Educational Research in China
Caiyun Zhang & Youchao Deng *Editors-in-Chief*

Hongen Li *Editor*

The Frontier of Education Reform and Development in China

Articles from *Educational Research* (2021–2022)

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Editors-in-Chief

Caiyun Zhang, China National Academy of Educational Sciences, Beijing, China

Youchao Deng, China National Academy of Educational Sciences, Beijing, China

This series is a collection of research findings on the highest levels of education in China. The articles in this series are from *Educational Research*, the top academic journal in the field of education research in China. It covers education reform and development, high quality education system, revitalization of rural education, quality-oriented education and other fields, focusing on the hot and frontier issues of education in recent years, such as the development of artificial intelligence and education, rural education teams and policies, vocational education development, adolescent development and educational competition.

Hongen Li
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Editor
Hongen Li
China National Academy of Educational Sciences (CNAES)
Beijing, China

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A Strategic Vision and Practical Explorations of Digital Transformation of Education

Yongzhi Li

Human society is transitioning from the industrial age into the digital age. The digital transformation of society is an inevitable result of technological progress and productivity development, as well as the basis for the construction of new production relations and a community with a shared future for mankind. The fundamental, pioneering and global role of education in social development has given greater strategic significance to the digital transformation of education. At present, it is imperative to implement national strategies such as Digital China, as well as strengthening the country through education by focusing on "updating education concepts and transforming education modes" [1], and also by promoting the strategic action of digital transformation of education.

1 The Strategic Significance of Digital Transformation of Education

The digital transformation of education is different from the informatization of education. To properly promote the digital transformation of education, we must accurately understand the essential differences between informatization, digitalization and digital transformation.

Informatization means the process of teaching and learning takes place in physical spaces, with information technology serving as a mere supplementary tool. Digitalization is the establishment of a twin digital space mirrored from physical space; the teaching and learning process is completed by establishing a closed logic loop in the digital space and invoking the elements of physical space. Digital transformation entails the integration of teaching and learning elements in physical space and digital

Y. Li (✉)
Shanghai Municipal Education Commission, Shanghai, China
e-mail: 6540396@qq.com

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space based on data elements. It will result in the deep optimization and integration of the whole process of education, the updating of education concepts, the construction of a new paradigm of teaching and learning, and the establishment of a new system of education, all of which are based on digital spaces.

Through the efforts on education informatization over the past 30 years, China has witnessed the continuous integration of information technology into deepening education reform, improving education quality, promoting education balance, thus cultivating a large number of high-level IT talents and builders and successors of socialism with certain information literacy and skills. All of this guarantees the supply of human resources for strengthening the country with strong network capability. However, due to the ongoing process of technological development and the need for further enhancement of awareness, teaching is still being practiced (delivered) in the traditional school paradigm established during the industrial age. Overall, education informatization is still confined to optimizing the presentation, dissemination, storage, retrieval, and statistics of the educational content, mainly the informatization of educational means, which is a superficial and minor improvement of traditional education.

With the rapid development and increasing popularity of digital technology, all physical spaces can be digitized. The whole process of education can be digitally identified, calculated and stored. The digital transformation of education will be a profound change featuring "updating education concepts and transforming education modes". It is a leap from minor improvements to overall transformation. If education informatization is a process of quantitative change in the technology-driven educational development, then digital transformation of education is a process of qualitative change based on the accumulation of quantitative change over years.

The digital transformation of education is an inevitable result of the technological progress and productivity development in the new era. In the industrial era, capital played the role of unifying functionality and sociality, i.e., it coordinated social resources, enhanced social efficiency, and promoted technological progress and productivity development. With the development and increasing popularity of digital technology, data has taken on the responsibility of coordinating social resources and enhancing social efficiency, resulting in a flattened connection between production and consumption. A new pattern of data-driven development of a digital society is taking shape. In essence, the digital transformation of education is a part of the digital transformation of society.

Technological progress exerts impact on education at two levels. At the macro level, digital technology represents the advanced productivity driving human society into the digital age, and shaping a new economic basis centering on digital economy, which in turn affects the consequent changes in education as a component of the superstructure. At the same time, digital technology, as a new medium, pioneers the complete digitalization of people and objects in physical space, and creates the possibility of interconnection and interaction between any two of them. In human history, "the strengths of a new medium will lead to the emergence of a new civilization" [2]. Any breakthrough in media that eventually dominates will trigger social changes, construct new social relations and social structures, create new ways of social life and new modes of social behavior, and reshape the forms of education [3].

At the micro level, education is a form of communication, and digital technology is a new medium of communication. Therefore, the development of digital technology inevitably leads to the change of education. This change can generally be divided into two stages. First, the new technology acts directly on the specific communication processes of teaching and learning. It improves the efficiency and effectiveness of education in corresponding specific aspects. Second, the new technology optimizes the whole educational process, forming a new paradigm of teaching and learning, and comprehensively changing the efficiency and effectiveness of education.

In summary, the technological advances and productivity improvement of the new era not only raise requirements but also offer possibilities for the digital transformation of education.

To strengthen the country through education, we must embrace the digital transformation of education. Education is the key to the long-term development of a country. Since the founding of the People's Republic of China over 70 years ago, education has played a fundamental, strategic and pioneering role in cultivating a large number of talents for the country's economic, scientific and technological and social development, as well as laying the foundation for human resources. However, alongside these developments, some deep-seated contradictions have also occurred. Under the influence of traditional education philosophy and traditional system, such contradictions are difficult to solve, despite deepening reforms, and they may even develop into involution with negative marginal benefit due to excessive efforts.

At the root of these problems and contradictions is the fact that the educational philosophy and system of the industrial age cannot adapt to the development of the digital age. The educational philosophy of the industrial age serves to expand production and maximize social wealth. The education system of the industrial age, on the one hand, focused quality resources on elite training through selection mechanisms, and on the other hand, turned out a large amount of homogeneous and functional labor force required by socialized mass production and collaboration through standardization and knowledge reproduction. Students at the compulsory education stage need to be uniformly stocked with all the basic knowledge that are available for use later.

Digital transformation provides the basis for solving the above-mentioned contradictions. Specifically, digital transformation of education is to establish a high-quality education system guided by the philosophy of education in the digital age. This transformation will construct a new paradigm of education, improve the digital literacy and skills of the people, cultivate the ability to innovate, promote social equity, and implement the strategy of strengthening the country through education.

