-based management	Percentage of schools with sufficient management information system (%)
		Percentage of schools with regular ICT-based teaching policy (%)
		Percentage of schools with policy for information technology-enabled work and management (%)
	Cyber and data security	Percentage of schools with cybersecurity policy (%)
Talent literacy	Digital literacy of students	Proportion of students with sufficient digital literacy (%) ★

(continued)

Table 7.1 (continued)

Dimension	Sub-dimension	Indicator
		Percentage of students enrolled in ICT-related majors (%)
		Indices of life-long learning ability among vocational education students ★
	Digital skills of laborer	Percentage of ICT-related major graduates working on ICT-related professions (%)
		Indices of average digital skills of population between ages 16 and 74

Note ★ indicates that data is temporarily unavailable

the Department of Development Planning, the Department of Science, Technology and Informatization, the Department of Vocational and Adult Education, the Department of College Students Affairs and Educational Informatization Strategy Research Base of the Ministry of Education, as well as the Smart Education of China, Platform for Vocational Education (SEC-PVE) along with some data set forth in the report series titled Digital Economy and Society Index.

At present, 22 indicators out of the 27 indicators of the development evaluation indicator system for smart education in the field of vocational education can be collected and applied to index calculation, whereas 5 indicators out of them are unavailable or with missing data. In the course of aggregating the normalized values, if there is an alternative to the indicator with missing data, the alternative indicator will be used temporarily; if there is no alternative to such an indicator, then the indicator will not be included in the calculation at this time.

7.2 Calculation Results

China Smart Education Development Index (Vocational Education) in 2022 is estimated to be 0.74. Among the four dimensions, the development of intelligent governance and talent literacy exceeds smart education environment, teaching and learning. (see Fig. 7.1).

7.2.1 Environment

The index for environment is estimated to be 0.72, indicating that the school environment of China's vocational education has reached the early stage of intelligent development. China is progressively advancing the application of infrastructure and facilities like the Internet and digital terminals, and the country is constantly scaling

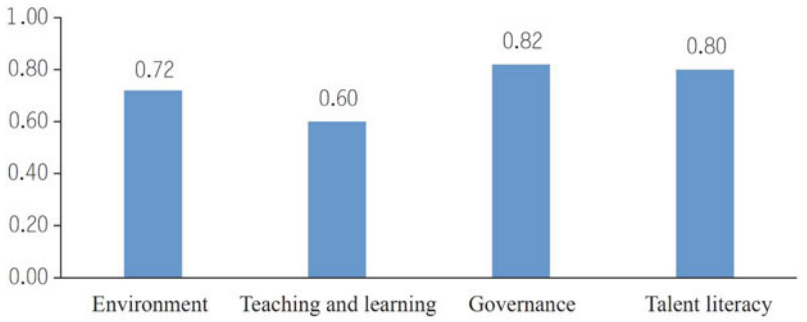

Fig. 7.1 China smart education development (vocational education) index by dimension

up the resources of digital education for vocational education. Up to 98.99% of vocational schools have been connected to the Internet and 73.49% of them have gained access to wireless networks. The classrooms with multimedia devices for teaching account for 61.68% of the total classrooms in vocational schools. Up to 67.47%[1] of the vocational education majors are covered by resources offered by SEC-PVE, and 84.97% of vocational schools and institutions now offer cyber learning spaces (see Fig. 7.2).

7.2.2 Teaching and Learning

The index for teaching and learning stands at 0.60, which reveals that the teaching and learning activities of China's Vocational Education are becoming increasingly personalized. Great changes have taken place in the education and teaching models of vocational education. To be more specific, 54.25% of teachers from vocational schools now conduct hybrid teaching by online platforms; 68.87% of students take advantage of cyber learning spaces for personalized online learning; 66.62% of teachers employ cyber learning spaces for teaching research and training. Up to 63.61% of the courses offered by SEC-PVE have been used effectively. Digital technology has been gradually applied to course evaluation and educational supervision. The coverage rate of ICT-based assessments on the curriculum resources of SEC-PVE has been lifted to 77.99%, and the coverage rate of ICT engaged educational supervision in vocational education institutions has risen to 25.65%[2](see Fig. 7.3).

[1] The data refers to the coverage rate of higher vocational education majors with major-related resources provided by SEC-PVE.

[2] The data refers to the coverage rate of ICT engaged educational supervision in higher vocational education institutions.

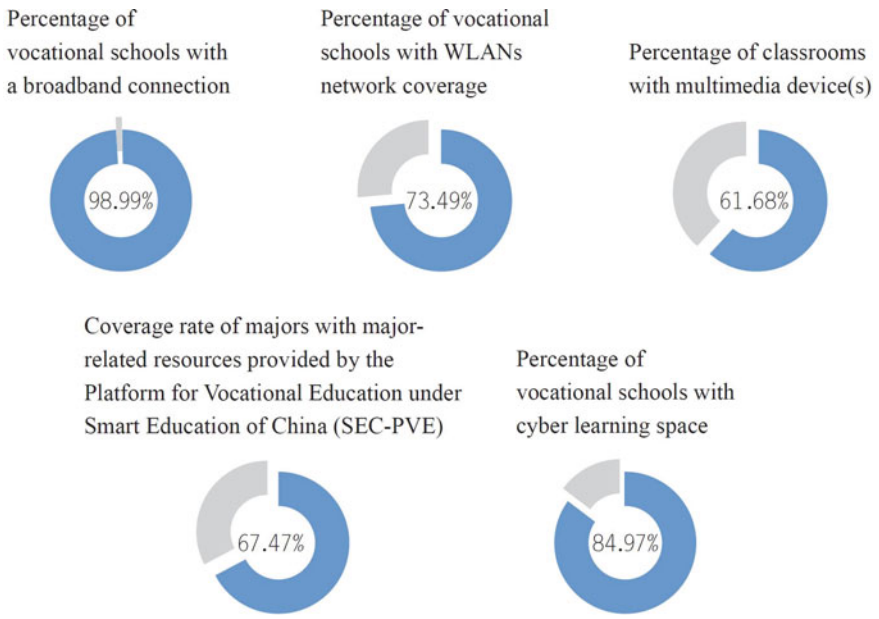

Fig. 7.2 Basic information of some indicators for environment

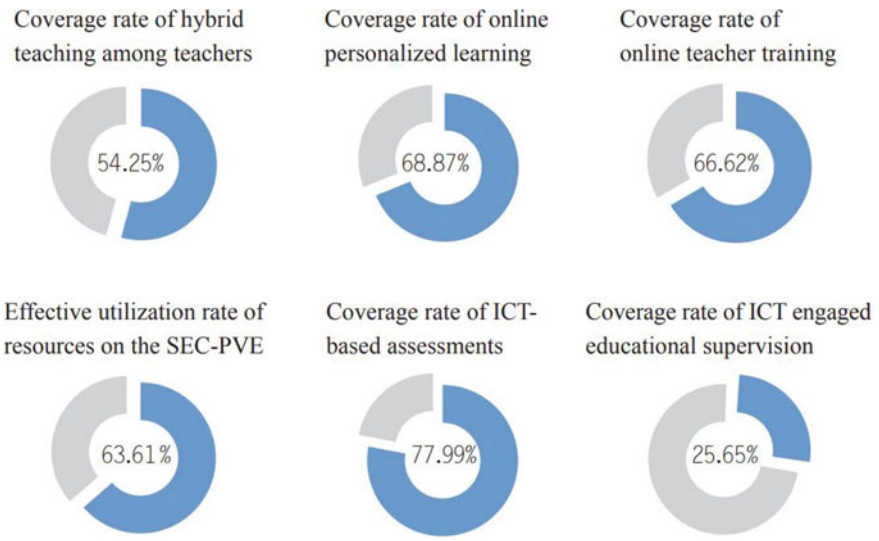

Fig. 7.3 Basic information of some indicators for teaching and learning

7.2.3 Governance

The index for governance comes in at 0.82, which shows that China's vocational education is gradually realizing intelligent governance. The basic data on vocational education is becoming increasingly sophisticated and the governance models of vocational education are undergoing constant transformation. It is transitioning from the model of "human resources-based management coupled with electronic control" to intelligent management, thereby delivering ongoing progress in governance. All the identity data of vocational education, including students, teachers and schools, are collected in national core databases. The percentage of schools covered by the national talent cultivation database has reached 100%. The share of vocational schools with a sufficient school-level management information system has climbed up to 35.82%. Up to 50.32% of vocational schools have regular ICT-based teaching policy, and 75.59% of vocational schools have instituted information technology-enabled work and management policy. Up to now, 93.73% of vocational schools have established robust cybersecurity management policy, enabling strong protection of the cybersecurity and data security of vocational education (see Fig. 7.4).

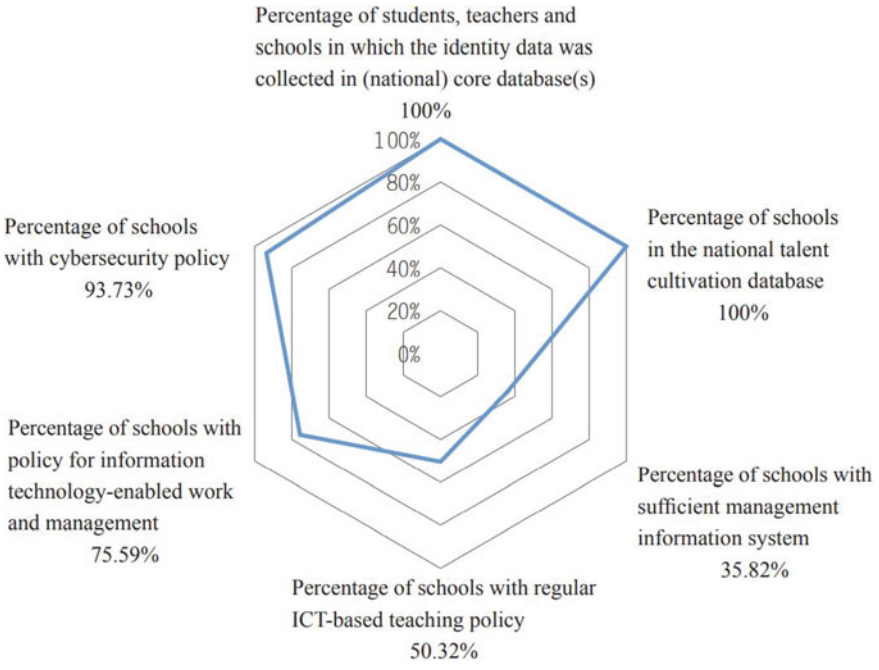

Fig. 7.4 Basic information of indicators for governance

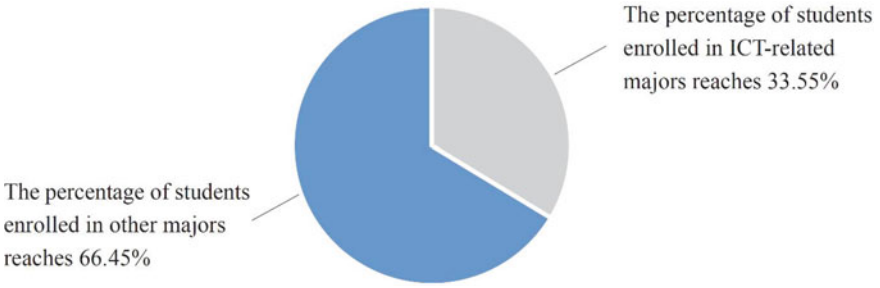

Fig. 7.5 Proportions of students enrolled in ICT-related and other majors

7.2.4 Talent Literacy

The index for talent literacy arrives at 0.80, indicating that China is working to expand the cultivation of talent with digital expertise through vocational education. The country makes continued efforts to advance the upgrading and digital transformation of vocational education programs, through which we have nurtured a large group of talent with excellent digital literacy to facilitate the development of the era. Vocational school students enrolled in ICT-related majors account for 33.55% of all students (see Fig. 7.5), and 73.41% of graduates of relevant majors find jobs in important sectors of the digital economy. Vocational education thus makes substantial contributions to the development of China's digital economy through talent cultivation. Overall, the digital human capital indices of China stands at 0.47,[3] which shows that much remains to be done to render improvements.

7.3 Achievements and Deficiencies

7.3.1 Achievements

i. Infrastructure and the education environment have been improved continuously

Efforts to speed up the digital development of vocational education are regarded as a concrete action to improve the education conditions of vocational schools, a vital move to transform the talent cultivation models of vocational education and an important instrument to achieve the high-quality development of vocational education. So far, nearly 100% of vocational schools in China have gained access to the Internet; more than 70% of vocational schools have been connected to WLANs networks;

[3] The original value of China's digital human capital comes in at 47. The standard measurement range falls between 1 and 100. To facilitate the comparison, the value of indexes is normalized between 0 and 1, yielding a converted value of 0.47.

over 7.7 million sets of digital terminals have been installed and more than 520,000 multimedia classrooms connected to the Internet have been built, paving the way to nurture more high-quality technical professionals and consummate craftsmen.

ii. The supply capacity of digital resources has been enhanced and resource sharing benefits more and more people

With a view to pushing forward China's Strategic Action Plan for Education Digitalization under the organization and coordination of the Department of Vocational and Adult Education under the MOE, vocational schools in pilot provinces have independently developed resources of digital education tailoring to local realities, through which they have introduced a large variety of high-quality resources with distinctive characteristics and achieved the joint development and sharing of high-quality resources via relevant public service platforms. The SEC-PVE was officially launched in March 2022. It has integrated nearly 32,000 online courses (more than 200 out of all the courses are virtual simulation courses) and 1317 professional resource libraries covering nearly 600 majors by the end of December. Several provinces have put in place provincial-level smart vocational education platforms which are connected to the SEC-PVE. These efforts have extended strong support to teachers and students from different regions, educational stages and vocational schools with different majors for the sharing of high-quality education resources.

iii. Online learning spaces enable the reform of teaching and learning models

China thrusts ahead with the reform of teaching and learning models through the establishment of real-name, controllable, well-organized and well-managed online learning spaces based on cloud service models. The MOE, the Ministry of Finance (MOF), the National Development and Reform Commission (NDRC), the Ministry of Industry and Information Technology (MIIT) and the People's Bank of China (PBC) printed and distributed the *Implementation Plan on the Construction of an Effective Mechanism to Expand the Coverage of High-quality Education Resources Through Information Means* in 2014 followed by several other documents, including the *2.0 Action Plan for Education Informatization and the Guidelines on Strengthening the Construction and Application of Online Learning Spaces* issued by the MOE in 2018. Under the guidance of these documents and the promotion of the annual notices issued by the General Office of the MOE on the popularization campaigns of online learning spaces, nearly 70% of teachers and students now engage in teaching and learning in online learning spaces. China is on the way to achieving the goal of "realizing universal access to online learning spaces."

