

# Digital Education: Connotation, Pathway, and Trend

Di Wu, Jun Wang, Ziyang Che

National Engineering Research Center for E-Learning, Central China Normal University, Wuhan 430079, China

© Higher Education Press 2024

**Abstract** The rapid development of digital technology has fundamentally changed the ways we live, work, and study. Digital education has gradually emerged under the influence of social change, technological advancements, global competition, and innovative educational practice. Digital education is not just a simple application of digital technology in education but a new educational paradigm. It builds a more equitable, higher-quality, environmentally friendly, and openly cooperative new education system through data-driven methods, human-technology integration, the combination of virtual and real elements, and open sharing. Developing digital education involves focusing on scenarios, resources, models, evaluation, and digital literacy. China has made significant progress in developing digital education, accumulating valuable experience that can inform the continued and prosperous growth of digital education worldwide. While acknowledging the advantages that digitalization brings to teaching, evaluation, and management, we also need to be aware of the risks and challenges it brings to data security, privacy protection, ethical issues, and humanistic concerns.

**Keywords** digital education, connotation, data-driven, human-technology combination

## 1 Introduction

From the early stages of audiovisual education and computer-assisted instruction to the current online learning platforms and intelligent teaching systems, technology has continuously transformed the methods and contents of education. This has breathed new life into traditional education. The widespread application of technologies such as artificial intelligence (AI), Big

Data, and high-speed internet has significantly changed people's lifestyle and work habit (Wu et al., 2023a). Digitalization has influenced every aspect of daily life, including education. As an emerging and rapidly developing domain, digital education is quickly rising to prominence, redefining the research and practical paradigms of education to meet the demands of modern society. Consequently, recognizing digital education's connotation, trajectory, and trend is critical to understanding the future direction of education (Wu et al., 2023b). This paper will discuss these topics, thoroughly exploring digital education's nature, pathway, and trend.

## 2 Background

The era of digital education is characterized by a variety of factors, such as social transformation, technological catalyst, global competition, and educational reform.

### 2.1 | Societal Transformation

The COVID-19 pandemic accelerated the digitization of society, driving the rapid emergence, constant evolution, and maturation of new industries, formats, and models in the digital economy. Typical examples of this change include integrated online education, remote working, digital governance, virtual industrial parks, unmanned economies, and shared living. These not only drive social and economic advancement but also improve overall productivity and standard of living. This societal transformation profoundly affects the demand structure for talent, updating the required skill sets. An abundance of highly skilled workers with digital literacy, creative and communication skills, problem-solving abilities, and the ability to quickly adjust to rapidly changing technology and market environment are increasingly needed in the digital economy. In September 2022, the United Nations Transforming Education Summit identified promoting digital learning and

transformation as one of the five major action areas, calling on nations to ensure high-quality digital education as a public good, benefiting all learners (United Nations, 2022).

## 2.2 | Technological Catalyst

The development of new-generation information technology provides powerful support for digital education. AI technology has become a crucial part of digital education. AI provides personalized learning materials and lesson plans for every student by evaluating students' learning process data. This automates evaluation and feedback on the efficacy of the learning process. Big Data technology also brings enormous potential to digital education. It possesses the capacity to gather and analyze extensive multimodal teaching and learning data, forecasting students' learning trends and actual needs. This capability assists teachers in refining their lesson plans and instructional strategies. The use of metaverse technologies in digital education has become popular. Combining several digital technologies, digital education creates immersive, interactive, and intelligent spaces featuring both virtual and real elements. This allows students to participate in interactive instruction, providing an enhanced experience akin to in-person learning. In May 2023, EDUCAUSE released the *2023 EDUCAUSE Horizon Report (Teaching and Learning Edition)*, which identified six key technologies and teaching practices impacting education. These include generative AI and AI-driven educational applications. The report emphasizes that technological advancements can create new education opportunities (Pelletier et al., 2023). These advancements can significantly increase the experiences of teachers and students and elevate teaching efficiency through close integration with educational practices.