Digital transformation of education is the requirement of providing education that satisfies the people's needs. Education is the foundation of people's livelihood. It is related to the happiness of thousands of families and the growth of each person. However, in recent years, the comprehensive reform of education has proved that some problems are difficult to solve simply by "putting more efforts". For instance, while the overall quality of education is improving, parents' anxiety is also accelerating; while compulsory education is popularized and the bottom of schooling

system are being effectively leveled up, social class solidification is also intensifying. There are several factors attributing to these problems. First, there is still room for improvement and reform within education. Second, these problems are the projections of external contradictions. Third and also the fundamental reason is that the current education philosophy, education system and content are not suitable for the development of the digital age as they were all created during the industrial age.

People's aspiration for promising future and dynamic technology advancement raise higher demands for education constantly. The traditional school education system, which was formed in the early industrial age, is no longer able to adapt to the development of the digital age. This conflict is manifested in four kinds of disjunctions. First, there are disjunctions between subjects, with subjects becoming more and more finely subdivided and not sufficiently linked to each other. Second, there are disjunctions between different schooling stages, with teachers and students focusing mainly on entrance examinations for higher schooling stages, leading to poor coherence in terms of complete knowledge, ability and thinking training. Third, there is a disjunction between knowledge and action, as exemplified by values and character education. Fourth, there is a disjunction between theory and practice (disjunction between teaching and real-world application), due to lack of the ability to apply knowledge across subjects to solve problems. These disjunctions seriously hinder the realization of a better life through education which satisfies the people.

The development of digital technology along with data-driven teaching in accordance with learner's aptitude offers the potential for higher level of education equity. Traditionally, equity in education means giving every student the opportunity to have the same quality of education, which is typical of industrial-era education philosophy. However, each student is unique in terms of suitable learning content, depth of learning, and methods of learning. The most suitable education is the real high-quality education, while the equal educational opportunity may not be the most suitable education for each individual. In the new era, we should use digital technology to explore students' potential. For instance, students who are particularly good at learning math are encouraged to learn more challenging content by assigning them to higher-level teachers. Students who are more suitable for arts should be allowed to take less challenging math content and divert time and resources to studying arts under the instructions of more sophisticated art teachers. On condition that all students have equal choice, providing each student with an education that suits his or her needs is the unique strength of digital technology, and also the essence of education equity under the digital transformation of education.

2 A Strategic Vision of Digital Transformation of Education

The digital transformation of education cannot be simply taken as an improvement of traditional education, or as an iterative upgrade of technology applications on a micro and local basis. Instead, it is a systematic change revolving around the renewal of concepts and mode changes. It should be emphasized that, despite the

systematic or even revolutionary changes, the purpose of education to promote human and social development will not be changed, the fundamental task of education to cultivate socialist builders and successors will not be changed, and we must adhere to the principles of education and talent cultivation. The strategic vision of digital transformation of education includes five aspects as follows.

2.1 Enhancing Digital Literacy and Skills of the People

The fundamental task of education is to cultivate people through moral education as its priority. The fundamental goal of digital transformation of education is to cultivate socialist builders' and successors' digital literacy and skills..

Digital literacy and skills refer to the whole set of qualities and abilities that are needed by citizens of digital societies in learning, work and life. These include digital acquisition, production, use, evaluation, interaction, sharing, innovation, safety and security, ethics and morality and others. Enhancing digital literacy and skills of the people is fundamental, strategic and pioneering work for building China into a strong network country and digital country [4]. The journey of building a modern socialist country and the march toward the second centennial goal are powered by cultivating citizens who have digital consciousness, digital logical thinking, lifelong learning ability and social community responsibility. This power will be uncovered by stimulating the enthusiasm, initiative and creativity of all people, by building a strong network country and digital China, and by enhancing the digital adaptability, competence and creativity of all people.

To enhance the digital literacy and skills education for students, four points should be adhered to. First, the top-level design should be strengthened. Digital awareness and digital logical thinking should be cultivated systematically by means of fully integrating relevant content into various disciplines within the national education system. Meanwhile, we should establish an integrated curriculum system for kindergartens, schools and universities, set up compulsory courses, prepare special teaching materials, build internship and training bases, carry out relevant extracurricular activities, innovate interdisciplinary digital talent training mechanisms, and encourage students to use digital technology for innovation and entrepreneurship. Second, we should continuously optimize the environment for students' digital literacy and skills development, enhance teachers' awareness and ability to use digital technology to improve education and teaching, promote the construction of digital twin schools, and enrich the supply of digital resources for the whole society. Third, we should improve the digital skills in vocational education and training system and build a digital skills certification system and a lifelong education service platform. Fourth, we should strengthen digital ethics, guide the scientific and reasonable use of digital products and services, deepen the construction of network integrity, cultivate moral and ethical awareness in the process of digital acquisition, production, use, interaction, sharing and innovation, and establish good behavioral norms.

2.2 Creating a High-Quality Personalized Lifelong Learning System

A high-quality education system that meets the needs of the new era is the concrete presentation of the digital transformation of education. The basic guideline for the creation of this system is to provide education that satisfies the people and gives every child the opportunity to excel in life. At the core lies a people-oriented nature. The key is teaching according to learners' aptitude; the motivation comes from the interest of learners. The large-scale data-driven teaching according to learners' aptitude has become the new core paradigm of education. Providing the most suitable education for each individual is not only possible, but also the primary goal.

—A more flexible and personalized school system should be designed, focusing on the well-being and happy growth of the people. In accordance with the principles of human growth and cognition, textbook-based cognitive process should alternate with practice-based cognitive process with equal importance to physical and mental health in the whole process of student's physical and emotional growth. Alongside such process knowledge and action should be integrated into moral, intellectual, physical, aesthetic and labor education. As the saying goes, reading ten thousand books is as important as travelling ten thousand miles. In addition, a flexible school system should be designed for individual life careers, such as making individualized and systematic scheduling spanning days, weeks, months and even years. For students in early childhood, they should build up a more systematic perceptual cognition of life space surrounding their physical development. For students in childhood, they should develop a more systematic perceptual cognition of natural space under the sun. For students in adolescence, they should build up a more systematic perceptual cognition of social space in social practice. On the basis of systematic perceptual cognition, the rational cognition should be developed in a targeted manner according to the needs of personal growth and social development. The education system of the industrial age should be finally upgraded into a personalized lifelong learning system.