iv. Smart education solutions address key challenges to internship and training

Internship and training are of prime importance to the cultivation of talent in vocational education and training. The students from vocational schools might have fewer opportunities to effectively gain firsthand experience during their internship and training in traditional model, which can also be costly and dangerous. These challenges could be addressed by applying virtual simulation technology in internship and training programs. The country has made relentless efforts to establish bases

for the virtual simulation training of vocational education. A total of 215 projects of demonstration bases for the virtual simulation training of vocational education were unveiled in 2021. Vocational schools seek to leverage digital resources, such as virtual simulations and digital twins to create teaching scenarios and design innovative teaching approaches, thus facilitating efforts to meet challenges confronting internship and training.

v. The country presses ahead with big data-driven reforms of education evaluation

As China builds big data platforms for education, administrative departments of education and vocational schools build on big data to continuously optimize analysis models, secure progress in reforms of education evaluation and thereby improve the quality of education and teaching. Big data enables more accurate education evaluation with more reliable results, given that it removes the limitations of traditional data which features a single, fragmented data source. Some vocational schools have already launched big data-enabled education evaluation to ensure their decision-making is well-founded.

vi. The universal coverage of digital monitoring has been basically achieved in vocational education

The National Data Platform for the Talent Cultivation Status of Vocational Schools, which was established in 2008, now covers all vocational schools in China. Among them, the Platform for the Data Collection and Management of the Talent Cultivation Status of Higher Vocational Schools has performed data collection for 14 consecutive years. In this way, it provides essential information for administrative departments of education to make appropriate macro decisions and make arrangements on important projects, and opens up an important opportunity for higher vocational schools to advance reforms and regulate teaching management. Furthermore, this platform provides data for higher vocational schools to draw up annual quality reports, establish resource libraries and formulate application analysis reports and other third-party evaluation. At present, the Data Management System for the Talent Cultivation Status of Secondary Vocational Schools has been connected to and matched with national-level and several provincial-level operation systems for data sharing. By keeping a record of the development trajectory of each school and regional secondary vocational education, it fully displays the educational achievements and progress trends of secondary vocational schools as well as the problems they face.

vii. Resource sharing mechanisms have been formed for vocational education

The key to developing and using high-quality digital resources lies in the establishment of resource development mechanisms and resource sharing models. At present, China has set up the following mechanisms for the development of digital resources of vocational education. The mechanism for "government projects" coordinates resource development; the mechanism for "the construction of resource bases" ensures continued and concentrated resource development; the mechanism

for "advancing coordinated joint development" hastens coordinated resource development via the National Alliance on Joint Development and Sharing of High-Quality Digital Resources for Vocational Education; the mechanism for "social solicitation of review" attracts resources from society to expand the national digital information resource library of vocational education, giving rise to a resource sharing model based on the development of the Internet. Among them, the National Professional Teaching Resource Pool for Vocational Education project launched by the MOE in concert with the MOF in 2010 has made significant contributions to expanding the professional teaching resources of vocational education and creating new models of joint development and sharing for school-school cooperation and school-industry cooperation.

viii. China advances the upgrading and digital transformation of vocational education programs

The program structure and enrollment of vocational schools are determined by the catalogues of programs, which also play an important role in observing the contribution made by vocational education to social and economic development. In 2019, the State Council printed and issued the *Implementation Plan for the National Vocational Education Reform*, which called for efforts to continuously update and develop the catalogues of programs. The MOE actively responded to the requirement of updating the programs of vocational education by issuing the *Catalogue of Vocational School Programs (2021)* in 2021. Tailored to the needs of economic and social development, and industrial transformation, this new edition included 269 new programs and adjusted over 60% of the existing programs. It has also enhanced and strengthened the program structure relating to digitalization and thereby advanced the digital upgrading and transformation of programs offered by vocational schools. Under the guidance of the catalogue, vocational schools optimize and adjust the program structure in a timely manner, advance the reform of talent cultivation and step up the training of talent with digital expertise, thus nurturing important talent reserves for the development of the digital economy in the intelligent era.

7.3.2 Deficiencies

i. The construction of infrastructure is yet to be balanced and improved

The construction of smart education infrastructure in the field of vocational education evidently lags behind that of regular higher education, in addition to the huge disparities between different regions, learning phases, schools and programs within the field. These facts pose a daunting challenge to achieving balanced high-quality development. There are few smart education application terminals for vocational education with inadequate adaptability to a variety of plug-ins and ports. Effective compatibility and conversion are yet to be achieved between different platforms. Furthermore, some regions and vocational schools struggle against poor school conditions, so they

find it hard to effectively implement the arrangements on and meet the requirements of adapting smart education to local conditions.

ii. High-quality resources of digital education remain inadequate

At present, vocational education has not yielded abundant resources for digital education, especially high-quality digital resources, so it is unable to keep up with the personalized and diversified demands of different entities in the field of vocational education. Virtual simulation courses are in short supply and are found to be ineffective, because they fail to produce a true-to-life production environment and are thereby unable to completely replace internship and training in real-world scenarios. In addition, there are not enough existing resources of digital education to cover general fundamental courses, specialized courses and practical training, so the demands of teachers and students of different learning phases in vocational education are not effectively met. Moreover, existing resources of digital education are presented in a single, traditional manner and new formats of education resources are scarce.

iii. Teachers and students have not fully understood the concepts of smart education and they have failed to make the best of smart education accordingly

Currently, smart education is still very much in its infancy. It needs to be continuously enriched and improved in education and teaching practices. The teachers and students from vocational schools have not developed a deep understanding of the concepts of smart education and are not highly-motivated to apply those ideas to the reform of teaching models and tap into the curriculum resources of smart education. For this reason, the advantages of smart education have not been brought into full play in teaching procedures, so it has not yielded remarkable results yet. Given the use of the SEC-PVE, approximately 839,200 teachers and students from vocational schools log in at least once a week. However, the total size of this group far outnumbers that figure, which indicates that there are still too few active users. Differences in their understanding of the concepts of smart education and the use of resources have, to a certain extent, resulted in polarized effects of education and teaching.

iv. The supervision on digital education in vocational schools lacks coordinated plan and security guarantee

Some vocational schools have promoted the construction and development of digital campuses without clear goals or visions or any systematic thinking over the goals, requirements, key contents or priorities, which explains the ubiquitous preference of construction to application in their endeavors. The planning, design, construction and implementation of digitalization in some schools rely on social enterprises or groups with outstanding cybersecurity and information security issues in lack of due attention to the operations and maintenance of the digital facilities and systems as well as security management.

v. The digital skill training system in vocational education urgently needs to be improved

According to the serial report of *The Digital Economy and Society Index* released by the European Commission, the digital skills of Chinese workers are moderate and there remains much room for improvement. Despite the fact that China is focusing on building a lifelong learning system for digital literacy across the country through the implementation of such policies as the Action *Outline for Upgrading Digital Literacy and Skills of the General Public* and the *14th Five-Year Plan (2021–2025) for National Informatization*, within the short time, there is little effect over the enhancement of digital literacy and skills training system in vocational education that urgently needs to be improved.

7.4 Development Recommendations

7.4.1 Optimizing the Investment in the Resources of Smart Education and Continuously Advancing Infrastructure Construction

i. Increasing effective investment and intensifying system-wide innovation

Further efforts will be made to coordinate resources in accordance with the principle of "continuously increasing the total and scientifically raising the proportion", keep expanding effective investment in smart education and accelerate the infrastructure construction of smart education in vocational schools. It is suggested to speed up the development of relevant standards or norms for smart education in vocational schools across the country and strengthen the investigation and supervision on their development of smart education. The regulations on originality, resource and copyright as well as incentives and sharing mechanisms for digital education need to be further improved. Meanwhile the enthusiasm and inclusion of stakeholders in smart education needs to be boosted.

ii. Increasing the supply of excellent resources in a demand-oriented approach

In-depth elements of smart education in vocational schools should be excavated based on the actual needs of relevant subjects in line with local conditions, different stages and levels, school-side classification and people-oriented policy implementation. On the one hand, it is necessary to revitalize the existing massive resources to sort out, screen and extract more high-quality ones that are popular among teachers and students for their wide application in teaching; on the other hand, efforts shall be made to increase high-quality supply with more efficiency and less redundancy. Increasing the number of such high-quality courses as virtual simulation and using virtual simulation training platforms and courses more frequently is suggested to help high-level development of practical training in vocational schools. It is better

to adopt the model of joint construction and shared benefits to dynamically generate a large number of high-quality digital resources in various forms and realize in-depth application and aggregation of high-quality digital resources. Efforts will be made to improve the national management system for smart education in vocational schools and to promote the formation of a comprehensive system with high-quality resources flowing from school development and application to provincial application and evaluation and then to national sharing.

7.4.2 Enhancing the Digital Literacy of Teachers and Students and Boosting User Activation of the Platform

i. Enhancing the digital application ability of teachers and students

Effort should be made to popularize the concept of smart education to teachers and students in vocational schools and enrich the paths of and methods for smart education. It is of great significance to improve the digital literacy and skills of teachers and students, comprehensively enhance their digital adaptability, competence and creativity and promote the integration of digital technology into teaching to innovate teaching forms, improve teaching quality and prevent "online teaching from becoming another version of offline education" and widening gaps among the students.

ii. Increasing the number of active users on the platform for smart education

It is suggested to further coordinate resources according to vocational education program categories, improve the system, integrity and overall quality of courses and provide better support of online teaching platforms for the mixed teaching environment. Effort should be made to further break down the needs of users, learn from the push mechanism of commercial platforms and establish a mechanism to actively push relevant courses to users for their better utilization. More active feedback from the course learners would help improve the mechanism for credit certification and conversion and encourage users to take the initiative in application.

7.4.3 Establishing a Digital Governance System and Setting up Digital Management Mechanisms

i. Establishing a digital governance system featuring law-based independence, democratic supervision and social participation

As of now, China has formulated relevant policies, laws and regulations to promote the digitalization of vocational schools, but it still needs to further strengthen the

implementation, promote the construction of a digital governance system, increase the participation of multiple subjects and make full use of existing digital resources under the leadership of the government to establish a self-diagnosis, feedback and improvement mechanism for personnel training in vocational education and provide a guarantee for the sustainable and sound development of digital vocational education.

ii. Improving digital management mechanism and enhancing the literacy and capability of digital management

Vocational schools should focus on the implementation of the Specifications for the Construction of Digital Campuses in Vocational Schools, formulate and improve the digital campus construction plan, do a good job in the overall design of the management for the information system and build an environment for the application of data concentration and system integration. Effort should be made to establish digital management systems and specialized agencies, determine full-time personnel and advance the management system for applying information and technical support services. In order to improve the management capacity of vocational schools, it is suggested to strengthen the digital awareness and application ability of management personnel and enhance the use of information technology to record, update, collect, analyze and diagnose various data.

7.4.4 Promoting Digital Education and Improving Training Systems for Digital Skills

i. Formulating a national frame for the development of digital literacy

The country should design and formulate a national framework, develop a supporting system for systematic, scientific, and professional improvement of digital literacy and enhance the awareness and ability to access and use digital resources for all. Effort should be made to actively explore national standards for digital skills in vocational education based on national conditions and integrate them as a professional ability into the assessment.

ii. Promoting the digital transformation of school education

Vocational schools should strengthen the construction of digital-related programs, provide compulsory digital courses, promote the construction of high-quality digital courses and practical training bases to provide a good external environment for students to improve their digital literacy. Effort should be made to improve the digital talent training mechanism, incorporate students' digital literacy into the overall quality evaluation, encourage students to use digital technology to innovate and start businesses and guide their learning and application of digital skills.

iii. Improving the digital skill training system in vocational education

At the national level, it is suggested to increase the intensity and breadth of digital skills in vocational training, develop training standards and contents according to industries and job characteristics for the cultivation of digital skills and standardize digital skills in vocational training. Effort should be made to build a number of digital learning service platforms, integrate and enrich online training in the digital economy and digital society area, open public courses for the training of digital skills to all, especially workers and build a lifelong digital learning system for all.

Chapter 8
Report on China Smart Education Development Index 2022 (Higher Education)

Developing smart education is the first and foremost move to implement strategies set out at the 20th CPC National Congress, the strategy for invigorating China through science and education, the workforce development strategy, and the innovation-driven development strategy. It opens up new areas and arenas to accelerate the modernization of education and build a country strong in higher education, fostering new edges and injecting new momentum for running education to the satisfaction of the people and building a high-quality education system. Currently, the comprehensive application of the new-generation information technology, artificial intelligence in particular, in the field of higher education has accelerated the restructuring, reshaping and refactoring of the elements, processes and links of higher education. A slew of improvements such as technical support in teaching and learning environment, platform for educational resources sharing, and refined services and management have boosted holistic transformation in various aspects, including the philosophy of higher education, teaching modes and governance of education. The reform of talent cultivation in universities is thus empowered, directing higher education towards a new form of smart education. This chapter looks into progress made in smart education in higher education, providing valuable reference for sustainable development.

8.1 Indicators

The Indicator System of Smart Education Development (Higher Education) includes four dimensions: environment, teaching and learning, governance, and talent literacy. Twelve sub-dimensions and several indicators are included. Experts' suggestions from administration departments, China Association of Higher Education, higher

China National Academy of Educational Sciences (CNAES), *Report on China Smart Education 2022*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-99-6109-2_8

educational institutions, research institutions and other relevant entities are considered. Eventually, the Index settles with 26 representative indicators that are both accessible and groundbreaking. See Table 8.1 for details.

The four dimensions covering major aspects of the development of smart education in higher education are as follows:

The first dimension focuses on the infrastructure, resources and environment for teaching. For sub-dimensions, "ICT infrastructure" looks into infrastructure and equipment supporting smart education; "Digital educational resources" zooms in on the availability of digital educational resources; "Smart education environment" presents the application of new-generation IT in the development of smart campus.

The second dimension exhibits the application of new-generation IT in teaching and learning of higher education. For sub-dimensions, "Digital literacy of teachers" is the pillar of teaching; "Utilization of resources" reflects the effective use of digital resources and the active degree of platform users; "Transformation in teaching and learning practices" demonstrates the impact of new-generation IT on the innovation of teaching forms; "Transformation in assessments" evinces progress being made in IT-aided formative assessments and innovations on assessment measures such as credit recognition of online education.

The third dimension sets forth the optimization of intelligent governance of education driven by technologies. For sub-dimensions, "Data accessibility" sheds light upon the data infrastructure construction and overall data management; "ICT-based governance" manifests the improvement of governance efficiency and service quality through adopting the new-generation IT; "Cyber and data security" represents the prerequisite for intelligent governance.

The fourth dimension showcases the leading role played by smart education to realize goals of talent cultivation and its social spillover effect. For sub-dimensions, "Digital literacy of students" shows graduates' ICT-related competency and the fruits of ICT talent cultivation; "The labor force digital skills" introduces the ICT talents channeled into the market.