## 2.3 | Global Competition

In the context of globalization, countries are competing for advantages and leading positions in the fields like economy, technology, and education. Particularly notable is the enormous transformative potential of digital education. To enhance their overall strength in the global competition, countries are actively investing in digital education, focusing on nurturing innovative talents with international perspectives and digital literacy. By engaging in competitive activities, this strategic focus not only helps countries in solidifying their places within the globalization process but also ignites their creativity. Thus, their sustainable development is supported by knowledge and technology. In the end, it is believed that by working tirelessly together, different countries would be able to create a worldwide digital education solution aligned with shared interests and revitalize

the global education industry. In September 2015, the United Nations released the *Transforming Our World: The 2030 Agenda for Sustainable Development*, aiming to address developmental issues across social, economic, and environmental dimensions through 17 sustainable development goals and 169 specific targets (United Nations, 2015) to ensure inclusive and sustainable growth for all countries and regions. This agenda offers a common framework for global competition, underscoring the significance of international cooperation and concerted action to tackle global challenges, such as climate change, poverty, and inequality.

## 2.4 | Educational Reform

Technology and education share a mutually reinforcing and co-evolving relationship. On the one hand, traditional education faces certain limitations such as concepts, content, models, methods, and evaluation. This requires profound reflection and innovation to adapt to the educational demands of the digital age. This process of reflection and improvement provides valuable space and opportunities for the development of digital education. On the other hand, digital education is characterized by its flexibility, diversity, interactivity, and intelligence. These qualities better meet student-centered educational needs and enhance the quality and optimize the allocation of educational resources. These accelerate the ongoing and healthy growth of the educational industry and offer a new chance for the overall transformation of education. In September 2020, the European Union issued the *Digital Education Action Plan (2021–2027)*, aiming to advance high-quality, inclusive, and accessible digital education in Europe to adapt to the digital era (European Commission, 2021). By the end of September 2022, the United States introduced the Biden administration's first educational digital transformation policy, *Advancing Digital Equity for All: Community-Based Recommendations for Developing Effective Digital Equity Plans to Close the Digital Divide and Enable Technology-Empowered Learning*, promoting educational equity through digital empowerment (U.S. Department of Education, 2022). In February 2023, Republic of Korea initiated the *Digital-Driven Education Reform Plan: Unlocking Opportunities for Personalized Learning in Education*, aiming to empower basic education through five key measures, such as applying AI-driven digital textbooks, forming high-tech upgraded classroom teacher teams, developing diverse digitalized teaching models, operating digital learning pilot schools, and expanding the digital infrastructure (Ministry of Education of Republic of Korea, 2023). In June 2023, Japan launched

the *Basic Plan for the Promotion of Education (2023–2027)*, positioning the push for educational digital transformation as one of the five primary directions for education reform in the next five years, emphasizing digital foundational systems in education, driving school digital transformation and cultivating digital skills in students and teachers (Ministry of Education, Sports, Science and Technology of Japan, 2019). In September 2023, Singapore unveiled the *EdTech MasterPlan 2030*, capitalizing on the transformative potential of technologies like AI in teaching and learning (Ministry of Education of Singapore, 2023). China also prioritizes the development of digital education, launching the *National Strategic Action Plan for Education Digitalization* in January 2022 (Ministry of Education of the People's Republic of China, 2022), building and continuously upgrading the National Smart Education Public Service Platform, actively fostering “Internet + Education,” and accelerating the digital and intelligent upgrade of education.

## 3 Connotation

Digital education involves using digital thinking and technology to update educational concepts, transform educational contents, innovate teaching paradigms, and optimize educational governance. It aims to create a new ecosystem for education in the digital era, one that is characterized by data-driven approaches, human-technology integration, the combination of virtual and real elements, and open sharing. This process supports the establishment of an education system that is more equitable, of higher quality, accessible to all, and consistent with sustainable development principles.