—A paradigm should be constructed for large-scale, personalized, autonomous, and inquiry-based learning. Schools may not disappear, but the mode of education may change. Learning communities spanning across grades, classes, disciplines, time and space will replace traditional classes as the basic unit of instruction on a regular basis. Based on the digital space, specific learning communities can be formed and dissolved at any time, depending on the needs of teaching or learning. The requirement to combine social and personalized learning is fully met. A more suitable education is provided for each student through a more suitable learning ecology. We will achieve a higher quality of balanced basic public education service through the provision of a suitable education for each student.

—Digital transformation should be learner-centered, rather than teacher-centered, as is done in the educational factories of the industrial age. In the new learner-centered system, through digital technology, teachers should help students discover their personal potential, stimulate their interest in learning, guide and supervise them

to learn independently in the most scientific and effective way in the areas that they are most gifted at and interested in, and strive to achieve their greatest value in society. It is important to emphasize that until revolutionary breakthroughs are made in artificial intelligence science and brain science, the teacher, although no longer the center of the teaching and learning process, still plays an irreplaceable and leading role. It is difficult for digital technology to replace the human teacher in the teaching and learning process. In short, artificial intelligence cannot replace teachers, but it can empower them.

—Learning of knowledge reserved for use in the industrial society should be upgraded into the construction of learner competence. At present, the content composition of basic education is still the same as it was first established during the industrial age, i.e., all students learn together to stock up on almost all the basic knowledge they can possibly use. In an era of knowledge explosion, the amount of new knowledge doubles approximately every two years. The pressure on education is increasing, with ever decreasing room for change. It is increasingly urgent that we should resolve the contradiction between the quality and capacity of educational content.

As digital technologies become more widely adopted, the bits of knowledge that are ready to be used will gradually be stripped away from the educational content. Instead, digital awareness, computational thinking, data governance and integrated innovation skills will constitute the main body of the educational content. By means of new media technologies, new educational communication symbols and combinations will be established. The development of digital technologies triggers knowledge fusion and fission, further contributing to the revolutionary reshaping of the educational content. However, it is worth to note that the redundancy and fragmentation of educational content can lead to new concerns.

2.3 Furthering Reform in Education

Teaching is the core of education, and its reform is the core of digital transformation of education. The large-scale data-driven teaching according to learner's aptitude lies at the core of education reform. The reform of education under the digital transformation of education is to build a new paradigm of teaching and learning by linking the physical space and its twin digital space, and establishing a closed logic loop based on digital spaces. It mainly concerns the following aspects.

—Large-scale data-driven teaching and learning should be adopted to suit individual needs. First, we should develop targeted teaching and learning based on data. The content, behavioral and physiological data, as well as the environmental data for education and learning shall be collected in an accompanying, imperceptible, ethical and secure manner. By mining and analyzing the data, we should improve the relevance and scientific nature of pre-course research, classroom teaching and after-school assignments. Second, we should focus on stimulating students' interest in learning. Just as a person pretending to be asleep cannot be woken up, a teacher cannot teach a student who is not interested in what they are learning. Data can help

teachers identify what interests the students and therefore stimulate their interest in what they are learning. The effect of such reform has been found to be significant. Third, we should tap students' potential. Through the use of data, each student is provided with the suitable education to help them follow a more promising path based on their talent.

—Data-driven evaluation of the whole process and all elements should be adopted. Traditional education assessment comes primarily in the form of examinations, uses a sample to represent the whole, uses a point in time to represent the norm, and infers qualitative results from partial quantitative analysis at a given moment, which inevitably leads to a certain degree of measurement error. Accumulated drawbacks on a large number of targeted methods leading to alienation of examination have become a major problem affecting the healthy development of education. The fundamental solution to these problems requires the assessment of the whole process and all related elements, for which complete data and effective models are necessary conditions. Through the digital transformation of education, the governance of education evaluation data will be strengthened, digital portraits of student growth and teacher development will be generated. Based on big data, evaluation models will be optimized, and education evaluation mechanism will be reshaped. In short, the outcome-based evaluation will be improved, the process-based evaluation strengthened, and value-added evaluation explored.

—Digital technology drives innovation in teaching and learning scenarios. We should develop inquiry-based and personalized teaching based on artificial intelligence, immersive and experiential teaching based on technologies such as AR and VR, CoMP teaching based on the new generation of communication technologies, quality resource sharing mechanisms based on blockchain technology, gamified learning paradigm based on meta-universe technology, new ecology of education and teaching based on low code and light application and constructed by user participation, and empowerment of teachers based on human-technology collaboration. For instance, pre-school education would focus on gamification applications for healthy eating, scientific scheduling and active communication; basic education would focus on ecological applications for enriching cognition, stimulating interest and developing good habits; vocational education would focus on virtual reality training platforms based on the workplace environments and complete workflows in real life; higher education would focus on digital applications for improving the efficiency of talent training and scientific research on the one hand, and on cutting-edge theoretical and applied research on digital transformation and the cultivation of high-level digital talents on the other hand.

2.4 Constructing Digital Educational Resources Systematically

The digital educational resources have richer connotation and extension than traditional resources, which include textbooks, teaching plans, auxiliary books, exercises, recordings of teaching, as well as the digitalized tools, platforms and applications. In a broader sense, this also includes all the staff, software, hardware and running environment for students' learning under the digital education system. In terms of modality, the digital educational resources take the form of graphics, texts, sounds, and videos, and the digitalized presentation methods such as VR and AR. In essence, the digital educational resources are superior to the traditional educational resources.