The data for measurement mainly comes from the departments of Ministry of Education, such as Department of Development Planning, Department of Science, Technology and Informatization, Department of Higher Education, Educational Informatization Strategy Research Base, Center for Scientific Research and Development in Higher Education Institutes of Ministry of Education, Education Quality Evaluation Agency of Ministry of Education, and other relevant institutions, as well as Smart Education of China, Platform for Higher Education (SEC-PHE), the official website of Ministry of Education, and *Global Competitiveness Report 2019*.

In the process of index synthesis, indicators for which data cannot be collected are temporarily excluded from the calculation, so are indicators for which data can be collected but theoretical optimal values are not available. At present, there are three indicators in the index with no data yet and five indicators with no theoretical optimal value. Therefore, a total of 18 indicators are included in the index measurement, and the data of the remaining indicators are presented in the form of descriptive analysis.

Table 8.1 Indicator system of smart education development (higher education)[1]

Dimension	Sub-dimension	Indicator
Environment	ICT infrastructure	Percentage of universities and colleges with mobile broadband connection (%)
		Percentage of universities and colleges with WLANs network coverage (%)
		Percentage of classrooms with multimedia device(s) (%)
	Digital educational resources	Number of open digital resources for higher education (pieces)
		Number of open digital curricular resources for higher education (number of courses)
	Smart education environment	Percentage of universities and colleges using new generation of technologies in smart campus construction (%)
Teaching and learning	Digital literacy of teachers	Proportion of teachers with sufficient digital literacy (%) ★
	Utilization of resources	Effective utilization rate of curricular resources on the Smart Education of China, Platform for Higher Education (SEC-PHE) (%)
		User activity indices of the SEC-PHE (time/person)
	Transformation in teaching and learning practices	Coverage rate of hybrid teaching among universities and colleges (%)
		Percentage of universities and colleges using data center in monitoring and analyzing teaching and learning practices (%)
		Percentage of MOOCs shared on foreign open-access platforms (%)
		Percentage of universities and colleges utilizing AI-related technology in education (%)

(continued)

[1] The Indicator System of Smart Education Development (Higher Education) is not exactly the same as that of basic education and vocational education. Indicators not applicable to the context are excluded, such as the number of digital devices per teacher, the percentage of teachers with online learning space, the percentage of students with online learning space, the coverage rate of online teacher training, the coverage rate of ICT engaged educational supervision. By contrast, indicators embodying the development trend of smart education in higher education are included, such as the percentage of universities and colleges using new generation of technologies in smart campus construction, the percentage of universities and colleges using data center in monitoring and analyzing teaching and learning practices, the percentage of MOOCs shared on foreign open-access platforms, the percentage of universities and colleges utilizing AI-related technology in education, the percentage of universities and colleges which can transform online credits to institutional credits, the percentage of universities and colleges with a data center, the coverage rate of one-stop administrative service system(s), the coverage rate of ICT-based scientific research service system(s), the percentage of university and college graduates using Smart Education of China, National Service Platform for College Student Employment, etc.

Table 8.1 (continued)

Dimension	Sub-dimension	Indicator
	Transformation in assessments	Coverage rate of ICT-based formative assessments (%)
		Percentage of universities and colleges which can transform online credits to institutional credits (%)
Governance	Data accessibility	Percentage of universities and colleges with a data center (%)
		Percentage of universities and colleges with multi-platform data coordination (%)
	ICT-based governance	Coverage rate of one-stop administrative service system(s) (%)
		Percentage of universities and colleges with ICT-related policy (%)
		Coverage rate of ICT-based scientific research service system(s) (%)
		Percentage of university and college graduates using Smart Education of China, National Service Platform for College Student Employment (%)
	Cyber and data security	Percentage of universities and colleges with cybersecurity policy (%)
Talent literacy	Digital literacy of students	Proportion of graduates from ICT-related majors (%)
		Proportion of graduates passing digital literacy tests (%) ★
		Students' lifelong learning ability ★
	The labor force digital skills	Index of digital skills among economically active population

Note ★ Indicates that data is temporarily unavailable

8.2 Calculation Results

The China Smart Education Development Index (Higher Education) in 2022 is 0.79, reaching a high level and demonstrating the guiding and pioneering importance of smart education in higher education in China. In terms of the scoring of the sub-dimensional index (see Fig. 8.1), the level of smart development in terms of the environment is relatively the highest, followed by the level of development in terms of talent literacy and governance, and the level of smart development in terms of teaching and learning implementation is relatively low.

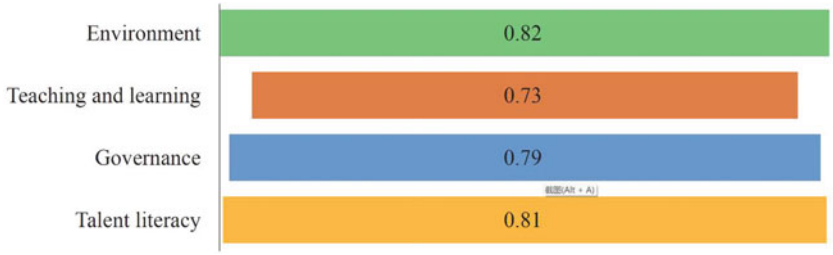

Fig. 8.1 China smart education development index (higher education) by dimension

8.2.1 Environment

The environment index is 0.82, indicating the outstanding achievements in the development of smart education in higher education in terms of ICT infrastructure and digital educational resources. For one thing, the ICT infrastructure of colleges and universities can meet the basic needs of smart education, the Internet access in colleges and universities reaches 100, 76.85% of colleges and universities have been fully covered by WLANs network, the percentage of classrooms with multimedia device(s) is 60.28%, and the percentage of universities and colleges using new generation of technologies in smart campus construction reaches 89.22%. For another, there are abundant digital resources in higher education, with 318,700 digital courses, such as MOOCs, resource-sharing courses and open video courses, open and shared on public platforms provided by higher education institutions. By the end of December 2022, the number of online MOOCs had exceeded 64,500, with 1,088 million participants. 27,000 high-quality MOOCs, and more than 65,000 textbooks, courseware, cases and other digital resources from more than 20 public platforms are underpinned by the SEC-PHE. The platform also links to iCourse and xuetangX, which are two international platforms for online teaching and learning, offering nearly 1,000 multilingual courses to the world.

In terms of the percentage of universities and colleges with WLANs network coverage (see Fig. 8.2), the maximum is 91.67% and the minimum is 40.00%. Most provinces see the rate between 70 and 90%, with 16 provinces higher than the national average.

The percentage of classrooms with multimedia device(s) is shown in Fig. 8.3. The maximum is 81.31%, and the minimum is 44.56%. Most provinces see the rate between 50 and 70%, and there are 15 provinces above the national average.

8.2.2 Teaching and Learning

The index of teaching and learning is 0.73, reflecting further improvement yet to be made in incorporating the underlying environment of smart education into reform in

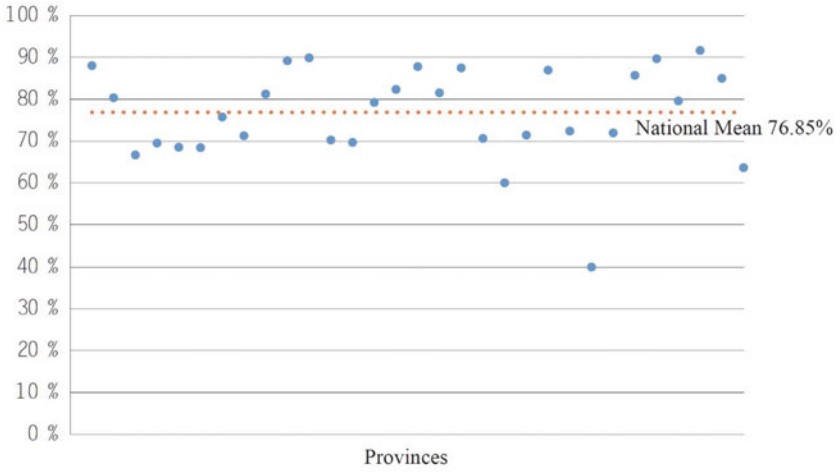

Fig. 8.2 Percentage of universities and colleges with WLANs network coverage by province[2]

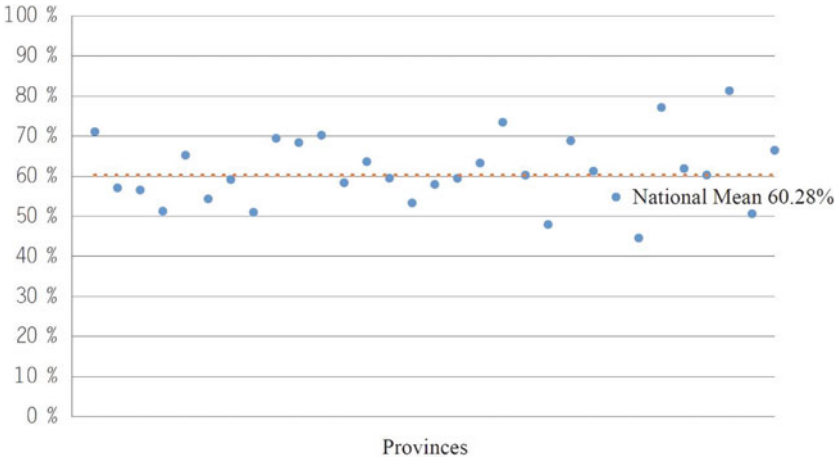

Fig. 8.3 Percentage of classrooms with multimedia device(s) by province

teaching and learning and innovation in higher education, but some indicators showcase that the trend of "application matters" is emerging. For example, the resources of the SEC-PHE are fully used, with the effective utilization rate of curricular resources on the SEC-PHE reaching 76.51% and user activity indices of the SEC-PHE at 31.03 times per person. By the end of December 2022, the total number of students enrolled in SPOC has reached 1.24 billion. The "Introducing MOOC to the West Program" has

[2] Scattered points in Fig. 8.2 represent the data of 31 provinces nationwide, which are treated anonymously in this report, as are those in Figs. 8.3, 8.5 and 8.6.

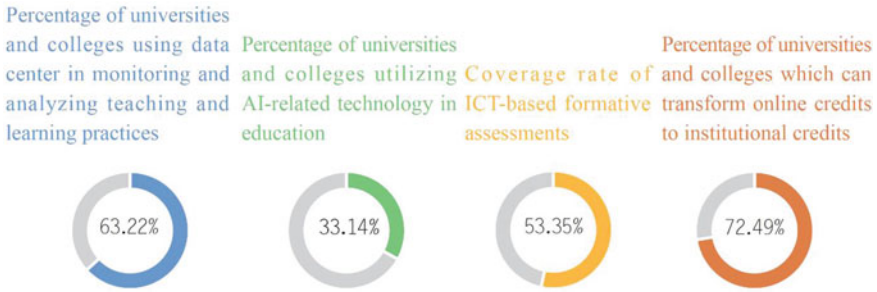

Fig. 8.4 Some indicators related to evolution in teaching and learning

provided 183,900 MOOCs and custom-made courses to all the colleges and universities in western China, and helped the western area to carry out hybrid teaching and learning activities 3.78 million times. Around 4.28% of MOOCs of Chinese universities and colleges are openly accessible on overseas platforms.

The application of new technologies has triggered evolution in teaching and learning. Coverage rate of hybrid teaching among universities and colleges has reached 100%. Around 63.22% of universities and colleges use data center in monitoring and analyzing teaching and learning practices, and 33.14% of universities and colleges utilize AI-related technology in education. Assessment of teaching and learning has gradually undergone digital transformation, the coverage rate of ICT-based formative assessments in universities and colleges has reached 53.35, and 72.49% of universities and colleges can transform online credits to institutional credits, as shown in Fig. 8.4.

8.2.3 Governance

The governance index is 0.79, at a high level. Around 97.30% of colleges and universities have established ICT-related policies, 73.81% of colleges and universities have built school-level data centers, and 99.04% of information systems of colleges and universities could achieve integrated management of data. Around 56.85% of colleges and universities could provide one-stop administrative services, and 81.44% of colleges and universities could provide ICT-based scientific research services.[3] Among university graduates, 48.23% have registered with the Smart Education of China, National Service Platform for College Student Employment (https://24365.ncss.cn/). The data of basic teaching and learning conditions of 1238 general undergraduate and 32 vocational undergraduate institutions nationwide have been incorporated into the national data platform for monitoring the quality of higher education,

[3] Digital research services include collaboration and exchange of research projects, sharing of research experiment data, online booking of large instruments and equipment, sharing of scientific lite-rature, and high-performance computing.

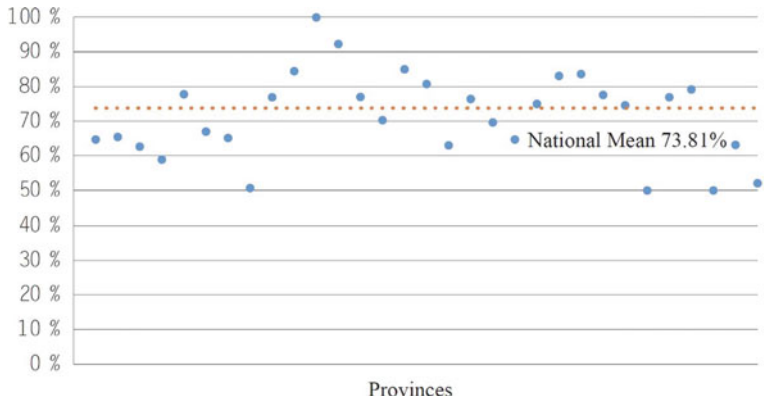

Fig. 8.5 Percentage of universities and colleges with a data center by province[4]

contributing to annual monitoring of the quality of teaching and learning. Cyber and data security is highly valued, with 98.03% of colleges and universities having established a sound cybersecurity policy. Chinese higher education has actively participated in global governance. China has initiated and established the Global MOOC and Online Education Alliance, implemented mutual recognition of credits in 13 world-renowned universities in 11 countries, offered 168 integrated courses and expanded its international influence.

The percentage of universities and colleges with a data center is shown in Fig. 8.5. The maximum is 100%, and the minimum is 50.00%. The coverage rate of school-level data centers in most provinces is between 60 and 85%, with a total of 16 provinces above the national average.

In terms of the coverage rate of one-stop administrative service system(s) by province, the maximum is 100%, and the minimum is 31.25%, as shown in Fig. 8.6. The standard deviation among provinces is 0.179, showing relatively large differences in coverage across provinces. Eighteen provinces are above the national average.

[4] The data for this indicator is divided into those covering colleges and universities directly under central government departments and colleges and universities under provincial governments. The sub-provincial data does not include those of colleges and universities directly under central government departments, and no school-level data is provided to categorize the overall data for colleges and universities directly under central government departments by province. Therefore, the national average in Fig. 8.5 includes both colleges and universities directly under central government departments and colleges and universities under provincial governments, but the sub-provincial values only include colleges and universities under provincial governments, and colleges and universities directly under central government departments are not included in the calculation of sub-provincial coverage.