### 3.1 | Data-Driven Approach

Digital education emphasizes reliance on and utilization of data, viewing it as a core resource to drive the development of various aspects and functions in educational instruction. This approach is mainly evident in differentiated teaching, personalized learning, and precise management. Specifically, digital education provides tailored teaching services in classroom instruction. It analyzes students' learning processes and academic performances, focusing on their progress, interests, and learning styles. This analysis forms personalized learning profiles and assessment reports for each student, offering individualized learning resources and plans. Additionally, it offers teachers' suggestions and guidance to enrich contents and improve the teaching interests (Dillenbourg, 2016). Overall, it

significantly enhances students' learning interests and abilities, along with boosting teachers' efficiency and effectiveness.

### 3.2 | Human-Technology Integration

Human intelligence and technical means are combined in digital education to create a synergistic, complementary, and augmented comprehensive system. It forms an “human-in-the-loop” intelligent education model, developing a more flexible, efficient, and thoughtful educational experience (Ertmer & Ottenbreit-Leftwich, 2013). Students become the central focus of teaching under this model, with technology acting not merely as a tool, but as an integral partner engaging in thorough interaction and collaboration with both students and teachers. Specifically, technology handles tasks such as data collection, processing, analysis, modeling, dynamic interaction, and content recommendation. Teachers concentrate on answering complex questions, facilitating social interactions, and providing emotional supports. Students enhance their knowledge and skills through their interactions with technology. Simultaneously, they develop emotional attitudes and values in their interactions with teachers.

### 3.3 | Virtual-Real Convergence

Digital education offers a learning environment that blends virtual and real elements, promoting the integration of multiple dimensions like space and time, content and method, technology and humanity, individuality and commonality, and learning and practicing. This supports a diverse and mixed educational model. Digital education extends the teaching space beyond traditional classrooms and schools to environments where the physical and digital worlds merge. It enables students to learn in an immersive and intuitive manner anytime and anywhere, realizing the fusion of virtual and real spaces in education. In addition, digital education provides a variety of learning scenarios, facilitating the easy transition between these scenarios through technological means, thus integrating diverse teaching contents and methods. It also offers enhanced creative supports and emotional experience for teaching, assisting teachers design contents that are emotionally rich and creative, and providing students with their own spaces for free creation.

### 3.4 | Open Sharing

Digital education fosters openness and sharing across four levels: resources, technology, teaching, and society. It provides diverse digital educational resources such as

electronic textbooks, online courses, instructional videos, and learning software, which are disseminated and shared globally through the internet and digital education platforms. Digital education employs shared digital technologies like AI, Big Data, and cloud computing to encourage educational institutions and enterprises to innovate in technology and teaching applications. This leads to the development of more specialized and intelligent teaching tools and platforms. Digital education shares teaching methods, models, and experiences through comprehensive service platforms. Teachers from various regions, schools, and disciplines form research communities to promote their professional development. Students create groups for coursework, extracurricular activities, and social engagement to improve their abilities and literacy. In the broader context, digital education will establish efficient and convenient regional and international cooperation mechanisms, breaking down barriers across various levels and fields. By employing strategies such as disseminating case studies, transferring resources, and exchanging talents, it will actively nurture international collaborations. This proactive approach seeks to advance openness, equity, and progress not only within the educational sphere but also at the societal level.

## 4 Vision

### 4.1 | Equal Education

Digital education breaks through geographical and time constraints, increases the availability of high-quality resources, reduces costs, and promotes educational equity. By transcending the limitations of schools and other public infrastructure, digital education delivers educational resources to every corner through the internet and other digital technologies. This enables students in remote areas to access a wealth of educational content, providing more people with equal educational opportunities (Chang et al., 2023; Haleem et al., 2022). Digital education is not confined by school schedules, allowing students to learn according to their own lifestyles and routines. It also allows individuals facing constraints such as work or family commitments to access education, overcoming barriers to traditional school-based learning participation. Digital education replaces traditional teaching materials, with digital resources allowing students to access a vast array of digital educational resources through digital devices, and significantly reducing the cost of using educational resources. Remote education can replace the needs for day or boarding schools by allowing students to participate in classes via the internet. This offers a cost-effective