—Knowledge map should be generated based on the network of logical relationships between bits of knowledge. The traditional education content comprises of bits of knowledge that are relatively discrete and increasingly divided into smaller fields. Such knowledge is arranged in a linear order in textbooks, barely reflecting their logical relationship on a comprehensive and accurate basis. In fact, network structures exist in such bits of knowledge. The digital educational resources can completely display such complicated logical relationships. In order to learn a bit of knowledge, from the starting point, one needs certain pre-learned bits of knowledge, which can be named "prior knowledge bits" and be roughly classified into must-learn prior knowledge bits and auxiliary prior knowledge bits. Every knowledge bit is the posterior knowledge bit of its preceding knowledge bit. All knowledge bits form a systematic map of relationships, which is called "knowledge map". A knowledge map constitutes the basis for students' autonomous learning centering on their development under the digital education system. Its multidisciplinary nature fundamentally rectifies the alienation of education caused by the overly fine division of traditional disciplines. In this sense, the electronic versions of traditional educational resources are not the real digital educational resources as they do not meet the goals of this new form of education.

—The effectiveness of instruction should be enhanced through empowering resources taken the form of super-reality. The presentation of traditional educational content mainly takes the form of description. The main modes of encoding and decoding are words and language, supplemented by figures and videos. By contrast, the AR technology enables students to directly see, hear, and feel the real mode and essence that are otherwise not accessible. For example, it takes a pea seed 21 days to germinate and the process happening in soil is not directly observable by naked eyes. However, if the process is recorded using special cameras and presented to students in one or two minutes, they can very clearly and vividly see the whole growth process. Likewise, VR simulates the scenarios in real life using digital technology, allowing students to see clearly and vividly the circulation mechanism of blood, the orbits and principles of celestial bodies' relative motion, reactions of different metals in aqua regia and the underlying principles, etc. In short, the educational content processed with digital technology will enable students to perceive knowledge more accurately.

—Digital educational content is also the platform node on which students construct learning communities. In the process of instruction, the learners, who have established connections with specific educational content, will form dynamic learning communities, which will attach the characteristics of learners to the corresponding educational content continuously to give it vigor and growth.

—The sharing of high-quality resources and application can effectively promote the high-quality equity of education among schools and districts. The marginal costs of digital content sharing and the repeated use of application systems are incredibly low, so are the requirements of transfer and use on technology and equipment. This is conducive to the large-scale application of high-quality educational content resources in weak schools, the widespread repeated use of mature application systems in schools without such system, the improvement of the conditions in relatively backward schools and areas, and the enhancement of high-quality educational equity. For instance, large-scale online education was applied in Shanghai in 2020 due to the pandemic. The sharing of high-quality educational resources not only improved teaching quality of teachers in weak schools, but also stimulated the vigor of teachers in high-performing schools. However, we must be aware that the sharing of high-quality educational resources and application does not automatically solve the contradictions and deep-rooted problems in the transition of education development from the industrial age to the digital age.

2.5 Re-engineering the Education Management and Service Process

Unlike traditional work process optimization, the re-engineering of education management and service process under the digital transformation of education requires a comprehensive sorting out of traditional work processes in the physical space, the establishment of a complete data process for work flow, the employment of intelligent technology, the coordination of data processing, transfer and storage, the streamlining of work processes with data governance strategies, so as to establish a new work logic loop in the digital space, invoke the necessary physical elements, and complete the work process re-engineering. For example, before 2019, in order to apply for the qualification certificates of primary and secondary school teachers, applicants had to provide 10 documents, go to at least 7 places and 11 departments, and visit the site in person twice. After the digital process re-engineering, through data governance, all materials are now transferred online and the verification process is automated, so that applicants only need to go to one place for medical examination and other processes can be completed without having to visit the site. The efficiency and quality of work of the operational staff have been greatly improved and the duration of work process has been reduced by 15 working days.

In summary, the efficiency and quality of management and service can be greatly improved by leveraging the role of data elements to achieve departmental linkage,

data interoperability, application integration and resource synergy, the enhancement of education administrative service and school management, refinement of management, precision of service and scientific decision-making, all of which are realized via digitalization.

3 Practical Explorations in Digital Transformation of Education

The digital transformation of education is an innovative and complex social system project concerning the rejuvenation of the nation and the happiness of thousands of families. Given the difficulty in implementation and the high stakes involved, we should examine and plan with full consideration before taking action. First, consensus should be reached and goals defined. Second, the transformation should be centered on talent cultivation, top-level design should be strengthened, and the coordinated planning across industries and districts should be enhanced. The planning should be conducted on a top-down basis while the construction should be conducted on a bottom-up basis, with the school being the smallest unit of implementation. Third, we should proceed systematically, plan holistically, implement step by step, conduct pilot explorations, and proceed through demonstration. Fourth, we should stick to the coordination of multiple elements, i.e., fully mobilize the strength of stakeholders from the government, industry, academia, research and society, coordinate the theoretical research, technological breakthrough, innovation and social synergy in the digital transformation of education. Fifth, we should adhere to the principle of safe and secure transformation, i.e., accelerate the construction of the security ecology compatible to the digital transformation of education, surrounding data, technology, system and network security. Although the digital transformation of education is an imminent task, we must be aware that it is a long journey to go with strong responsibilities and obstacles, rather than a sprint. We must grasp five key points as follows.

3.1 Data Governance as the Core of Digital Transformation

Data is an indispensable element of digital transformation of education, both in physical space and in digital space. Data connects the digital space and the physical space. Data being the core element, data governance is the core of digital transformation of education.

—Data is what connects everything. The Internet connects the computers, the Internet of things (IoT) connects the various elements in physical space, mobile network connects people. The natural space, social space, life space are all connected by data and projected into the digital space.

Some isolated instances of applications, systems and data occur in the informatization process, due to the lack of data interconnectivity. If we gather all the data of such instances into a pool of data, then the occurrence will be all connected with one another, and thus the integrated digital space will be created. Integration is the essential characteristic of digital space.

The digital transformation of education in Shanghai is based on the previous achievements of informatization construction and digital construction. *The Implementation Plan for Digital Transformation of Education in Shanghai (2021–2023)* stipulated that data from all systems and platforms, i.e., three core databases derived from students, teachers and educational organizations, shall return to the three core databases aforementioned after being processed and treated. The integration of application shall be realized via data consistency.

—Data is the only wealth that lasts. Whether in informatization or digital transformation, the costly high-tech hardware and sophisticated software will be upgraded or replaced with the development of technology. Only data are reserved, turns into wealth, and gains new value with the development of technologies such as data mining, data processing, computation and application. Data bits that are not effectively indexed or stored do not hold prospects of being exploited, and may even become junk. In a word, whether at present or in the future, data governance is the prerequisite condition for realizing the value of data.