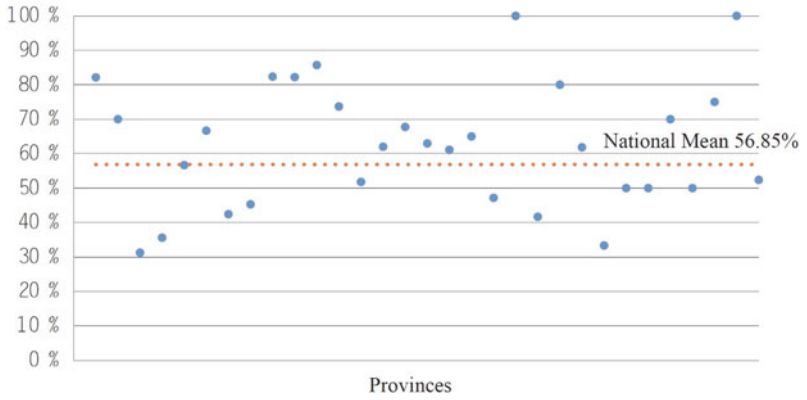

Fig. 8.6 Coverage rate of one-stop administrative service system(s) by province

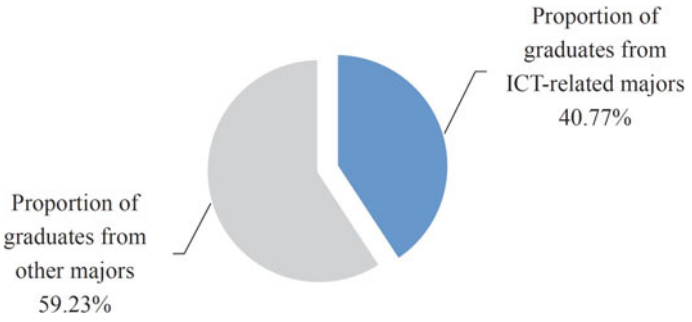

Fig. 8.7 Proportion of graduates from ICT-related and other majors

8.2.4 Talent Literacy

The talent literacy index stands at a high place of 0.81. The proportion of graduates from ICT-related majors of colleges and universities in 2021 is 40.77% (see Fig. 8.7), which ranks high in the world. However, further integration of digitalization related technologies into the student development of the various disciplines is needed in the future. At the society level, the index of digital skills among economically active population reaches 0.62,[5] ranking the top one-third globally. The structure and scale of higher-education talent-development disciplines have better met the development needs of the digital economy and provided the necessary human-resource support to turn China into a digital power.

[5] The original value of the index of digital skills among economically active population is 4.7 and the standard range for the measurement is [1, 7]. For visual comparison, the indicators are all norma-lized to the range [0, 1], and the normalized value is thereby 0.62.

8.3 Achievements and Deficiencies

8.3.1 Achievements

First, a smart learning environment for higher education is established, featuring a learning network for all, which comprises digital resource platform of various levels in different categories. China's effort at informatization provides a ubiquitous learning environment conducive to smart education. Facilities and equipment based on new-generation IT are popularized, and national, regional, university and private sector digital resource platforms offer users a more customized, open and interactive learning environment where "learning is available at anyplace at any time". Digital resource platforms, SEC-PHE in particular, are cornucopias of quality education resources. They offer higher education courses and teaching services to students and faculty of higher educational institutions as well as other learners, realizing education for all. The SEC-PHE, the largest, most comprehensive of its kind with the largest number of users, offers easy access to quality resources from universities, teachers, and courses both home and abroad.

Second, smart educational resources and application can be co-created and shared across time and space, and new technologies such as AI are promoting innovation in higher education. China's smart education has emerged from the preliminary stage of system building, marching into the phase of application, in which technologies are put into practice in a more in-depth manner. Colleges and universities in China are promoting the deep integration between new-generation IT and education and are pursuing reform and innovation of educational philosophy and methods. The teaching and learning modes in colleges and universities are becoming more diversified and individualized. MOOCs and SPOCs have emerged in large numbers and online teaching has become the new normal. Education assessment, empowered by technologies and supported by big data, is going through formative assessments. It has become both more comprehensive and more targeted. Quality educational digital resources can be shared at a larger scale: it plays a vital role not only in facilitating online teaching during the COVID-19 pandemic, but also in supporting programs aiming to promote education equality in less affluent central and western regions through resources sharing. Smart education stimulates the coordinated development of China's higher education, which bolsters its responsibility, vision, quality, and brand by serving China's socioeconomic development.

Third, a sound system of higher education digitization is being established, and big data is boosting education governance. Integrated with smart education, governance of higher education is improved, informatized and systematized, with new models emerging. Cyber and data security is given adequate attention and guaranteed by the system. The information barrier is broken by data accessibility, data centers and data coordination. The governance system provides administrative department for education and colleges and universities with teaching, learning, research and administration services, which are accurate, science-based and efficient.

Fourth, digital capabilities trainings are offered in multiple disciplines at scale, and the labor force is equipped with high digital literacy, supporting the country's path toward digitalization. After decades of informatization in the education sector, the disciplinary structure and scale of higher education have become more compatible with the development of digital economy. Faculty and students have shown relatively high digital and IT literacy, by applying new technologies to teaching and learning. During the outbreak of the COVID-19 pandemic, all colleges and universities in China were capable of conducting all the teaching online. Moreover, the high digital literacy of China's workforce has narrowed the digital divide, boosted the digital economy, and stimulated China's digitalization process.

Fifth, smart education acquires the share of China's voice in higher education, with the country's MOOCs and online teaching setting a new mode in the field. The number of MOOCs offered by China and their application scale rank first in the world, which has become a milestone in China's higher education going global. China's MOOCs available exceed 64,500, with more than 1,088 million views. The SEC-PHE provides services in 166 countries and regions. By accessing iCourse and xuetangX, both of which are global online education platforms, students both home and overseas can learn more than 1,000 courses in various languages. Further, more than 100 courses are offered to counties such as Indonesia for free. China's higher education's increasing global influence can also be seen in Global MOOC and Online Education Alliance, which is proposed and established by China. China has hosted more than 50 global online education exchanges and has launched global open courses. All these showcase smart education's role in enhancing China's voice in higher education in the world.

8.3.2 Deficiencies

First, smart education has seen disproportionate development in infrastructure construction. Despite the accomplishments in college and university's informatization and the satisfaction of the essential requirements of smart learning environment, the infrastructure of central and western China still lags behind. The WLANs network coverage among colleges and universities and the popularization of web-based multimedia classrooms are still substandard. Surveys have also revealed that during the COVID-19 pandemic, some online education platforms and systems of colleges and universities experienced problems in fluency, stability, and usability.

Second, new technologies are not sufficiently applied in education. The amount and application of quality resources offered by the Smart Education of China platform still have room for improvement, given the large population and the increasing diversity of people's demands. The platform is still expected to have the function of accurately pushing personalized resources, and the interactive application function needs to be optimized. The misuse and lack of usage of information technology can be seen in teaching: some teachers are not motivated enough to keep up to the changes brought by smart education reform; the effect of new technologies on teaching is not

yet satisfactory; some colleges and universities and disciplines have not yet found proper scenarios for the application of new technologies.

Third, gaps in higher education governance lie in coordination and accuracy. Assisted by digital technologies, Chinese colleges and universities have established a smart education governance system featuring integrated data, upgraded services, and high-level security. However, improvements are still needed in the following areas: (1) coordination between educational entities; (2) a system that allows non-governmental sectors such as businesses to participate in digital resource development, and the research and application of technologies; (3) cooperation in digital governance of colleges and universities across departments, fields, and levels; (4) science-based decision making and customized services; (5) the establishment and implementation of a assessment and decision making system based on technologies such as the big data; (6) the coverage of one-stop administrative services of colleges and universities and the employment service of public platforms.

Fourth, not enough attention is given to the ICT literacy of faculty and students. The mass scale online teaching during the COVID-19 pandemic has proven that the faculty and students are equipped with basic IT skills, but given the rapid development of IT and digital society, people's digital literacy requires constant upgrading, in which higher education should be playing a greater role. The gaps are twofold. First, there isn't a standardized tool to assess faculty, students and the whole population's digital literacy. Second, a gap exists in trainings related to digital literacy. Current trainings cover the fundamentals but are neither systematic nor targeted enough.

8.4 Development Recommendations

8.4.1 Optimize Smart Education Platforms for Efficient Use of High-Quality Resources

More resource platforms should be built on national, regional, college and other levels. Infrastructure should not be left vacant and should be used more effectively. Platforms should be more interactive and offer customized content services, to better meet the needs of students, faculty and the self-taught, and provide them with more diversified public education resources with easier access and higher efficiency. Stakeholders should coordinate and contribute to quality digital resources on these platforms. New mechanisms should promote interconnectivity of platforms along with their resources, so that digital educational resources are better shared and applied. Colleges and universities should shift from the establishment to the application of platforms, and not only the popularization but also the deep application of the platforms should be considered.

8.4.2 Promote Digital Technology Application to Synergize Educational Innovations

New digital education philosophy is needed to fully leverage technologies such as AI and create an education environment incorporating multiple dimensions (for instance, offline courses or MOOCs). Research should be conducted on the teaching and learning in the age of intelligence, to promote the application of new technologies in teaching, and the comprehensive and in-depth synergy of digital technology and education. New teaching modes should adopt smart pedagogy empowered by technology and innovative teaching methods such as online flipped classrooms, hybrid education and situational teaching, to stimulate the establishment of quality education that is smart, customized and student oriented.

8.4.3 Step up Coordination for Intelligent Governance of Education

Coordinated governance across departments, fields, and levels should be pursued to break digital barriers and free information from isolation. Improvements in digital certification system are needed, including shared digital review, clarification on the property and scope of digital sharing, and standardized sharing procedures, to ensure the appropriate and effective usage of technologies in governance. Assisted by digital empowerment, coordination and technology, governance should be directed toward a path featuring common participation of stakeholders, clear division of power and responsibility corporation and coordination. A data-based assessment and decision-making system should be established with the support of big data of education, to provide customized contents and more accurate, science-based governance.

8.4.4 Enhance Digital Literacy for All and Improve the Competence of Digital Talent

A digital skill framework should be established to meet the needs of digital society. The framework should include assessment tools for digital literacy, sound plans for digital talent development to improve the digital literacy of the faculty, students as well as the population at large. The structure of disciplines and majors should be adjusted to better integrate with technologies related to digitalization. Reforms in higher education should be carried out via platforms such as the SEC-PHE. A series of digitalized core courses, textbooks and resources for practice needs to be provided, so as to improve the competence of digital talent, which is conducive to the digital economy and China's digitalization.

8.4.5 Acquire Share of Voice on Smart Education, and Take International Leadership in Higher Education

Measures should be taken to improve international online education platform, improve the quality of online courses, popularize credit recognition of online courses, establish national brand, and present to the world quality educational recourses, so that more high-caliber courses taught by prominent teachers can go global. China should actively participate in global educational governance, involve in the making of international standards for digital education, and acquire its share of voice on smart education via international forums such as Global MOOC and Online Education Alliance. The country should also adopt new ways of international exchanges and cooperation. To elevate China's influence of higher education, the sector should share its experiences on smart education with the rest of the world.

In conclusion, China's higher education sector has witnessed remarkable accomplishments in smart education. The pivotal role of smart education can be seen in speeding up educational modernization, strengthening higher education, promoting educational equity and learning society, supporting China's digitalization, and enhancing the country's voice in higher education. Therefore, great efforts should be made for its improvement.

Epilogue

The second centenary goal has set China off on a new journey toward a modern socialist country in all aspects. It is in this spirit that the Communist Party of China (CPC) convened the 20th National Congress, which takes the pulse of a fast-changing world and sheds insight into how society develops. At the conference, a blueprint for Digital China, smart society, and education digitalization was outlined, calling for efforts to turn China into a modern country strong on education in the Chinese way. Going forward, China will work faster to roll out smart education, ushering in a reform of the Chinese education sector. Yet, it is crucial to see that smart education, which remains a less-explored territory.

There should be a common emphasis on the collaboration between smart education and digital society. China needs to pool strengths to enable extensive sharing of digital education resources in and outside schools, improve the digital literacy of its people, and train more digitally innovative talents. The integration of education, technology, and industry chains is key to building an open, sound, resilient system for smart education and ensuring that smart education goes hand in hand with digital society.

Another focus of attention should be the integration of smart education and digital technologies. China should work faster to develop a new set of rules, standards, and regulatory frameworks compatible with the digital environment. This could help ensure the use of education resources, algorithms and data is ethical, non-discriminating, and orderly and give rise to new forms of education that are safe, inclusive, and sustainable.

Last but not least, China should pay attention to new traits and trends that emerged during the development of smart education. It is vital to spark more discussions on how smart education could transform traditional education philosophy, teaching methodologies, and organization patterns to facilitate the paradigm shift in education and herald a new wave of the learning revolution. Digital technologies should play a role in driving the growth of smart education and striking a balance among quality, equality, and efficiency.

China National Academy of Educational Sciences (CNAES), *Report on China Smart Education 2022*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-99-6109-2

As a Chinese saying goes, a knowledgeable man should know everything from the heaven above to the earth beneath, just as a ray of light shall shine in all directions. Digital civilization gives us endless hopes for the future. We humans are a community of shared destiny. That is why building a digital society and fostering digital natives requires all of us to work together toward smart education. In this regard, the following three initiatives are proposed.

First, building common understanding. Smart education is new, and humanity knows little about its intrinsic patterns and external influence. It is, therefore, advisable to conduct joint research on smart education to deepen the understanding of its patterns and roles. Holding regular meetings at the global level and setting up dedicated international academic organizations and professional journals would be a good way to further understanding on the fundamental characteristics and pluralistic values of smart education. This could contribute to a broad consensus on smart education and pool strength for a shift in the education paradigm.

Second, creating an enabling environment. A high-quality smart education system needs fast roll-out and a robust global education ecosystem. Joint actions, therefore, are recommended to build an international smart education coalition and improve smart education facilities and equipments, standards and norms, ethical construction and other ecological conditions. It is also crucial to help developing regions and countries improve their digital education infrastructure, create common standards for areas related to smart education, align digital education regulations and optimize smart education governance system. This could lead to greater connectivity in smart education worldwide.

Third, expanding international cooperation. Digital technologies are the bedrock for smart education, which features diverse data applications and sharing. This calls for the collective creation and sharing of digital education resources and a renewed commitment to a global community of smart education. As digital technologies integrate deeper into education, countries will be able to draw on each other's strengths, allowing smart education to benefit all.