solution by mitigating the needs for expensive travel and prolonged accommodation expenses, especially in meeting educational needs in emergencies such as pandemics. Cloud computing technologies offer resource sharing and centralized management, minimizing the needs for schools to develop and maintain major facilities such as classrooms, libraries, and dormitories, thus decreasing repetitive construction and operational and management costs. Digital education can also provide customized learning tools and resources for students with physical and mental disabilities. It provides diverse ways to enhance teaching interactions by adjusting the complexity and presentation of learning content and placing lessons based on the talents and needs of students, enabling specific groups to have equal access to education.

### 4.2 | High-Quality Education

Digital education creates intelligent, personalized learning scenarios, blending online and offline teaching, and innovating talent training models to lead high-quality educational development. Digital education considerably improves educational models, accelerating the implementation and widespread adoption of precise academic diagnosis, adaptive learning, and intelligent classroom evaluation. It provides more interactive and immersive learning environments to fulfill students' diverse and individualized learning needs. This helps teachers to instantly understand students' learning situations and optimize teaching content and activity arrangements. It enables more comprehensive and precise evaluations of student learning performance and teacher professional levels. Digital education encourages the integration of online and offline, virtual and real interactions, and shifts classroom instruction from teacher-centered to student-centered, as well as from a single method to diverse approaches. This transformation enhances the educational process by making it more creative, experiential, and inspirational, hence increasing students' enthusiasm for learning and innovative spirit. Digital education advances talent cultivation by recommending appropriate learning resources and activities based on students' abilities, habits, and personal characteristics, providing abundant resources and tools for interdisciplinary learning, and creating realistic environments for professional skill development. Moreover, digital education serves to seamlessly integrate industry and education. Platforms in digital education provide students with real-time insights into the latest industry trends and requirements, guiding their active involvement in practical projects. These also allow students to acquire the skills needed for future development through hands-on experience, preparing them for their upcoming professional careers.

### 4.3 | Green Education

Digital education achieves efficient use of educational resources and environmental protection, promoting sustainable development in education through the digitization of resources, optimization of space, precision in teaching, and integration of environmental education. Digital education platforms effectively use and share resources, leaving fewer resources being wasted. Traditional education methods require a large amount of paper materials like textbooks and exam papers, resulting in considerable waste of resources. In contrast, digital education employs electronic means to digitize resources such as textbooks and exam papers. This enables students to utilize electronic devices for studying, reducing the need for paper materials and avoiding the production of substantial waste, thereby helping to conserve resources and protect environment (Haleem et al., 2022). Traditional schools need extensive buildings to accommodate students, and the construction and maintenance of these buildings consume a lot of energy and materials. Digital education reduces reliance on physical school spaces, as students can learn online from home or other locations, optimizing the use of space and reducing the costs and environmental impacts of building and maintaining educational infrastructure. Digital education analyzes students' learning situations and needs precisely, providing teachers with more effective teaching references, improving teaching effectiveness and efficiency, and minimizing waste of resources like paper. Furthermore, environmental education can be incorporated into the curriculum of digital education. Students can access a wealth of environmental knowledge and vivid cases through digital platforms, such as these platform's green design and energy-saving strategies, fostering their environmental awareness and habits.

### 4.4 | Open and Collaborative Education

Global learning experience, open innovation platforms, and integrated learning environments help digital education achieve higher levels of open collaboration. Digital education connects global educational resources via the internet, enabling students from different countries and regions to enhance their international perspectives through cross-border learning. Intelligent technologies enable real-time translation between different languages, removing language barriers and significantly promoting exchange and understanding between various cultures. Open education platforms, such as those established by digital education, draw participation from multiple entities, including schools, educational institutions, and corporations. This builds an educational ecology that is

open, interactive, and collaborative. Based on this foundation, these organizations collaborate to create new educational products and services, facilitating knowledge-sharing and innovation (Safonov et al., 2022). Digital education encourages school-society-family integration to form a collaborative educational effort. It guides parents to participate in their children's educational process by providing timely feedback on the children's learning status and development at school. Digital education encourages students to engage in social practices by utilizing online educational communities and volunteer activities, developing a sense of social responsibility.