—The unified data standards and data management is the basis of data governance. In order to connect the digital spaces via data, we must first unify the data standards and data management, which is the basis of data governance and also the basis of digital transformation of education. It is the government's responsibility to unify data standards and data management.

The digital transformation of education in Shanghai emphasizes the leading role of standards. For this purpose, the Committee for the Digital Transformation of Education in Shanghai was set up, comprising representatives from the government, industries, enterprises and experts. The committee is responsible for formulating a series of digital construction standards or guidelines covering all education stages. It has established the education data standard system, and issued *Measures for Educational Data Management in Shanghai (for Trial Implementation)*, *Classification and Codes of Basic Information of Educational Administration in Shanghai (for Trial Implementation)*, *Shanghai Educational Data Quality Management Standards (for Trial Implementation)*, *Measures for Education Data Security Management in Shanghai (for Trial Implementation)*, *Measures for Data Integration Technology for Shanghai Municipal Education Data Resource Management (for Trial Implementation)*, and *Measures for Administration of Digital Service Delivered by Technological Platforms for Shanghai Municipal Education Data Resource Management (for Trial Implementation*), among others. In addition, the committee has developed the *School Digital Base Requirement Statement and Construction Standards* (300,000 words).

—Data governance is the key to the solution of practical problems. The digital transformation and establishment of the digital space aims at more effective solutions for the educational problems in real life.

We should stimulate students' interest through learning resource data governance using VR and AR technology. Furthermore, we should establish the holographic knowledge map based on the logic linkages between knowledge bits, promote personalized and autonomous learning, and solve the problems such as students' inadequate learning ability and weak innovation ability.

With learning behavior data governance, we can carry out teaching that is driven by big data according to students' aptitudes on a large-scale, provide each student with suitable education, realize the equal supply of high-quality public education service, and alleviate the anxieties of parents and society as a whole.

Through education administration data governance, we promote the comprehensive growth-oriented quality assessment that is based on the whole process and all elements of data. Furthermore, education administration data governance will promote education quality monitoring and assessment based on big data in order to solve the problem of unscientific assessment orientation, solve abstract education work processes, extract key characteristic factors, use intelligent algorithms to match typical education scenarios, build data models of work flow, automatically process information, optimize, upgrade and re-engineer the work flow, deepen the education reforms in terms of streamlining administration and delegating power, improve regulation and upgrading services, as well as enhance the capability and efficiency of education management services.

—Data security is a fundamental requirement for digital transformation. The non-physical nature of data makes it more vulnerable to untraceable tampering, theft and destruction. As the use of data becomes more and more widespread, its role becomes more important, and its value becomes more prominent. In short, data security emerges as an increasingly prominent issue.

It is true that data security, regulation and protection of operation are very important, but more critical is the planning and construction of the facilities. Metaphorically speaking, we cannot use an unreasonably planned and poorly constructed building, however hard we strive to make up for the anti-theft, earthquake-proof, fire-proof and water-proof facilities after its completion.

The Implementation Plan for Digital Transformation of Education in Shanghai (2021–2023) makes provisions for data security. We shall strengthen the management of data in digital transformation of education in accordance with the *Data Security Law of the People's Republic of China*, the *Personal Information Protection Law of the People's Republic of China*, and the *Shanghai Data Regulations*. The ownership of education data belongs to education users and administrative departments. In educational digital applications and services, whether tailor-made or purchased or rented, the equipment vendors, application developers, and operation and maintenance operating agencies do not own data property rights. They can only use, store and destroy relevant data under the supervision of users according to their authorization. The educational users and administrative departments shall assign the rights concerning data collection, storage, use, processing, transmission, provision, disclosure, among others, on a scientific basis and in strict accordance with laws and regulations.

3.2 Bases as the Key Node in Constructing Digital Space for Education

How should digital transformation of education be implemented at the provincial, city, county and school levels? How do we integrate the construction and application of schools in different districts? *The Implementation Plan for Digital Transformation of Education in Shanghai (2021–2023)* proposes the design for digital bases for schools. Both the district digital bases and the provincial and municipal digital bases are based on the school digital base linkage. By using the same type of bases or the same interface standard, schools in each district are linked together, as are schools in the provinces and municipalities. Administrative platforms are set up at provincial, municipal and county or district levels, which are known as provincial education digital bases, municipal education digital bases, county or district education digital bases.

The base is the standardized digital school hub and the connection point between the school in real life and its digital twin. It is the hub for collaboration among all stakeholders, the place for data sharing, the foundation for extensive reuse of high-quality applications, and the safeguard for data security protection. If the digital school is compared to a complex computer system, the base is equivalent to the system's fully functional operating system. It is responsible for the unified access management of IoT devices, the unified authentication management of institutional personnel, the management of data integration, the one-data-and-one-source management,[1] the integrated interface management of various applications, and the communication management of institutional personnel and functional modules.

In principle, data is stored independently outside the base and applications, and used under the authorization and supervision of schools, teachers and students. The school bases of the unified standard are adopted across the city. Teaching and learning applications can be reused in different schools and can also be used in bases made by different enterprises. In terms of the construction, operation and maintenance, the government sets the unified standard, enterprises make products and guarantee operation and maintenance, and schools purchase services.

According to the *School Digital Base Requirement Statement and Construction Standards in Shanghai*, each base contains five centers. First, it has a data center. All data is stored independently outside the base and applications. Through the base, under the authorization and supervision of the school or the data owner (usually teachers and students), the application system collects, invokes, processes, uses, and returns data. Second, it has an organizational center, which is responsible for setting granting identities and accesses for all digitized personnel, groups and institutions, as well as the daily authentication and management. The third is the IoT center. All hardware devices are connected to the base in a unified manner, under the unified management and sharing scheme. The fourth is the application center. All system

[1] It refers to the requirement that for any basic data entry there should be a definite party responsible for its truthfulness and accuracy.

applications are connected to the base through standard interfaces in the form of plug-ins to invoke the necessary data, equipment and authentication services to achieve their respective functions. The fifth is the message center, which enables information interaction among people, organizations, and devices through the base. In addition, the data and functions of the digital schools are converged in one screen, and the base management platform is established in the form of a cockpit, allowing data, users, devices, applications, and messages to be interconnected and displayed on the same screen, using the Internet of Things (IoT), digital access, and intelligence connection.