China has made great headways in bolstering education informatization. Today, digital technologies are penetrating further and deeper into education at an unprecedented speed, thus laying the groundwork for China's transition to smart education. As China moves toward a modern country with a strong education sector, smart education must and will see greater growth. To advance smart education, China must learn from the world and make its due contribution.

Appendix A
Explanations for the Indicator System of Smart Education Development

1. Percentage of educational institutions with a broadband connection, including both fixed and mobile (%)

Definition: The percentage of educational institutions with a broadband connection, including both fixed and mobile refers to the percentage of educational schools connected to the Internet in the total number of educational institutions connected to that level.

Formula: Percentage of educational institutions with a broadband connection = number of schools connected to the Internet/total number of schools × 100%

Data source: Ministry of Education, Department of Development Planning.

2. Percentage of educational institutions with WLANs network coverage (%)

Definition: The percentage of educational institutions with WLANs network coverage refers to the percentage of the number of schools that establish campus wireless network and achieve full coverage of campus wireless network in the total number of educational schools at that level.

Formula: Percentage of educational institutions with WLANs network coverage = number of schools with full coverage of wireless network/total number of schools × 100%

Data source: Ministry of Education, Department of Development Planning.

3. Percentage of classrooms with multimedia device(s) (%)

Definition: The Percentage of classrooms with multimedia device(s) refers to the percentage of the number of online multimedia classrooms built at a certain level of education in the total number of educational classrooms at that level.

Formula: Percentage of classrooms with multimedia device(s) = the number of online multimedia classrooms/the total number of classrooms × 100%

China National Academy of Educational Sciences (CNAES), *Report on China Smart Education 2022*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-99-6109-2

Data source: Ministry of Education, Department of Development Planning.

4. Number of digital devices per teacher (device/person)

Definition: The number of digital devices per teacher refers to the comprehensive evaluation of dedicated teaching terminals for full-time teachers at each level of education that are included in the fixed assets of the school.

Formula: Number of digital devices per teacher = number of digital devices per teacher in basic education × weight + number of digital devices per teacher in vocational education × weight + number of digital devices per teacher in higher education × weight.

Data source: Ministry of Education, Department of Development Planning.

5. Average amount of digital educational resources by person (piece/person)

Definition: The average amount of digital educational resources by person refers to the ratio of the total digital education resources incorporated into the Smart Education of China platform to the total national population.

Formula: Average amount of digital educational resources by person = total digital education resources of the Smart Education of China platform/total population of the country × 100%

Data source: Smart Education of China platform, National Population Census data.

6. Number of digital curricular resources per 100 students (class hours/100 people)

Definition: The number of digital curricular resources per 100 students refers to the total amount of digital curriculum resources provided by every 100 students in the Smart Education of China platform at a certain level.

Formula: Number of digital curricular resources per 100 students = total class hours of digital curriculum resources of the Smart Education of China platform/total number of students × 100.

Data source: Smart Education of China platform, and Ministry of Education, Department of Development Planning Education Statistics.

7. Coverage rate of digital educational resources (%)

Definition: The coverage rate of digital educational resources refers to the proportion of the users of the Smart Education of China platform in the national population over 6 years old.

Formula: Coverage rate of digital educational resources = number of registered users of the national smart education public service platform/total number of people over 6 years old in the country × 100%

Data source: Temporarily unavailable.

8. Percentage of teachers with cyber learning space (%)

Definition: The percentage of teachers with cyber learning space refers to the percentage of full-time teachers who open online learning space at a certain level in the total number of full-time teachers at that level. Cyber learning space refers to the online learning space recognized by the competent education authorities or schools and opened on the public service platform for teachers to use.

Formula: Percentage of teachers with cyber learning space = number of full-time teachers who open cyber learning space/total number of full-time teachers × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

9. Percentage of students with cyber learning space (%)

Definition: The percentage of students with cyber learning space refers to the percentage of students who open online learning space at a certain level of education in the total number of students at that educational level. Cyber learning space refers to the online learning space recognized by the competent education authorities or schools and opened on the public service platform for students to use.

Formula: Percentage of students with cyber learning space = number of students who open cyber learning space/total number of students × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

10. Proportion of teachers with sufficient digital literacy (%)

Definition: The proportion of teachers with sufficient digital literacy refers to the percentage of the number of teachers who have reached the standard in the digital literacy assessment in the total number of the teachers participating in the nationally recognized teacher digital literacy assessment.

Formula: Proportion of teachers with sufficient digital literacy = the number of teachers who have reached the standard in the digital literacy assessment/ the total number of teachers who have participated in the digital literacy assessment × 100%

Data source: Educational Informatization Strategy Research Base (Central China), Ministry of Education.

11. Effective utilization rate of digital educational resources (%)

Definition: The effective utilization rate of digital educational resources refers to the comprehensive evaluation of the effective utilization rate of public digital education resources of the Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE), the Smart Education of China, Platform for Vocational Education (SEC-PVE) and the Smart Education of China, Platform for Higher Education (SEC-PHE).

Formula: Effective utilization rate of digital educational resources = effective utilization rate of public digital education resources of the SEC-PPSE × weight + effective utilization rate of public digital education resources of SEC-PVE × weight + effective utilization rate of public digital education resources of SEC-PHE × weight.

Data source: Temporarily unavailable.

12. Effective utilization rate of curricular resources on the Smart Education of China platform (%)

Definition: The effective utilization rate of curricular resources on the Smart Education of China platform refers to the comprehensive evaluation of the effective utilization of digital curriculum resources of the SEC-PPSE, SEC-PVE and SEC-PHE.

Formula: Effective utilization rate of curricular resources on the Smart Education of China platform = effective utilization rate of digital curriculum resources of the SEC-PPSE × weight + effective utilization rate of digital curriculum resources of the SEC-PVE × weight + effective utilization rate of digital curriculum resources of the SEC-PHE × weight.

Data source: Smart Education of China platform.

13. User activity indices of the Smart Education of China platform (time/person)

Definition: The user activity indices of the Smart Education of China platform refers to the comprehensive evaluation of the user activity of the SEC-PPSE, SEC-PVE and SEC-PHE.

Formula: User activity indices of the Smart Education of China platform = user activity of SEC-PPSE × weight + user activity of SEC-PVE × weight + user activity of SEC-PHE × weight.

Data source: Smart Education of China platform.

14. Hit rate of resources recommended to users by the Smart Education of China platform (%)

Definition: The hit rate of resources recommended to users by the Smart Education of China platform refers to the active push of public digital education resources to users by SEC-PPSE, SEC-PVE and SEC-PHE, and the comprehensive evaluation of effective users' click usage.

Formula: Hit rate of resources recommended to users by the Smart Education of China platform = reach rate of public digital education resources push of SEC-PPSE × weight + reach rate of public digital education resources pushed by SEC-PVE × weight + reach rate of public digital education resources pushed by SEC-PHE × weight.

Data source: Temporarily unavailable.

15. Coverage rate of hybrid education (%)

Definition: The coverage rate of hybrid education refers to the comprehensive evaluation of the application of digital resources of the SEC-PPSE, SEC-PVE, and SEC-PHE in teaching and learning activities.

Formula: Coverage rate of hybrid education = coverage rate of hybrid education in basic education × weight + coverage rate of hybrid education in vocational education × weight + coverage rate of hybrid education in higher education × weight.

Data source: Smart Education of China platform, Department of Development Planning, Center for Scientific Research of Ministry of Education, and Development in Higher Education Institutes of Ministry of Education, Educational Informatization Strategy Research Base (Central China), Ministry of Education.

16. Coverage rate of online teacher training (%)

Definition: The coverage rate of online teacher training refers to the percentage of the number of full-time teachers in basic education institutions and secondary level vocational education institutions using the network learning space to carry out network research and study in the total number of full-time teachers in the certain level.

Formula: Coverage rate of online teacher training = number of full-time teachers in primary and secondary schools and secondary vocational schools using network learning space to carry out network research/total number of full-time teachers in primary and secondary schools and secondary vocational schools × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

17. Coverage rate of online personalized learning (%)

Definition: The coverage rate of online personalized learning refers to the percentage of the number of students in a certain level of education who develop personalized learning in the total number of students in the natural year.

Formula: Coverage rate of online personalized learning = number of students using Cyber learning space to carry out personalized learning/total number of students × 100%

Data source: Temporarily unavailable.

18. Percentage of users learning with online videos (%)

Definition: The percentage of users learning with online videos refers to the proportion of weekly users watching the educational videos among internet users aged 16–64.

Formula: Percentage of users learning with online videos = the number of internet users who watch educational videos every week/the total number of internet users who participate in the survey × 100%

Data source: 2022 Global Digital Overview Report jointly released by We Are Social and Hootsuite.

19. Coverage rate of ICT-based formative assessments (%)

Definition: The coverage rate of ICT-based formative assessments refers to the percentage of the number of schools conducting digital process evaluation at a certain level of education in the total number of the educational schools in the natural year.

Formula: Coverage rate of ICT-based formative assessments = number of schools conducting digital process evaluation/total number of schools × 100%

Data source: Temporarily unavailable.

20. Coverage rate of AI-based assessments (%)

Definition: The coverage rate of AI-based assessments refers to the percentage of the number of schools conducting intelligent evaluation at a certain level of education in the total number of the educational schools at that level. Intelligent evaluation refers to the method of carrying out personalized evaluation of students by means of information technology and various evaluation methods, including student electronic portfolio, online test, adaptive test and other information student evaluation methods.

Formula: Coverage rate of AI-based assessments = number of schools carrying out intelligent evaluation/total number of schools × 100%

Data source: Temporarily unavailable.

21. Percentage of students, teachers and institutions in which the identity data was collected in (national) core database(s) (%)

Definition: The percentage of students, teachers and institutions in which the identity data was collected in (national) core database(s) refers to the proportion of students, teachers and schools who have been collected and stored in the number of all students, in-service teachers and schools.

Formula: Percentage of students, teachers and institutions in which the identity data was collected in (national) core database(s) = coverage of basic school data × weight + coverage of teachers' basic data × weight + coverage of students' basic data × weight.

Data source: Ministry of Education, Department of Basic Education, Department of Vocational and Adult Education, Department of Higher Education, Department of Teacher Education.

22. Percentage of region-level educational management system in which data is available to national Education Data Exchange Network (%)

Definition: The percentage of region-level educational management system in which data is available to national Education Data Exchange Network refers to the proportion of basic education data of all levels and various types of education connected

to the data exchange system of the national Education Management Information System.

Formula: Percentage of region-level educational management system in which data is available to national Education Data Exchange Network = number of city, district, county and school basic databases that have been connected to the data exchange system of the National Education Management Information System/total number of city, district, county and school basic databases × 100%

Data source: Temporarily unavailable.

23. Coverage rate of one-stop online educational affairs and services

Definition: The coverage rate of one-stop online educational affairs and services mainly refers to the proportion of "all-in-one" online education government services with unified standards, comprehensive integration, full-time online, diversified channels, and national universal functions of education government services. (In 2022, it will be replaced by the proportion of schools with normalized all-in-one card function.)

Formula: Coverage rate of one-stop online educational affairs and services = the number of provincial, municipal, district and county education administrative departments that have provided "One Network" service/the total number of provincial, municipal, district and county education administrative departments × 100% (Alternative formula for 2022 index: Coverage rate of one-stop online educational affairs and services = proportion of schools with normalized all-in-one card function in basic education sample schools × weight + proportion of schools with normalized all-in-one card function in vocational education sample schools × weight + proportion of schools with normalized all-in-one card function in sample higher education schools × weight).

Data source: Higher Education Evaluation Center, Higher Education Press, Educational Informatization Strategy Research Base (Central China), Ministry of Education.

24. Coverage rate of ICT engaged educational supervision (%)

Definition: The coverage rate of ICT engaged educational supervision refers to the proportion of educational administrative departments at all levels that have built education supervision and management platforms.

Formula: Coverage rate of ICT engaged educational supervision = number of education supervision departments in provinces, prefectures, districts and counties with education supervision informatization management platform/ number of education administrative departments in provinces, prefectures, districts and counties × 100%

Data source: Temporarily unavailable.

25. Percentage of educational institutions with ICT-related policy (%)

Definition: The percentage of educational institutions with ICT-related policy refers to the proportion of schools that have established a special information work and management system.

Formula: Percentage of educational institutions with ICT-related policy = percentage of basic education institutions with ICT-related policy × weight + percentage of vocational education institutions with ICT-related policy × weight + percentage of higher education institutions with ICT-related policy × weight.

Data source: Ministry of Education, Department of Higher Education, Department of Teacher Education.

26. Percentage of educational institutions with data-driven decision-making process (%)

Definition: The percentage of educational institutions with data-driven decision-making process refers to the proportion of schools in which the data of all kinds of established education management (educational administration management, administrative management, financial management, personnel management, student management and equipment asset management, etc.) information systems, is applied to daily decision-making and management service activities.

Formula: Percentage of educational institutions with data-driven decision-making process = percentage of basic education institutions with data-driven decision-making process × weight + percentage of vocational education institutions with data-driven decision-making process × weight + percentage of higher education institutions with data-driven decision-making process × weight.

Data source: Educational Informatization Strategy Research Base (Central China), Ministry of Education.

27. Percentage of schools with cybersecurity policy (%)

Definition: The percentage of schools with cybersecurity policy mainly refers to the proportion of schools that have established a sound cybersecurity responsibility system and a special cybersecurity management system in accordance with the requirements of The Cybersecurity Law of the People's Republic of China.

Formula: Percentage of schools with cybersecurity policy = number of schools with sound cybersecurity responsibility system and specific cybersecurity management system/total number of schools × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

28. Proportion of students with sufficient digital literacy (%)

Definition: The proportion of students with sufficient digital literacy refers to the percentage of students who pass the national recognized digital literacy assessment at a certain level.

Formula: Proportion of students with sufficient digital literacy = qualification rate of primary school students' digital literacy × weight + qualification rate of middle school students' digital literacy × weight.

Data source: Educational Informatization Strategy Research Base (Central China), Ministry of Education.

29. Percentage of graduates from ICT-related majors (%)

Definition: The percentage of graduates from ICT-related majors refers to the proportion of graduates of science (S), technology (T), engineering (E), mathematics (M) and other ICT-related disciplines among higher education graduates.

Formula: Percentage of graduates in ICT-related discipline = number of graduates in STEM disciplines of higher education/total number of graduates of higher education × 100%

Data source: Ministry of Education, Department of Development Planning.

30. Indices of students' lifelong learning ability

Definition: The indices of students' lifelong learning ability refer to the development level of students' lifelong learning attitude consciousness, self-management, thinking quality, adaptability and other aspects formed under the intelligent education environment.

Formula: Indices of students' lifelong learning ability = basic education students' lifelong learning ability level × weight + lifelong learning ability level of vocational education students × weight + lifelong learning ability level of higher education students × weight.

Data source: Temporarily unavailable.