As a crucial direction of educational innovation, digital education incorporates various aspects in its pathway. The next section will expound on the following specific aspects:

- (1) The pathway of digital education in constructing new scenarios;
- (2) The pathway of digital education in providing new resources;
- (3) The pathway of digital education in exploring new models;
- (4) The pathway of digital education in establishing new evaluations;
- (5) The pathway of digital education in developing new abilities.

## 5 Pathway

As a crucial direction in educational innovation, digital education encompasses various aspects in its developing pathway. This includes creating new scenarios, providing novel resources, exploring innovative models, implementing new assessments, and cultivating new competencies.

### 5.1 | Creating New Scenarios

Digital education reshapes the educational and teaching scenarios from three aspects: expanding learning spaces, transforming learning methods, and improving learning experiences. Digital education offers various forms of learning spaces, such as physically enhanced classroom spaces, remotely synchronized platform spaces, community spaces for group interaction, and intelligent personal spaces. This allows learners to engage in teaching and learning interactions with teachers and peers, transcending time, space, and language barriers. They can even collaborate more agilely and personally with intelligent machines (Bygstad et al., 2022). Digital education offers diverse learning approaches such as remote synchronous learning, immersive experience, and simulated practical activities by utilizing online courses, virtual venues, and

simulated experiments. These approaches cater to varied teaching needs, increasing learning interests and teaching effectiveness. Meanwhile, through online socializing, group collaboration, and human-machine co-creation, digital education can improve communication and collaboration between teachers, students, and intelligent computers, fostering higher levels of cognition. People, events, and objects may all be personalized and dynamically tailored to specific digitalized scenarios, significantly optimizing the learning experience. Through visual narratives and gamified tasks, teachers and students can personalize virtual avatars, interact freely with virtual companions, and transform abstract knowledge into vivid, physical experience.

China is actively exploring the application of intelligent teaching equipment and digital textbooks in serving the classroom teaching process. For example, the Experimental Second Elementary School in Xingqing District, Yinchuan City, Ningxia Hui Autonomous Region has collaborated with enterprises and research institutions to jointly develop a digital terminal—the Digital Desk. This Digital Desk integrates resources such as the teachers' preparation manual, students' learning manual, multimedia courseware, and more. It promotes the effective circulation of digital resources from the cloud to the students' end, creating a blended classroom centered around the Digital Desk. This realizes an integrated and interactive learning experience combining online and offline elements. The school has established smart classrooms for 12 fifth-grade classes currently, providing each student with a Digital Desk. Through the embedded electronic screen of the Digital Desk, students can view the teaching contents, and directly answer and submit their assignments. This setup improves the process recording and evaluation of classroom teaching data, fostering students' autonomous learning and collaborative inquiry abilities, and is conducive to the implementation of precision teaching.

## 5.2 | Providing New Resources

Digital education infuses the field with new vitality and possibilities by offering open, immersive, interactive, and intelligent resources. It delivers open resources, allowing students, educators, and scholars free access worldwide. These resources can be freely updated, recombined, and instantly shared through open license agreements, enabling customized and diversified educational resources. Digital education provides immersive resource formats, utilizing technologies like virtual reality (VR) and augmented reality (AR) to offer students immersive learning experience. For instance, students can visit ancient cities or observe the structure of biological cells through

VR devices, making their learning more intuitive and vivid. Digital education also offers interactive resource services, allowing students' real-time and two-way interaction with the learning contents. For example, interactive models let students observe and interact by rotating, zooming, and dissecting, increasing engagement and making learning more enjoyable. Furthermore, digital education supports students to learn anytime, anywhere by using cloud computing and Big Data technology. Intelligent resource provision can dynamically adjust the difficulty, complexity, and presentation of learning content based on student learning data, ensuring students learn at an appropriate challenge level while retaining motivation.