3.3 Ecological Cultivation as the Basis of Sustainable Development

As a complex social system project, the digital transformation of education should fully mobilize the strength of all stakeholders from the government, industry, academia, research and society to lay the foundation and form the basis for sustainable development through ecological cultivation. This includes, but is not limited to the exploration and establishment of a new network infrastructure environment represented by 5G technology, a new system of personalized lifelong learning, a new application platform with digital bases as key nodes, a new teaching model of data-driven teaching according to aptitude, and a new evaluation scheme of talents covering the whole process of talent cultivation and all elements involved.

The government is responsible for setting up goals, systems and standards, as well as infrastructure construction. As the digital transformation of education is a collective action involving more than 300 million teachers and students, we must clarify not only strategic goals, but also the goals of each phase, domain-specific goals and local goals. A unified and coordinated organizational system needs to be established, and we need to develop unified and scientific technical standards. Only in this way can we keep the correct direction, avoid confusion and deviation, and reduce the cost of reform. Only then can we form a synergy to transform the massive number of users into development advantages, and achieve integrated construction and development. The construction of education digital infrastructure should be actively integrated into the new national infrastructure project, and telecom operators should be urged to establish overall solutions for digital campus infrastructure, with the current focus on the continued construction of the education logic private network, cloud-network integration and IPv6 and 5G applications.

Enterprises are responsible for developing digital bases and basic applications, as well as providing corresponding operation and maintenance services. Schools are responsible for resource construction, application coordination, and user management. Scientific research departments are responsible for theoretical research, technical research, and innovation of methods for education digital transformation.

The Implementation Plan for Digital Transformation of Education in Shanghai (2021–2023) requires that companies providing digital bases should provide educational application platforms that features "low-code, light application", development tools and functional module libraries. This requirement enables the front-line educators who are not technical professionals to participate in the development of education and teaching applications. It also promotes the development of various educational applications on the digital base, which will build a good ecology of educational applications consisting of application developers, application markets, open application platforms, school digital bases, basic data of education, and operation service specification.

3.4 Purchase of Services as the Basic Means of Implementation

Traditionally, the education informatization follows a customized model, i.e., the government provides funds, schools put forward their needs, and enterprises develop certain functional systems. The customized model is capital intensive, but does not always achieve expected outcomes, i.e., the maintenance and upgrading cannot be guaranteed and some problems arise and trouble schools and administration departments, damping the confidence and determination to construct. First, the imbalance of informatization construction among different schools keeps accelerating. Due to the high cost of customized development, the limited funding for informatization can only support a limited number of schools. In the beginning, funds go to schools with excellent performance. Later, funds are given to schools to create model schools in the follow-up informatization construction. The tendency of diverting funds to those model schools will continue, thus causing increased disparity between schools, which is not conducive to educational balance and equity. Second, the construction of information technology in schools is relatively blind. On the one hand, the macro regional scientific planning is not clear, and the informatization lacks overall design and long-term consideration, often resulting in fragmentation and random construction. On the other hand, barriers of domain knowledge exist in communication between schools and enterprises, i.e., schools find it hard to submit a complete, standardized, professional demand report for customized development. The enterprises find it hard to transform the schools' vague description of needs into appropriate products, and cannot accurately satisfy schools' needs. The repeated failures to deliver expected service frustrate the constructors and supporters, which affects the normalized and systematic use of education informatization. Third, the operation and maintenance of the informatization applications cannot be guaranteed. After being paid the balance, the teams for the customized development always move to do other business or even disband. The primary and secondary schools do not have professional expertise for operation, maintenance, or upgrading the systems. As a result, some application systems are suspended upon delivery. Fourth, there is no guarantee that the competent

developers can always win the bid, because it is difficult to compare the deliverables in the cases of customized products and it is as difficult to compare their prices. Nontechnical factors often severely interfere with the bidding process. In the end, it is obvious that there is a phenomenon of bad money driving out good money among the enterprises that undertake construction.

In order to solve the above problems, stimulate the enthusiasm of enterprises to participate in digital education construction, bring into play their innovation and professional ability, and improve the effectiveness of information construction and application, we propose in *the Implementation Plan for Digital Transformation of Education in Shanghai (2021–2023)* that purchase services be the basic way of implementing digital transformation of education. Specifically, the government is responsible for top-level design, overall planning, setting the goals, and establishing policies and systems to guarantee the purchase of services. On the basis of unified standards and full compatibility, Shanghai bids for three school digital base products, and schools in different districts choose to purchase services on the basis of merit. Through the purchase of services, the funding that was originally sufficient for the digital construction by only a few schools can basically support the simultaneous implementation of digital transformation in all schools.

Large enterprises are encouraged to develop base products and provide operation and maintenance (O & M) services, provide development tools and platforms for light applications and O & M services. The restricting factors of digital base production, such as a long development cycle, heavy investment, high requirements of technology and capability as well as a long cash collection cycle, discourage the small and medium enterprises, reduce the interference of non-technical factors in bidding, as well as the risk of uncertainty. The fact that no more than three base products came into the shortlist ensures that the base products developed by large enterprises have an adequate market share. The purchase of base services by a sufficient number of schools enables large enterprises to obtain stable cash flow, establish a fixed development team for upgrade, operation and maintenance, and support the continued good use of base products. The competition among the three large enterprises has injected vitality into the base upgrade and O & M operation.

Small and medium enterprises are encouraged to develop typical applications, provide corresponding operation and maintenance service, and participate in light application development. Both typical applications and light applications can generate a fast and considerable revenue because they are attached to standardized school digital bases and are easy to be widely reused. Small and medium-sized enterprises can concentrate on the construction of education digital applications based on their own advantages.

The purchase of services helps schools to focus on resource construction centering on the bases, develop light applications based on the digital bases, and carry out basic data governance and security construction more comprehensively and precisely.