31. Indices of average digital skills of population between ages 16 and 74

Definition: The indices of average digital skills of population between ages 16 and 74 is calculated from five indicators of the two dimensions of internet user skills and advanced skill development.

Formula: Adopt the measurement results in the European Commission's Digital Economy and Social Index series reports.

Data source: European Commission Digital Economy and Social Index series reports.

32. Indices of digital skills among active population

Definition: The indices of digital skills (such as computer skills, basic coding, digital reading, etc.) among active population is derived from a questionnaire for senior business executives in the Executive Opinion Survey.

Formula: Adopt the measurement results in the Global Competitiveness Report 2019 of the World Economic Forum.

Data source: World Economic Forum 2019 Global Competitiveness Report.

Appendix B
Explanations for the Indicator System of Smart Education Development (Basic Education)

1. Percentage of schools with a broadband connection, includes both fixed and mobile (%)

Definition: The percentage of schools with a broadband connection, including both fixed and mobile, refers to the percentage of primary and secondary schools connected to the broadband internet in the total number of educational schools connected to that level.

Formula: The percentage of schools with a broadband connection, including both fixed and mobile = number of primary and secondary schools connected to the internet /total number of primary and secondary schools × 100%

Data source: Ministry of Education, Department of Development Planning.

2. Percentage of schools with WLANs network coverage (%)

Definition: The percentage of educational institutions with WLANs network coverage refers to the percentage of the number of schools that establish campus WLANs network and achieve full coverage of wireless network in the total number of educational schools at that level.

Formula: Percentage of schools with WLANs network coverage = number of primary and secondary schools with WLANs network coverage/total number of primary and secondary schools × 100%

Data source: Ministry of Education, Department of Development Planning.

3. Percentage of classrooms with multimedia device(s) (%)

Definition: Percentage of classrooms with multimedia device(s) refers to the number of online multimedia classrooms built at a certain level of education, divided by the total number of educational classrooms at that level, counted by percentage.

China National Academy of Educational Sciences (CNAES), *Report on China Smart Education 2022*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-99-6109-2

Formula: Percentage of classrooms with multimedia device(s) = number of primary and secondary school classrooms with multimedia device(s)/the total number of primary and secondary school classrooms × 100%

Data source: Ministry of Education, Department of Development Planning.

4. Number of digital devices per 100 students (device/100 people)

Definition: The number of digital devices per 100 students refers to the average number of teaching terminals per 100 students included in the fixed assets of the school.

Formula: Number of digital devices per 100 students = total number of devices for basic education/ total number of students in basic education × 100%

Data source: Ministry of Education, Department of Development Planning.

5. Number of open digital curricular resources for primary and secondary education (class hours)

Definition: The number of open digital curricular resources refers to the total amount of digital curriculum resources on the Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE).

Formula: Number of open digital curricular resources for primary and secondary education = total number of digital curricular resources provided by SEC-PPSE.

Data source: Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE).

6. Number of open digital resources for pedagogical research for primary and secondary education (pieces)

Definition: The number of open digital resources for pedagogical research refers to the total amount of digital resources for pedagogical research on the SEC-PPSE.

Formula: Number of open digital resources for pedagogical research for primary and secondary education = total number of digital resources for pedagogical research provided by SEC-PPSE.

Data source: Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE).

7. Percentage of teachers with cyber learning space (%)

Definition: The percentage of teachers with cyber learning space refers to the number of full-time teachers who open online teaching space divided by the total number of full-time teachers, written by percentage. Online teaching space refers to the online teaching space recognized by the education authorities or schools and opened on the public service platform for used by teachers.

Formula: Percentage of teachers with cyber learning space = number of basic education teachers registered account for cyber learning space/total number of basic education teachers × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

8. Percentage of students with cyber learning space (%)

Definition: The percentage of students with cyber learning space refers to the number of students who open online learning space divided by the total number of students, written by percentage. Online learning space refers to the online learning space recognized by the education authorities or schools and opened on the public service platform for students to use.

Formula: Percentage of students with cyber learning space = number of basic education students registered account for cyber learning space/total number of basic education students × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

9. Number of ICT professionals in education per 100 students (people/100 people)

Definition: The number of ICT professionals in education per 100 students refers to the average number of staff working on ICT-related professions per 100 students in the last school year. The staffs working on ICT-related professions include full-time management, operation and maintenance personnel of network centers in information centers in schools, kindergarten, and audio-visual education centers.

Formula: Number of ICT professionals in education per 100 students = total number of ICT professionals in education /total number of students in basic education × 100%

Data source: Ministry of Education, Department of Development Planning.

10. Number of ICT-related training per 100 teachers (times/100 people)

Definition: The number of ICT-related training per 100 teachers refers to the average number of times of ICT-related training for every 100 full-time teachers in the past school year.

Formula: Number of ICT-related training per 100 teachers = total number of ICT-related training sessions received by basic education teachers last year/ total number of basic education teachers last year × 100%

Data source: Temporarily unavailable.

11. Proportion of teachers with sufficient digital literacy (%)

Definition: The proportion of teachers with sufficient digital literacy refers to the percentage of the teachers who passed the digital literacy assessment in the nationally recognized teacher ICT-literacy assessment.

Formula: Proportion of teachers with sufficient digital literacy = number of teachers passed the digital literacy assessment/total number of teachers participated in the assessment × 100%

Data source: Educational Informatization Strategy Research Base (Central China), Ministry of Education.

12. Annual user activity indices of the Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE)

Definition: The annual user activity indices of the Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE) refers to the result of using the total page view divided by the total unique view on the SEC-PPSE during this year.

Formula: Annual user activity indices of the Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE) = annual number of page views of SEC-PPSE (PV)/annual number of unique visitors of SEC-PPSE (UV).

Data source: Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE).

13. Effective utilization rate of resources on the SEC-PPSE (%)

Definition: The effective utilization rate of resources on the SEC-PPSE refers to the proportion of resources effectively utilized in the SEC-PPSE every year. Among them, "effective utilization" means the web page resources with more than 10,000 views.

Formula: Effective utilization rate of resources on the SEC-PPSE = amount of resources effectively utilized in the SEC-PPSE in a year/total amount of resources in the SEC-PPSE.

Data source: Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE).

14. Hit rate of resources recommended to users by the SEC-PPSE (%)

Definition: The hit rate of resources recommended to users by the SEC-PPSE refers to the percentage of the annual resources of the SEC-PPSE resources that are actively recommended to users and get the users' clicks.

Formula: Hit rate of resources recommended to users by the SEC-PPSE = total number of resources recommended by the platform and clicked by users/ the number of resources on the platform.

Data source: Temporarily unavailable.

15. Effective utilization of moral, physical, aesthetic, and labor education related resources on the SEC-PPSE (%)

Definition: The effective utilization of moral, physical, aesthetic, and labor education related resources on the SEC-PPSE refers to the percentage of effectively utilized resources that related to moral, physical, aesthetic, and labor education related resources on the SEC-PPSE. Among them, "effective utilization" refers to web page resources with more than 10,000 views.

Formula: Effective utilization of moral, physical, aesthetic, and labor education related resources on the SEC-PPSE = number of effectively utilized moral, physical, aesthetic, and labor education related resources/total number of moral, physical, aesthetic, and labor education related resources on SEC-PPSE × 100%

Data source: Temporarily unavailable.

16. Coverage rate of hybrid education (%)

Definition: The coverage rate of hybrid education refers to the percentage of schools that use the SEC-PPSE to carry out daily teaching and learning.

Formula: Coverage rate of hybrid education = number of schools using SEC-PPSE to carry out teaching and learning/ total number of basic education schools × 100%

Data source: Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE).

17. Coverage rate of online personalized teaching (%)

Definition: The coverage rate of online personalized teaching refers to the percentage of teachers using online learning space for personalized teaching.

Formula: Coverage rate of online personalized teaching = number of basic education teachers using online learning space for personalized teaching/total number of basic education teachers × 100%

Data source: Educational Informatization Strategy Research Base (Central China), Ministry of Education.

18. Coverage rate of ICT engaged classroom lessons (%)

Definition: The coverage rate of ICT engaged classroom lessons refers to the percentage of classroom engaged by ICT technologies and resources.

Formula: Coverage rate of ICT engaged classroom lessons = online basic education class hours supported by ICT /total basic education class hours of in a year × 100%

Data source: Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE).

19. Coverage rate of ICT engaged homework assignments (%)

Definition: The coverage rate of ICT engaged homework assignments refers to the percentage of homework assignments engaged by ICT-related technologies and resources.

Formula: Coverage rate of ICT engaged homework assignments = number of basic education schools with homework assignments engaged by ICT-related technologies/ total number of basic education schools × 100%

Data source: Temporarily unavailable.

20. Number of ICT-based assessment patterns

Definition: The number of ICT-based assessment patterns refers to the number of assessment patterns supported by ICT-related technologies.

Data source: Temporarily unavailable.

21. Coverage rate of ICT-based assessments (%)

Definition: The coverage rate of ICT-based assessments refers to the percentage of schools administrate ICT-based assessments. The ICT-based assessments refers to a variety of individualized assessments supported by ICT-related technologies, including but not limited to online tests, online grading, ICT-based PE, aesthetics and labor-skill assessments, student electronic portfolios, computerized adaptive tests (CATs), and other assessment formats.

Formula: Coverage rate of ICT-based assessments = number of basic education schools carrying out ICT-based assessments/total number of basic education schools × 100%

Data source: Temporarily unavailable.

22. Average hours of teachers participating in online professional training per year (hours)

Definition: The average hours of teachers participating in online professional training per year refers to the average number of credit hours for each teacher to participate in the online professional training in last academic year.

Formula: Average hours of teachers participating in online professional training per year = total hours spent by basic education teachers on online professional training/ total number of basic education teachers.

Data source: Ministry of Education, Department of Development Planning.

23. Coverage rate of online pedagogical research (%)

Definition: The coverage rate of online pedagogical research refers to the percentage of the full-time teachers conduct online pedagogical research using the online pedagogical research spaces provided by the SEC-PPSE.

Formula: Coverage rate of online pedagogical research = number of basic education teachers using cyber space for online pedagogical research/total number of teachers in basic education × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

24. Percentage of students, teachers and schools in which the identity data was collected in (national) core database(s) (%)

Definition: The percentage of students, teachers and schools in which the identity data was collected in (national) core database(s) mainly refers to the proportion of numbers of students basic data (including demographic information, school roll, learning experience information and graduation employment information, etc.), teachers basic data (including demographic information, work information, assessment information, learning information, etc.), school assets and school conditions data (including basic information, classroom information, funding information, equipment information, etc.) of all the number of students, working teachers and schools included respectively.

Formula: Percentage of students, teachers and schools in which the identity data was collected in (national) core database(s) = school rate × weight + teacher rate × weight + student rate × weight (school rate = number of schools that identity data was collected in database/total number of schools × 100%; teacher rate = number of teachers that identity data was collected in database/total number of teachers × 100%; student rate = number of students that identity data was collected in database/total number of students × 100%).

Data source: Ministry of Education, Department of Basic Education.

25. Percentage of region-level learning management systems join in national Education Data Exchange Network (%)

Definition: The percentage of region-level learning management systems join in National Education Data Exchange Network mainly refers to the proportion of basic education database of all levels and various types of education connected to the data exchange system of the National Education Management Information System.

Formula: Percentage of region-level learning management systems join in national Education Data Exchange Network = number of basic databases of cities, counties and schools connected to the National Education Management System's exchange portal/total number of basic databases of cities, counties and schools × 100%

Data source: Ministry of Education, Department of Basic Education.

26. Coverage rate of one-stop online educational affairs and services (%)

Definition: The coverage rate of one-stop online educational affairs and services refers to the proportion of "online education government services". ("One-stop" mainly refers to the online service have integration of education government services

thus schools, teachers and students, families, educational and scientific research institutions and other interests only need to browse an online general portal, complete a login.)

Formula: Coverage rate of one-stop online educational affairs and services = number of basic education schools using the National Primary and Secondary School Management Platform/total number of basic education schools × 100%

Data source: Ministry of Education, Department of Basic Education.

27. Coverage rate of ICT engaged educational supervision (%)

Definition: The coverage rate of ICT engaged educational supervision refers to the proportion of educational administrative departments at all levels that have built education supervision and management platforms.

Formula: Coverage rate of ICT engaged educational supervision = number of education regulators in provinces, cities and counties that have built IT platforms for education supervision and management/total number of education regulators in provinces, cities and counties × 100%

Data source: Temporarily unavailable.

28. Coverage rate of after-school service management system (%)

Definition: The coverage rate of after-school service management system refers to the proportion of schools that access to national after-school service management system for primary and secondary schools.

Formula: Coverage rate of after-school service management system = number of schools access to national after-school service management system/total number of basic education schools × 100%

Data source: Ministry of Education, Department of Basic Education.

29. Percentage of schools with ICT-related policy (%)

Definition: The percentage of schools with ICT-related policy refers to the proportion of schools that have established the information work and management policy for school management.

Formula: Percentage of schools with ICT-related policy = number of schools with ICT procedures and management system/total number of schools × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

30. Percentage of schools with data driven decision-making process (%)

Definition: The percentage of schools with data driven decision-making process mainly refers to the data of education management information system (including administration, administrative management, financial management, personnel management, student management and equipment asset management, the school

management business) have been applied to the daily decision-making and management service activities of the school.

Formula: Percentage of schools with data driven decision-making process = number of schools with data driven decision-making process/total number of schools in the sample survey × 100%.

Data source: Educational Informatization Strategy Research Base (Central China), Ministry of Education.

31. Financial expenditure on ICT in education (%)

Definition: The financial expenditure on ICT in education refers to the percentage of the government financial input in public primary and secondary education informatization in the total education input this year.

Formula: Financial expenditure on ICT in education = ICP spending in a year/total education investment in the year × 100%

Data source: Temporarily unavailable.

32. Percentage of schools with cybersecurity policy (%)

Definition: The percentage of schools with cybersecurity policy mainly refers to the proportion of schools that have established a cybersecurity and a cybersecurity policy in accordance with the requirements of law.

Formula: Percentage of schools with cybersecurity policy = number of schools with cybersecurity accountability and management policy/total number of schools × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

33. Percentage of students with satisfactory digital literacy (%)

Definition: The percentage of students with satisfactory digital literacy refers to the percentage of students with excellent digital literacy passing the assessment of a certain level and the total number of students participating in the ICT literacy assessment of this level of education.

Formula: Percentage of students with satisfactory digital literacy = number of basic education students passing the digital literacy assessment/ total number of basic education students participating in the assessment × 100%

Data source: Educational Informatization Strategy Research Base (Central China), Ministry of Education.

34. Indices of students' lifelong learning ability among primary and secondary schools

Definition: The indices of students' lifelong learning ability among primary and secondary schools refers to the characteristics and development level of students' lifelong learning attitude consciousness, self-management, thinking quality, adaptability and other aspects formed under the intelligent education environment.