To deepen the implementation of the national education digitalization strategy and create a high-quality digital education platform, the Chinese government launched the Smart Education of China on March 28, 2022. The platform provides resources and services targeting primary and secondary education, vocational education, higher education, and college student employment. By June 2023, the platform had accumulated 26 billion page views with over 1.92 billion visits. On June 9, 2023, Smart Education of China won the 2022 UNESCO King Hamad Bin Isa Al-Khalifa Prize for the Use of Information and Communication Technologies (ICTs) in Education. The United Nations Educational, Scientific and Cultural Organization (UNESCO) recognizes that China's "Smart Education of China," launched in 2022, is all-encompassing. It provides a vast array of learning resources aligned with the curriculum, including 44,000 fundamental educational content items covering various grades and subjects, 19,000 vocational education resources, 27,000 online courses for higher education, and extracurricular materials on mental health, sports, arts, and more. With 13.15 million registered users, the platform played a crucial role during the COVID-19 pandemic, significantly assisting large-scale home learning.

## 5.3 | Exploring Innovative Models

Through blended, collaborative, and personalized learning models, digital education increases student autonomy, innovative thinking, and practical skills, as well as teamwork, communication, and self-management abilities. Blended learning models effectively combine the strengths of traditional and digital education. Methods like online courses and flipped classrooms foster student-led and inquiry-based learning, nurturing innovative thinking and practical skills (Anthony et al., 2020). Collaborative learning models, which are based on group learning, promote interaction and cooperation among teachers and students. Digital education supports and

facilitates collaborative learning through online collaboration tools and social media, significantly advancing the practice and development of these models. Personalized learning models are tailored to students' interests, abilities, and needs. Digital education employs Big Data and AI to track and analyze student learning behaviors and academic performance, providing more scientific learning advice and appropriate resources for each student. Moreover, personalized learning models also foster students' independent learning and self-management skills, enhancing their learning effectiveness and motivation.

Many universities in China have actively explored and experimented with digital teaching methods. For example, Central China Normal University in Wuhan has consistently and actively researched digital teaching models, forming various cases. When developing digital teaching resources for geography, they use self-designed virtual simulation experiments and AR sandboxes for geography teaching. These tools allow students to more realistically and actively engage in geography teaching skills training in flipped classrooms. In literature appreciation classes, they employ a collaboratively developed intelligent teaching platform and smart classroom technology. Through a blended classroom teaching model, non-Chinese major teacher-training students and international students studying Chinese language education analyze the meanings of poems and spread China's culture. Modern educational technology application classes utilize eye-tracking devices and large, smart screens. Students work together to analyze instructional videos, developing a deeper understanding of the design principles behind instructional video visuals. In music teaching and evaluation classes, intelligent music composition systems and music assessment tools are used to provide music teacher-training students with an integrated experience of knowledge and skills.

#### 5.4 | Establishing New Assessments

Digital education transforms evaluation methods from manual to machine-led with human assistance, increasing assessment efficiency and fairness. It also expands the aspects of evaluation to include moral, aesthetic, and labor education, concentrating on students' well-rounded development. Digital education transitions from traditional paper-based tests to online computer-based exams. After students complete questions on a digital education platform, the platform automatically uses preset algorithms to evaluate their answers and generate assessment results. For example, multiple-choice questions involve simple logic comparing students' answers with correct ones, while subjective questions require

more complex natural language processing technologies or AI algorithms for assessment, supplemented by human's re-evaluation to ensure the accuracy and fairness of machine evaluations. Digital education extends traditional educational assessments from intellectual education to moral, aesthetic, and labor education. Student behaviors on digital platforms are used for evaluation in moral education, such as their language and attitude in discussions or teamwork skills in group collaborations. Students' participation in artistic activities and the number and quality of creative works are recorded by the platform to assess their performance in this area of aesthetic education. Students' labor time, task completion quality, and efficiency are tracked by the platform to comprehensively evaluate students' consciousness and ability to perform practical labor tasks in labor education.