3.5 *Talent Cultivation as the Compass for Digital Transformation of Education*

Talent cultivation is the top priority of education. The principles of education must be observed in the digital transformation of education. Otherwise, the transformation may lose its direction or even make the mistake of attending to trifles but neglect of essentials. During the informatization of education, there was technology-driven alienation featuring obsession with new technology, new equipment, new applications and negligence of the original purpose of education, concept-driven alienation that features heated discussions about the concepts such as intelligence, and even profit-driven alienation.

In the implementation of the digital transformation of education, to tell whether the planning is scientific and feasible, whether the technology and equipment is appropriate, and whether the application is effective, we should adhere to the fundamental criteria: whether it is conducive to the overall development of students' moral, intellectual, physical, social and aesthetic development, and whether it is conducive to the training of socialist builders and successors of the new era.

If the digital transformation of education goes in a wrong direction, it will cause irreparable lifetime damage to the students, not to mention the loss of resources and social impact. Therefore, practice without right principles and guidelines is by no means appropriate.

Digitization drives globalization, offering new possibilities and higher social demands for the development of education in the new era. At the moment of transition from the industrial age to the digital age, the digital transformation of education aims to upgrade education concepts, transform education modes, improve the digital literacy and skills of the people, construct a high-quality personalized lifelong learning system, provide each learner with the most suitable education, realize their greatest social value, explore learners' potential and stimulate their interest using digital technology, conduct large-scale data-driven teaching according to learners' aptitude, and develop comprehensive innovative capability, all of which are the mission and pursuits of educators and the whole society.

References

1. Xi Jinping. Speech at the Meeting with Experts from Education, Cultural, Health, Sports Fields (在教育文化卫生体育领域专家代表座谈会上的讲话) [EB/OL]. http://www.xinhuanet.com/politics/leaders/202009/22/c_1126527570.htm,2020-09-22.
2. Harold A. Innis. The Bias of Communication (传播的偏向) [M] Beijing: China Renmin University Press, 2003:28.
3. Li Yongzhi. Education Informatization 2.0 in the Perspective of Media Ecology [J]. Journalism Lover, 2018(9):46.
4. Outline of Actions for Improving the Digital Literacy and Skills of the People (提高全民数字素养与技能行动纲要) [EB/OL]. http://www.cac.gov.cn/2021-11/05/c_1637708867754305.htm, 2021–11–05.

Revisiting "Computational Pedagogy": How Artificial Intelligence Is Changing Educational Research

Sannyuya Liu, Zihe Zhou, and Qing Li

In recent years, the education field has witnessed a surge of interest in the new generation of information technology, represented by artificial intelligence, which results in the broadening of the horizons of educational research, the emergence of novel methodologies, and the establishment of the interdisciplinary field known as "computational pedagogy". It is of paramount importance, both from practical and future-oriented perspectives, to consolidate and critically analyze the transformative impact of artificial intelligence on educational research, as this endeavor aims to discern the prevailing patterns in educational research within the new era and facilitate sustainable advancement of the nascent discipline of "computational pedagogy".

1 Literature Review

It is the mission of educational research to explore the laws of talent cultivation and educational development. Amidst the wave of integration and advancement propelled by computational social sciences that encompass both natural sciences and humanities and social sciences, education research is undergoing a crucial transitional phase. Computational pedagogy has emerged as a response to the challenges faced by the education discipline itself, as well as the imperative need for educational change and

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S. Liu (✉) · Z. Zhou · Q. Li
National Engineering Research Center of Educational Big Data, Central China Normal University, Wuhan 430079, China
e-mail: lsy5918@mail.ccnu.edu.cn

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innovation in the new era. Over the past years since its inception in 2014, computational pedagogy has showcased its capacity to effectively extract and analyze extensive datasets across various dimensions. Simultaneously, the rapid ascendance and proliferation of the new generation of information technology, spearheaded by artificial intelligence, have fostered a propitious environment for the flourishing of computational pedagogy, generating fervent discussions within academic circles. Some scholars posit that computational pedagogy diverges from traditional quantitative education research paradigms due to its disparities in data characteristics, data acquisition methods, and research trajectories [1]. Regarding its disciplinary nature, some scholars assert that computational pedagogy constitutes a novel interdisciplinary field anchored in traditional social sciences, computational sciences, environmental sciences, and engineering sciences. Its essence lies in quantifying the interactive processes among diverse elements within the realm of education, for the purpose of collecting, analyzing, modeling, and predicting various phenomena and behavioral data [2]. From the perspective of dynamic applications of computational pedagogy, some scholars have divided computational pedagogy into four themes: "research on pedagogical laws based on data mining, research on online education with cognitive and behavioral simulation, research on students' motivation and emotional engagement based on big data, and research on teachers' and students' personality and gender analysis" [3]. However, some scholars caution against oversimplification and classification, emphasizing that the intricate interplay of phenomena, contexts, and subjects in educational activities defies a linear "assembly line" process, owing to the distinctive nature of education and the uniqueness of educational subjects [4].

The discourse on educational research paradigms and their classification has been longstanding. The growing interest among educational researchers in computational pedagogy reflects a departure from singular disciplinary and conceptual perspectives in contemporary educational research. The integration of diverse research paradigms holds great promise for generating fresh insights into the principles of education, particularly in alignment with the evolving times. We are on the cusp of entering an "era of computational social science" where data and computational analysis are poised to become the predominant means of describing natural and social phenomena. In this era, computational pedagogy, as a burgeoning interdisciplinary field, presents both opportunities and challenges for educational research. However, existing studies predominantly focus on the impact of AI on educational practices, overlooking the transformative potential of AI in educational research itself. It is essential to explore and comprehend these implications, leveraging AI to advance educational research and gain a comprehensive understanding of educational laws in line with contemporary realities. The establishment of any discipline begins with the "possibility" of its formation and subsequently transforms this possibility into reality. In the nascent stage of computational pedagogy, it becomes crucial to strike a balance between current realities and future prospects. This involves anticipating the transformative impact of AI on educational research, charting the developmental trajectory of computational pedagogy, and elucidating the inherent values forged throughout this process. By harnessing the proactive potential of AI as representative of the

new generation of information technology, it becomes possible to advance the disciplinary construction of computational pedagogy. This, in turn, enables a timely and effective response to the challenges posed by the technological era, accelerating the future trajectory of educational research and fostering a comprehensive construction of a new ecological framework within educational research.