Formula: Indices of students' lifelong learning ability = basic education students' lifelong learning ability level.

Data source: Temporarily unavailable.

35. Indices of learning experience of users on SEC-PPSE

Definition: The indices of learning experience of users on SEC-PPSE refers to the comprehensive evaluation of the resource quality of the national smart education platform for primary and secondary schools, which is obtained by the weighted synthesis of the average score of the resources and the number of "likes".

Formula: Indices of learning experience of users on SEC-PPSE = sum of score of the content on the SEC-PPSE/number of the content on SEC-PPSE.

Data source: Smart Education of China, Platform for Primary and Secondary Education (SEC-PPSE).

Appendix C
Explanations for the Indicator System of Smart Education Development (Vocational Education)

1. Percentage of vocational schools with a broadband connection (%)

Definition: Number of vocational schools with access to the Internet expressed as a percentage of the total number of vocational schools.

Formula: Percentage of vocational schools with a broadband connection = the number of vocational schools with access to the Internet/the total number of vocational schools × 100%

Data source: Ministry of Education, Department of Development Planning.

2. Percentage of vocational schools with WLANs network coverage (%)

Definition: Number of vocational schools with full wireless network coverage expressed as a percentage of the total number of vocational schools.

Formula: Percentage of vocational schools with WLANs network coverage = the number of vocational schools with complete wireless network coverage/the total number of vocational schools × 100%

Data source: Ministry of Education, Department of Development Planning.

3. Percentage of teachers and students with digital devices (%)

Definition: Number of digital devices owned by full-time teachers and students in vocational schools expressed as a percentage of the total number of full-time teachers and students in vocational schools.

Formula: Percentage of teachers and students with digital devices = total number of digital terminals for teachers and students in vocational schools/total number of teachers and students in vocational schools × 100%

Data source: Ministry of Education, Department of Development Planning.

China National Academy of Educational Sciences (CNAES), *Report on China Smart Education 2022*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-99-6109-2

4. Percentage of classrooms with multimedia device(s) (%)

Definition: Number of multimedia classrooms in vocational schools expressed as a percentage of the total number of their classrooms.

Formula: Percentage of classrooms with multimedia device(s) = number of networking multimedia classrooms in vocational schools/total number of classrooms in vocational schools × 100%

Data source: Ministry of Education, Department of Development Planning, Ministry of Education.

5. Coverage rate of majors with major-related resources provided by the Platform for Smart Education of China, Platform for Vocational Education (SEC-PVE) (%)

Definition: Number of majors with major-related resources provided by SEC-PVE expressed as a percentage of the total number of majors in Specialties Catalogue of Vocational Education.

Formula: Coverage rate of majors with major-related resources provided by the SEC-PVE = number of majors with major-related resources provided by SEC-PVE/ total number of majors in Specialties Catalogue of Vocational Education × 100%

Data source: Smart Education of China, Platform for Vocational Education (SEC-PVE); Specialties Catalogue of Vocational Education (2021).

6. Percentage of vocational schools with cyber learning spaces (%)

Definition: Number of vocational schools that have opened cyber learning spaces expressed as a percentage of the total number of vocational schools. In particular, cyber learning spaces refer to those approved by the competent authorities in education or schools, open on the public service platform for teachers to use.

Formula: Percentage of vocational schools with cyber learning spaces = number of vocational schools with cyber learning spaces/total number of vocational schools × 100%

Data source: 2021 Survey Data on Educational Informatization Development in China from the Educational Informatization Strategy Research Base (Central China), Ministry of Education.

7. Proportion of teachers with sufficient digital literacy (%)

Definition: Number of vocational school teachers with sufficient digital literacy expressed as a percentage of the total number of participants from vocational schools in the nationally recognized assessment on teachers' digital application abilities.

Formula: Proportion of teachers with sufficient digital literacy = number of vocational school teachers who have passed the assessment on digital application abilities/total number of participants from vocational schools in the nationally recognized assessment on teachers' digital application abilities × 100%

Data source: Temporarily unavailable.

8. Percentage of active users in SEC-PVE (%)

Definition: Number of teachers and students in vocational schools who log in SEC-PVE at least once a week calculated by natural years and expressed as a percentage of the total number of registered teachers and students in vocational schools in the past three years.

Formula: Percentage of active users in SEC-PVE (%) = number of teachers and students who log in the national platform for smart education in vocational schools at least once a week in vocational schools/total number of the registered teachers and students in vocational schools in the past three years × 100%

Data source: Smart Education of China, Platform for Vocational Education (SEC-PVE).

9. Effective utilization rate of resources on the SEC-PVE (%)

Definition: Number of curriculum resources with certain click through rate (CTR) on the SEC-PVE expressed as a percentage of the total number of curriculum resources on the platform. In particular, courses of general education with more than 10,000 clicks are included in the calculation, and professional courses will be calculated according to the proportion of students in each specialty, namely, more than 330 clicks for agriculture, forestry, husbandry and fishery, 103 for resources, environment and safety, 66 for energy, power and materials, 569 for civil engineering and construction, 24 for water conservancy, 1,020 for equipment manufacturing, 61 for biology and chemical industries, 74 for light industry and textile, 108 for food, drug and grain, 858 for transportation, 1,710 for electronics and information, 1,183 for medical and health care, 1,442 for finance, commerce and trade, 434 for tourism, 596 for cultures and arts, 86 for journalism and communication, 1,117 for education and sports, 71 for public security and justice and 148 for public management and services.

Formula: Effective utilization rate of resources on the SEC-PVE (%) = number of curriculum resources with certain click through rate (CTR) on the platform for smart education in vocational schools that year/the total number of curriculum resources on the platform × 100%

Data source: Smart Education of China, Platform for Vocational Education (SEC-PVE).

10. Click-through rate of resources recommended to users by the SEC-PVE (%)

Definition: Number of user clicking on the resources pushed by the SEC-PVE across the country that year expressed as a percentage of the total number of resources pushed by the platform.

Formula: Click-through rate of resources recommended to users by the SEC-PVE = number of user clicks on the resources pushed by SEC-PVE across the country that year/total number of resources pushed by the platform × 100%

Data source: Temporarily unavailable.

11. Coverage rate of hybrid teaching among teachers (%)

Definition: Number of vocational school teachers who conduct hybrid teaching that year expressed as a percentage of the total number of vocational school teachers.

Formula: Coverage rate of hybrid teaching among teachers = number of vocational school teachers who have conducted hybrid teaching by online platforms that year/ total number of vocational school teachers × 100%

Data source: Higher Education Press, and Ministry of Education, Department of Development Planning.

12. Coverage rate of virtual simulation resources by vocational education schools (%)

Definition: Number of vocational schools with virtual simulation teaching resources expressed as a percentage of the total number of vocational schools.

Formula: Coverage rate of virtual simulation resources by vocational education schools = number of vocational schools with virtual simulation teaching resources/ total number of vocational schools × 100%

Data source: Temporarily unavailable.

13. Coverage rate of online personalized learning (%)

Definition: Number of vocational school students who carry out personalized learning in online learning space expressed as a percentage of the total number of vocational school students.

Formula: Coverage rate of online personalized learning = number of vocational school students who carry out personalized learning in online learning space/total number of vocational school students × 100%

Data source: 2021 Survey Data on Educational Informatization Development in China from the Educational Informatization Strategy Research Base (Central China), Ministry of Education.

14. Coverage rate of online teacher training (%)

Definition: Number of full-time teachers in vocational schools who carry out online training in online learning space expressed as a percentage of the total number of full-time teachers in vocational schools.

Formula: Coverage rate of online teacher training = number of full-time teachers in vocational schools who carry out online training in online learning space/total number of full-time teachers in vocational schools × 100%

Data source: 2021 Survey Data on Educational Informatization Development in China from the Educational Informatization Strategy Research Base (Central China), Ministry of Education.

15. Coverage rate of ICT-based assessments (%)

Definition: Number of courses with online examinations in the database of SEC-PVE expressed as a percentage of the total number of curriculum resources.

Formula: Coverage rate of ICT-based assessments = number of courses with online examinations in the database of SEC-PVE/total number of curriculum resources on the platform × 100%

Data source: Smart Education of China, Platform for Vocational Education (SEC-PVE).

16. Coverage rate of ICT engaged educational supervision (%)

Definition: Number of vocational schools that have opened online educational supervision tours expressed as a percentage of the total number of registered vocational schools on the online platform.

Formula: Coverage rate of ICT engaged educational supervision = number of vocational schools that have opened online educational supervision tours/total number of registered vocational schools on the online platforms × 100%

Data source: Higher Education Press.

17. Percentage of students, teachers and schools in which the identity data was collected in (national) core database(s) (%)

Definition: Basic data of students (mainly including students' basic information, study status, learning experience, financial aid and graduation and employment), teachers (including teachers' and other faculty's basic information, job, assessment, learning experience, rewards and punishment records and resume) and schools (including schools' basic information, accommodation, funding information, conditions and equipment and teaching and scientific research) that have been collected and stored in the database of the vocational schools expressed as a percentage of the total number of students, teachers and vocational schools.

Formula: Coverage rate of basic data in vocational education = coverage rate of students' basic information × weight + coverage rate of teachers' basic information × weight + coverage rate of schools' basic information × weight (coverage rate of students' basic information = number of registered students in the database of student status/total number of students in schools × 100%; coverage rate of teachers' basic information = number of registered teachers in the database of teachers' information for management/total number of in-service teachers × 100%; coverage rate of schools' basic information = number of registered schools in the database of conditions for school-running/total number of schools × 100%).

Data source: Ministry of Education, Department of Vocational and Adult Education.

18. Percentage of schools in the national talent cultivation database (%)

Definition: Number of the vocational schools with a talent training status database expressed as a percentage of the total number of vocational schools.

Formula: Percentage of schools in the national talent cultivation database = the number of vocational schools that have stationed on the educational informatization management platform by competent authorities in education at the provincial, prefectural and district/county level/total number of vocational schools × 100%

Data source: Reports of statistics submitted by educational departments (bureaus and commissions) in different provinces (municipalities and cities).

19. Percentage of schools with sufficient management information system (%)

Definition: Number of vocational schools with management functions for assets, general affairs, teachers, students and health in their school management information system expressed as a percentage of the total number of vocational schools.

Formula: Percentage of schools with sufficient management information system = number of vocational schools with management functions on asset, general affairs, teachers, students and health in their school management information system/total number of vocational schools × 100%

Data source: 2021 Survey Data on Educational Informatization Development in China from the Educational Informatization Strategy Research Base (Central China), Ministry of Education.

20. Percentage of schools with regular ICT-based teaching policy (%)

Definition: Number of vocational schools that with regular ICT-based teaching policy expressed as a percentage of the total number of vocational schools.

Formula: Percentage of schools with regular ICT-based teaching policy = number of vocational schools that have established a promotion mechanism for the normal application of teachers' teaching information technology/total number of vocational schools × 100%

Data source: 2021 Survey Data on Educational Informatization Development in China from the Educational Informatization Strategy Research Base (Central China), Ministry of Education.

21. Percentage of schools with policy for information technology-enabled work and management (%)

Definition: Number of vocational schools that have released policy for information technology-enabled work and management expressed as a percentage of the total number of vocational schools.

Formula: Percentage of schools with policy for information technology-enabled work and management = number of vocational schools that have established specialized informatization and management systems/total number of vocational schools × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

22. Percentage of schools with cybersecurity policy (%)

Definition: Number of vocational schools that have established sound network security accountability systems and specific cybersecurity management systems in accordance with the Cybersecurity Law of the People's Republic of China expressed as a percentage of the total number of vocational schools.

Formula: Percentage of schools with cybersecurity policy = number of vocational schools that have established sound cybersecurity accountability systems and specific cybersecurity management systems/total number of vocational schools × 100%

Data source: Ministry of Education, Department of Science, Technology and Informatization.

23. Proportion of students with sufficient digital literacy (%)

Definition: Number of vocational school students who have passed the assessment on digital competence expressed as a percentage of the total number of participants from vocational schools in the assessment on students' digital competence.

Formula: Proportion of students with sufficient digital literacy = number of vocational school students who have passed the assessment on digital competence/total number of participants from vocational schools in the assessment on students' digital competence × 100%

Data source: Temporarily unavailable.

24. Percentage of students enrolled in ICT-related majors (%)

Definition: Number of students in vocational schools who study electronics and information and other digital majors expressed as a percentage of the total number of students in vocational schools.

Formula: Percentage of students enrolled in ICT-related majors = number of students in vocational schools in digital majors/total number of students in vocational schools × 100%

Data source: Ministry of Education, Department of Development Planning.

25. Indices of life-long learning ability among vocational education students

Definition: Characteristic performance and development of lifelong learning attitude, awareness, self-management, thinking, adaptability and other aspects formed by students in the smart education of vocational schools.

Data source: Temporarily unavailable.

26. Percentage of ICT-related major graduates working on ICT-related professions (%)

Definition: Number of graduates from ICT-related majors of vocational schools who enter the main industries of the digital economy expressed as a percentage of the total number of digital graduates entering the job market.

Formula: Percentage of ICT-related major graduates working on ICT-related professions = number of graduates from ICT-related majors of vocational education who enter the main industries of the digital economy/total number of graduates from ICT-related majors entering the job market $\times$ 100%

Data source: Student information management system in secondary vocational schools, Work status data collection and management platform for the talent training of higher vocational colleges.

27. Indices of average digital skills of population between ages 16 and 74

Definition: Digital skills of the population aged 16–74, which is calculated on five indicators of two dimensions: internet user skills and advanced skill development.

Formula: Based on the calculation in the serial report of Digital Economy and Society Index by the European Commission.

Data source: The serial report of Digital Economy and Society Index by the European Commission.

Appendix D
Explanations for the Indicator System of Smart Education Development (Higher Education)

1. Percentage of universities and colleges with mobile broadband connection (%)

Definition: The percentage of universities and colleges with mobile broadband connection.

Formula: Percentage of universities and colleges with mobile broadband connection = the number of universities and colleges with mobile broadband connection/the total number of universities and colleges × 100%

Data source: Ministry of Education, Department of Development Planning.

2. Percentage of universities and colleges with WLANs network coverage (%)

Definition: The percentage of universities and colleges with WLANs network coverage in teaching, learning, school activities, offices and other spaces in the campus.

Formula: Percentage of universities and colleges with WLANs network coverage = the number of educational institutions with WLANs network coverage/the total number of educational institutions × 100%

Data source: Ministry of Education, Department of Development Planning.

3. Percentage of classrooms with multimedia device(s) (%)

Definition: The percentage of classrooms with multimedia device(s). Classrooms with multimedia device(s) refer to those that are connected to the Internet or campus WLANs and can deliver multimedia teaching content such as digital educational resources to all students.