In 2013, Nanchang City in Jiangxi Province, was the first in China to explore the reform of high school history exams with computer-based testing, gradually expanding this approach to cover all subjects. By 2021, Nanchang extended computer-based testing to middle school biology and geography exams. After over a decade of continuous exploration, Nanchang has accumulated rich experience in the reform of computer-based academic exams, developing mature working mechanisms and procedural standards. In September 2023, Nanchang officially implemented the *Specification for the Academic Level Qualification Examination (Computer Aided Examination) for Ordinary Middle Schools*. This set of standards provides unified regulations on exam organization, comprehensive exam management platforms, exam environments, network security systems, exam question banks, and assessment evaluation. It also clearly defines the technical architecture, logical layers, functional modules, equipment configuration, and network security requirements. This establishes a foundation for further improving exam efficiency, reducing exam costs, and minimizing exam risks.

#### 5.5 | Developing New Competencies

Teachers need to possess the awareness, ability, and literacy to use digital technology for acquiring, processing, managing, and evaluating digital information and resources, as well as identifying, analyzing, and solving pedagogical challenges, thereby optimizing, innovating, and transforming educational activities to excel in education and teaching in the digital era. This encompasses digital awareness, knowledge and skills in digital technology, digital applications, digital social responsibility, and professional development. Specifically, teachers need to master principles and methods for selecting

digital devices, software, and platforms within educational contexts. They should be able to use digital assessment tools to analyze students' learning conditions and apply intelligent grading systems, question bank systems, and assessment systems to evaluate students' knowledge, learning abilities, and styles. Moreover, teachers should leverage digital resources to identify student learning differences and provide targeted guidance. Teachers' digital literacy must be prioritized to assist them in better addressing the challenges and opportunities presented by education digitization. Encouraging active participation in digital education practice through initiatives such as digital education training, promotion of digital teaching methods, formation of digital teaching communities, and establishment of effective incentive and recognition systems is key to enhancing teachers' digital literacy and competitiveness.

Ministry of Education of the People's Republic of China (MoE of China) issued the *Digital Literacy for Teachers* in November 2022 to enhance teachers' digital literacy. Since 2018, the authors and their research team have been entrusted by the MoE of China to conduct large-scale assessments of teacher digital literacy for five consecutive years. This assessment covered 47 regions, 40,000 primary and secondary schools, and 1.55 million teachers, creating a national map of digital literacy among elementary and middle school teachers and compiling the *Teacher Digital Literacy Research Report*. China continually optimized the assessment mechanisms, upgraded the assessment systems, developed a series of course resources, conducted teachers' training on the Smart Education of China, provided services to over 10 million teachers, and accumulated experience in enhancing digital literacy for a large-scale teacher population during this process.

## 6 Trend

Digital education is an evolving field that will face a variety of new trends and challenges in the future. This section will explore digital education trends, including pedagogy, educational decision-making, privacy and security, and ethical issues.

### 6.1 | Personalized Pedagogy

The educational experience will evolve toward AI-enhanced and precision-personalized-pedagogy. The hybrid teaching model of human-computer collaboration will be widely applied in teaching and learning scenarios, where AI assistants with rich and continuously improved plugin systems play a larger role in transaction handling, teaching support, personalized coaching, and

emotional companionship. The hybrid teaching model of human-computer collaboration will be widely applied in various scenarios, including teaching and learning, as well as learning and practice. Education content customized by AI can more scientifically and accurately adapt to the individual interests, learning styles, and levels of different students. This is accomplished through diversified evaluation methods for learning outcomes, customized adaption of learning plans, personalized organization of teaching contents, and intelligent recommendation of teaching resources. Such an approach enhances learners' intrinsic motivation and further improves learning efficiency. Furthermore, the continuous development of digital technology brings us closer to a more advanced form of the educational metaverse capable of establishing richer dimensions and more realistic sensory interactions. It better integrates real space with virtual space through higher-level virtual-real mapping and dynamic connections, enabling the development of more participatory and interactive educational activities, enriching learning experiences, expanding cognitive boundaries, and promoting communication and cooperation.