2 Evolution of Scientific Research Paradigms: The Rise of Computational Pedagogy in the Age of Artificial Intelligence

The emergence of information technology has progressively transformed the landscape of scientific practice, offering novel and enhanced support for deductive, inductive, and testing endeavors in the process of educational science research.

2.1 The Manifestation of Technological Power in the Scientific Research Process

Scientific research is a distinct method of knowledge acquisition, encompassing two dimensions: "observation and experiment" and "description and explanation" [5]. The scientific revolution, initiated by figures like Copernicus, Galileo, and Newton five centuries ago, marked the beginning of a systematic development of modern science. This transformative shift discarded subjective conclusions derived from contemplation and imagination, replacing them with rigorous experimentation and logical reasoning to attain objective outcomes. Consequently, natural and social sciences transitioned from obscurity to maturity. Technological advancements over time have significantly enhanced the infrastructure of scientific research, with the advent of printing, in particular, facilitating innovative modes of collaboration between science and technology, which enriched the mechanisms of knowledge transfer and record-keeping. However, the dissemination of scientific discoveries and research data among scientists remained relatively slow, primarily reliant on the traditional channels of publication and peer review.

The information technology revolution that emerged in the post-1950s was not only a culmination of the earlier scientific revolution but also had a profound impact on the practice of scientific research in subsequent years. In the latter half of the 20th century, the "digital convergence" of diverse media, encompassing printed text, images, sound, and immersive experiences offered by virtual reality, catalyzed the evolution of knowledge accumulation. This unprecedented dynamic communication mode transcended the influence of print technology on knowledge production and dissemination [6]. Scientific research underwent a significant transformation from a slow, linear, paper-driven process to a faster, more creative, and collaborative parallel

scientific research system [7]. Within this system, scientists are capable to inspire one another, and increased interaction between the scientific community and the public has propelled scientific research towards a new level of openness, giving rise to the concept of "open science" [8]. The initial signs of "open science" are beginning to emerge.

In the 21st century, the development and application of information technology have ushered in a new paradigm of scientific research [5]. The advent and utilization of advanced information technologies such as big data, artificial intelligence, and the Internet of Things have transformed data into a new factor of production, propelling the digital transformation of smart education [9]. Research tools that are faster, more accurate, and more automated are becoming increasingly abundant, and there is a rapid growth in multimodal approaches to data representation, with digital data sources gaining popularity [10]. This has given rise to the emergence of "telescience" in the natural sciences [11] and "digital scholarship" in the humanities and social sciences [12]. In a data-driven world, algorithms have assumed a fundamental role in explaining and understanding individuals, societies, and various phenomena, akin to human knowledge, neural networks, and thinking methodologies [13]. By leveraging data science and technology to explore data correlations, scientific research has shifted from focusing solely on "causality" to "correlation + causality" [1]. In the era of big data, traditional sampling studies are losing their relevance, as individuals increasingly have direct access to vast amounts of information [14]. Although this information may be messy and unrefined, it possesses qualities of being extensive, comprehensive, and authentic, often leading to unexpected outcomes. Such transcendence is emblematic of the times and presents new challenges to the creative capacity of scientific research [15].

2.2 The Rise of Computational Pedagogy in the Age of Artificial Intelligence

In the era of artificial intelligence, the world assumes a distinctive structure comprising three realms: the real world, the mathematical world, and the computational world [16], or a multidimensional space involving individuals, the physical realm, intelligent machines, and the virtual information domain, as proposed by some scholars [17]. Contemporary social science research is currently at a transformative juncture, driven by the exponential growth of the new generation of information technology, particularly artificial intelligence, which highlights the formation of a new ecosystem in educational research [18]. The advent of open access facilitated by the Internet enables near-infinite dissemination of educational research outcomes, while social media facilitates the establishment of global academic communities in educational research. Additionally, teaching and learning analytics aid in testing educational research findings in practical teaching and learning contexts. The scientific advancement of educational research is a pressing need and a fundamental

pathway to enhance the value and academic standing of the pedagogy discipline. Quantitative research serves as an essential benchmark for gauging the scientific progress of educational research [19]. In recent years, the new generation of information technology, exemplified by artificial intelligence, has expanded the horizons of educational research, shaping novel research modalities, and giving birth to the interdisciplinary field of "computational pedagogy".

The emergence of computational pedagogy addresses the need for scientific advancement in educational research and aligns with the contemporary trend of integrating educational research paradigms with natural science paradigms. It has been acknowledged that "computational pedagogy transforms qualitative and experiential-based educational science into a quantitative and precise science, utilizing big data as its fundamental object and employing computation and modeling as the means" [20]. Empowered by technology, computational pedagogy engages in research and practice based on a data-intensive research paradigm, focusing on key areas such as computational educational ethics, computational educational subjects, computational educational contexts, and computational educational services. By elucidating educational activities and issues in the information age and unveiling the underlying mechanisms and operational principles of complex educational systems, computational pedagogy significantly enhances the depth and breadth of educational research. It facilitates the transition of educational research from an "empirical" approach to a "scientific" and "precise" one, thus paving the way for accurate understanding and guiding intricate educational systems [21].

According to scholars, computational pedagogy is a concept that has emerged through multidisciplinary cross-pollination [22]. Due to its novelty, there are diverse and potentially controversial interpretations and perceptions of this concept [23]. The initial reaction to any new concept typically revolves around its feasibility. Linguistically speaking, this concerns whether the "referent" upon which the concept's "signifier" and "signified" are based truly exists or has the potential to exist in the future. If the referent does not exist or cannot exist in the future, the concept remains a product of delusional imagination. Conversely, if the referent already exists, discussing its possibility becomes unnecessary. However, if the referent does not currently exist but may emerge in the future, the new concept goes beyond delusional imagination and represents a natural outcome of disciplinary imagination. Disciplinary imagination cannot be replaced by mere imagination detached from any disciplinary context. Nonetheless, a rational disciplinary imagination possesses the potential to nurture and even create a new discipline, highlighting the power of theory and logic. Therefore, a responsible examination of the possibility of computational pedagogy must transcend superficial linguistic analysis, stand at the crossroads of reality and the future, and explore the significant changes that the new generation of information technology, particularly artificial intelligence, may bring to educational research.