Formula: Percentage of classrooms with multimedia device(s) = the number of classrooms with multimedia device(s)/the total number of classrooms in universities and colleges × 100%

China National Academy of Educational Sciences (CNAES), *Report on China Smart Education 2022*, SpringerBriefs in Education,
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Data source: Ministry of Education, Department of Development Planning.

4. Number of open digital resources for higher education (pieces)

Definition: The total amount of digital higher educational resources that are open and shared on Smart Education of China, Platform for Higher Education (SEC-PHE) and its associated sub-platforms.

Formula: number of open digital resources for higher education = the total amount of digital educational resources on Smart Education of China, Platform for Higher Education (SEC-PHE) and its associated sub-platforms.

Data source: Smart Education of China, Platform for Higher Education (SEC-PHE).

5. Number of open digital curricular resources for higher education (number of courses)

Definition: The total number of digital courses such as MOOCs, open courses and videos shared on public platforms by higher educational institutions.

Formula: Number of open digital curricular resources for higher education = the total number of open digital curricular resources shared on public platforms by higher educational institutions.

Data source: Education Management Information System, Department of Science, Technology and Informatization, Ministry of Education.

6. Percentage of universities and colleges using new generation of technologies in smart campus construction (%)

Definition: The percentage of higher educational institutions utilizing new-generation IT such as the Internet of Things, cloud computing, big data, artificial intelligence, VR/AR, 5G, blockchain, etc. in building smart educational institutions.

Formula: Percentage of universities and colleges using new generation of technologies in smart campus construction = the number of higher educational institutions utilizing new generation information technology in building smart educational institutions/the total number of surveyed higher educational institutions × 100%

Data source: 2021 Survey on the Development of Higher Education Informatization, Educational Informatization Strategy Research Base (Central China), Ministry of Education.

7. Proportion of teachers with sufficient digital literacy (%)

Definition: The percentage of teachers who passed the ICT literacy test that year.

Formula: Proportion of teachers with sufficient digital literacy = the number of teachers who passed the ICT literacy test/the total number of teachers who took the test that year × 100%

Data source: Temporarily unavailable.

8. Effective utilization rate of curricular resources on the Smart Education of China, Platform for Higher Education (SEC-PHE) (%)

Definition: The percentage of the digital curricular resources effectively utilized on the Smart Education of China, Platform for Higher Education (SEC-PHE).

Formula: Effective utilization rate of curricular resources on the Smart Education of China, Platform for Higher Education (SEC-PHE) = the amount of digital curricular resources effectively utilized on the Smart Education of China, Platform for Higher Education (SEC-PHE)/total amount of curricular resources on the Smart Education of China, Platform for Higher Education (SEC-PHE) × 100%

Data source: Smart Education of China, Platform for Higher Education (SEC-PHE).

9. User activity indices of the Smart Education of China, Platform for Higher Education (SEC-PHE) (time/person)

Definition: The ratio of page views (PV) to unique visitors (UV) of the Smart Education of China, Platform for Higher Education (SEC-PHE).

Formula: User activity indices of the Smart Education of China, Platform for Higher Education (SEC-PHE) = page views (PV) of Smart Education of China, Platform for Higher Education (SEC-PHE)/unique visitors (UV) of Smart Education of China, Platform for Higher Education (SEC-PHE).

Data source: Smart Education of China, Platform for Higher Education (SEC-PHE).

10. Coverage rate of hybrid teaching among universities and colleges (%)

Definition: The percentage of higher educational institutions carrying out hybrid teaching activities each year.

Formula: Coverage rate of hybrid teaching among universities and colleges = the number of educational institutions carrying out hybrid teaching activities/the total number of surveyed higher educational institutions × 100%

Data source: Big Data and Monitoring System of Educational Informatization, Center for Scientific Research and Development in Higher Education Institutes, Ministry of Education.

11. Percentage of universities and colleges using data center in monitoring and analyzing teaching and learning practices (%)

Definition: The percentage of higher educational institutions with school-level big data center tracking curriculum implementation and supporting teaching quality analysis.

Formula: Percentage of universities and colleges using data center in monitoring and analyzing teaching and learning practices = the number of educational institutions with school-level big data center tracking curriculum implementation and supporting teaching quality analysis/the total number of higher educational institutions surveyed × 100%

Data source: 2021 Survey on the Development of Higher Education Informatization, Educational Informatization Strategy Research Base (Central China), Ministry of Education.

12. Percentage of MOOCs shared on foreign open-access platforms (%)

Definition: The percentage of MOOCs shared by higher educational institutions on foreign platforms.

Formula: Percentage of MOOCs shared on foreign open-access platforms = the number of MOOCs shared by higher educational institutions on foreign platforms/ the total number of MOOCs of higher education institutions × 100%

Data source: Education Management Information System, Department of Science, Technology and Informatization, Ministry of Education.

13. Percentage of universities and colleges utilizing AI-related technology in education (%)

Definition: The percentage of higher educational institutions using AI-related technology to assist teaching (AI teaching assistants, etc.).

Formula: Percentage of universities and colleges utilizing AI-related technology in education = the number of higher educational institutions using AI-assisted teaching methods (AI teaching assistants, etc.)/the total number of surveyed higher educational institutions × 100%

Data source: 2021 Survey on the Development of Higher Education Informatization, Educational Informatization Strategy Research Base (Central China), Ministry of Education.

14. Coverage rate of ICT-based formative assessments (%)

Definition: The percentage of higher educational institutions that apply technologies such as big data and AI to carry out ICT-based formative assessments such as student learning analysis, student development prediction and early warning, classroom attention analysis, etc.

Formula: Coverage rate of ICT-based formative assessments = the number of higher educational institutions conducting ICT-based formative assessments/the total number of surveyed higher educational institutions × 100%

Data source: 2021 Survey on the Development of Higher Education Informatization, Educational Informatization Strategy Research Base (Central China), Ministry of Education.

15. Percentage of universities and colleges which can transform online credits to institutional credits (%)

Definition: The percentage of higher educational institutions that recognize the credits of online courses.

Formula: Percentage of universities and colleges which can transform online credits to institutional credits = the number of higher educational institutions that can transform online credits to institutional credits/the total number of surveyed educational institutions × 100%

Data source: Ministry of Education, Department of Higher Education.

16. Percentage of universities and colleges with a data center (%)

Definition: The percentage of higher educational institutions with school-based data centers.

Formula: Percentage of universities and colleges with a data center = the number of higher educational institutions with school-level data centers/the total number of higher educational institutions × 100%

Data source: Education Management Information System, Department of Science, Technology and Informatization, Ministry of Education.

17. Percentage of universities and colleges with multi-platform data coordination (%)

Definition: The percentage of higher educational institutions whose school information system can realize integrated data management of schools and assets, students, teachers, teaching affairs, and general affairs.

Formula: Percentage of universities and colleges with multi-platform data coordination = the number of higher educational institutions whose school-level information system can realize integrated data management/the total number of higher educational institutions × 100%

Data source: Education Management Information System, Department of Science, Technology and Informatization, Ministry of Education.

18. Coverage rate of one-stop administrative service system(s) (%)

Definition: The percentage of higher educational institutions that can provide one-stop online school management services.

Formula: Coverage rate of one-stop administrative service system(s) = the number of higher educational institutions that can provide one-stop school management service/the total number of surveyed higher educational institutions × 100%

Data source: Big Data and Monitoring System of Educational Informatization, Center for Scientific Research and Development in Higher Education Institutes, Ministry of Education.

19. Percentage of universities and colleges with ICT-related policy (%)

Definition: The percentage of higher education institutions that have formulated ICT-related policy.

Formula: Percentage of universities and colleges with ICT-related policy = the number of schools that have formulated ICT-related policy/the total number of schools nationwide × 100%

Data source: Education Management Information System, Department of Science, Technology and Informatization, Ministry of Education.

20. Coverage rate of ICT-based scientific research service system(s) (%)

Definition: The percentage of higher educational institutions that provide digital services for science and research services such as collaboration and exchanges of research projects, sharing of experiment data, online reservation of large instruments and equipment, sharing of scientific literature and high-performance computers.

Formula: Coverage rate of ICT-based scientific research service system(s) = the number of higher educational institutions that provide ICT-based science and research services/the total number of surveyed higher educational institutions × 100%

Data source: Big Data and Monitoring System of Educational Informatization, Center for Scientific Research and Development in Higher Education Institutes, Ministry of Education.

21. Percentage of university and college graduates using Smart Education of China, National Service Platform for College Student Employment (%)

Definition: The percentage of graduates from higher educational institutions served by the National Student Employment Service Platform.

Formula: Percentage of university and college graduates using Smart Education of China, National Service Platform for College Student Employment = the number of general graduates served by National Service Platform for College Student Employment/total number of graduates × 100%

Data source: National Student Employment Service Platform.

22. Percentage of universities and colleges with cybersecurity policy (%)

Definition: The percentage of higher educational institutions that have established a sound cybersecurity responsibility system and a special cybersecurity management system in accordance with the requirements of the Cybersecurity Law of the People's Republic of China and other relevant laws and regulations.

Formula: Percentage of universities and colleges with cybersecurity policy = the number of higher educational institutions with a sound cybersecurity responsibility system and a special cybersecurity management system/the total number of higher educational institutions × 100%

Data source: Education Management Information System, Department of Science, Technology and Informatization, Ministry of Education.

23. Proportion of graduates from ICT-related majors (%)

Definition: The percentage of higher education graduates in science (S), technology (T), engineering (E) and mathematics (M) (or STEM disciplines).

Formula: Proportion of graduates from ICT-related majors = the number of higher education graduates in STEM disciplines/the total number of higher education graduates × 100%

Data source: 2021 Statistics of Education, Department of Development Planning, Ministry of Education.

24. Proportion of graduates passing digital literacy tests (%)

Definition: The percentage of graduates who passed the digital literacy test in all graduates from higher educational institutions that year.

Formula: Proportion of graduates passing digital literacy tests = the number of graduates who passed the digital literacy test/the total number of graduates who took the test that year × 100%

Data source: Temporarily unavailable.

25. Students' lifelong learning ability

Definition: Characteristics and capabilities of college students in lifelong learning attitude, self-management, thinking, adaptability and others shaped by the smart education environment.

Formula: Temporarily unavailable.

Data source: Temporarily unavailable.

26. Index of digital skills among economically active population

Definition: The extent to which the economically active population has sufficient digital skills (computer skills, basic coding, e-reading, etc.), derived from a survey of senior executives from the World Economic Forum's Executive Opinion Survey.

Formula: Results from the Global Competitiveness Report 2019 conducted by the World Economic Forum.

Data source: Global Competitiveness Report 2019, World Economic Forum.

Afterword

As a national education think tank, China National Academy of Educational Sciences (CNAES) brings together domestic and international practices and research results, extensively consults all parties, and builds consensus to form the China Smart Education Bluebook 2022 and "1 + 3" reports on China smart education development index. It is the first systematic summary of the progress of smart education in China, showing the world the Chinese concept, standards, solutions, and propositions of smart education. On February 13, 2023, at the World Digital Education Conference organized by the Ministry of Education and the National Commission of the People's Republic of China for UNESCO, Li Yongzhi, the party-secretary and president on behalf of CNAES, officially presented the above research results to people at home and abroad. This book is compiled on top of extracting and summarizing these research results.

This research was led by CNAES, guided by the General Office and the Department of Science, Technology and Informatization of the Ministry of Education, and coordinated by the Department of Research Administration and Future Education Research Center of CNAES. The research team was constructed with the strengths of eight research centers, namely, the Future Education Research Center, the Educational Information and Statistics Research Center, the Basic Education Research Center, the Vocational, Technical and Continuing Education Research Center, the Higher Education Research Center, the Educational Strategy and Macro Policy Research Center, the Education Inspection and Evaluation Research Center, and the International Comparative Education Research Center. On the basis of bringing together Chinese research forces and drawing on international research fruits, the research team has compiled this book of original research findings.

The research has adhered to the scientific and systematic design and carried out organized scientific research, resulting in "1 + 1 + 3" research results, namely, the China Smart Education Bluebook 2022 (Part One of the book), Report on China smart education development index, and reports on China smart education development index in three sub-fields (basic education, vocational education, and higher education) (Part Two of the book). The above research findings are interrelated and

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form a complete system. The bluebook attempts to scientifically define the connotation and features of smart education and provide theoretical support for constructing a smart education development index system. The index report fully absorbs domestic and international representative research results, designs an index system centering on the connotations and features of smart education, and measures and analyzes the development level of smart education in China. On this basis, three sub-field indicator systems have been constructed for basic education, vocational education, and higher education according to the characteristics and actual situation of different types of education. Then the development indexes of smart education in each field are measured, and three sub-field reports are formulated.

The research process drew references from a large amount of domestic and international literature. Meanwhile, the research group traveled to six pilot provinces to conduct field research and comprehensively collect information and data with the help of 15 relevant departments, bureaus, and units of the Ministry of Education and the Educational Informatization Strategy Research Base (Central China) of the Ministry of Education. CNAES sent the discussion draft of the findings to 31 relevant departments, bureaus, and units of the Ministry for comments and entrusted the Chinese Society of Education, the China Association of Higher Education, the Chinese Society for Technical and Vocational Education, and the China Education Association for International Exchange to solicit the opinions of more than 200 Chinese and foreign experts. After carefully studying and absorbing all the feedback, the research group revised and improved the results. When preparing the final draft, the research group actively explored channels and methods to fully collect various types of information and data in an attempt to enhance the data accessibility and richness and comprehensively and accurately define the connotation of smart education so as to reflect the development process and the actual state of smart education in China.

During the preparation of the report, the Minister of Education of the People's Republic of China, Huai Jinpeng, attached great importance to this work and made several centralized deployments for this study. He also visited CNAES for first-hand field research and discussions. Then Vice Minister Tian Xuejun and current Vice Minister Wang Jiayi gave crucial guidance to the report.

Both theory and practice have proved that the development of smart education in China has a solid foundation and distinctive characteristics. In other words, it attaches great importance to upholding the values of putting people first and running education to the satisfaction of people. It put much stress on the inheritance and development of traditional education philosophies, such as education for all without discrimination, aptitude-based teaching, and the unity of knowledge and practice. It also values the appropriate blending of a top-down approach to macro adoption of initiatives and a bottom-up approach to ecological construction. Revolving around the above theoretical and practical achievements, CNAES focuses on theoretical originality, highlights practical generalization, and links to international discourse, forming a set of high-quality research reports that are professional, scientific, pioneering, and authoritative. This series of reports is expected to provide implications and references for researchers, decision-makers, and practitioners in the smart education field

at home and abroad. In the future, the Report on China Smart Education will be published annually to continuously track the dynamics and summarize experiences. The theme of each report will be determined according to the year's progress in smart education to build consensus and lead development. Finally, we would like to express our heartfelt thanks to institutions, experts, and colleagues who have helped and supported this research series.

China Smart Education Bluebook and Smart Education Development Index Research Group, CNAES.