### 6.2 | Data-Driven Management

Educational decision-making will evolve toward a data and intelligence dual-driven and timely feedback approach. Data-driven education management decisions, spurred by both numerical and intelligent forces, will make use of intelligent machines' outstanding fitting capabilities. They will describe the high-dimensional and complex relationships among educational variables. Drawing on prior experience in the domestic and international education fields ensure that decision recommendations and predictive outcomes are more scientifically grounded. These provide education managers with decision support that is professional, rational, accurate in results and operates efficiently. The robust foundation of digital education is formed by national and regional multi-level educational Big Data centers and platforms. Data from various educational platforms, systems, applications, and terminals are aggregated, and through APIs (Application Programming Interfaces) or ETL (Extract-Transform-Load) tools, cross-regional and cross-platform data pipelines are established to automate data flow and real-time updates. The current status of various management elements is captured promptly with intelligent modeling and decision-making technologies, and their trend predictions assist decision-makers in adjusting management strategies in time to ensure the proper alignment of educational needs and the effective achievement of management objectives.

### 6.3 | Privacy and Security Protection

Data security will require the establishment of a comprehensive data privacy protection system. The digital era brings convenience to learning, working, and living, but it also gradually blurs the boundaries between individual and group data, leading to increasingly prominent risks of data security and privacy breaches. Educational data tampering and leakage can have major consequences for all stakeholders. It is imperative to implement appropriate measures, including the establishment of detailed data management regulations, the application of advanced encryption technologies, and secure storage methods, as well as intensifying supervision over data usage. These steps are crucial to ensure the safety and control of all aspects of educational data collection, storage, processing, and sharing, to prevent data misuse and protect the personal rights of teachers, students, and parents. To manage incidents such as data breaches, it is also necessary to build a comprehensive emergency response scheme, reinforce prevention measures, and patch vulnerabilities.

### 6.4 | Ethical Care

In terms of ethical order, students' ethical awareness and social responsibility in the digital age become more important than ever. Intelligent tutoring and personalized recommendations in digital education rely on algorithms, and poor algorithm design or algorithmic bias may lead to educational inequity. The ubiquitous and frequent use of digital tools might result in students' over-reliance on and addiction to technology, impacting their mental and physical health and overall development. Measures must be taken, including rigorous algorithm reviews, optimized algorithm design, establishment of data filtering criteria, and reasonable control of the time and frequency of digital tool usage. These actions aim to create a secure, healthy, and equitable digital education environment. In addition, parents' lack of acceptance and understanding could also be an important barrier. For example, some parents worry that their children's use of digital devices might occupy their free time and damage their health. In this context, it is important to actively communicate, understand, and progressively promote digital education. Additionally, expanding ethical education and enhancing humanistic care are critical. Students are guided to consciously fulfill their social duties by promoting norms for online behavior and taking cyber ethics education. Attending to students' emotional and psychological well-being through personalized care and guidance is essential to creating a loving and support-

ive digital educational environment, assisting in facilitating the growth of students into responsible digital citizens.

## 7 Conclusion

Technological advancements and industry innovation provide an unlimited driving force for the advancement of digital education. Governments, educational institutions, educators, and enterprises should pay more attention to the progress of digital education in the future, increasing investment and providing continuous necessary support, delivering the latest concepts and technologies in digital education to stakeholders, and promoting the development of digital education further.

**Acknowledgment** This work was supported by "An International Comparative Study on the Digital Transformation of Education", a Major Program of the National Social Science Fund of the Ministry of Education of the People's Republic of China for the year 2022 (No. 22JZD045).

**Conflict of Interest** Di Wu is one of the Executive Associate Editors-in-Chief of *Frontiers of Digital Education*, who was excluded from the peer-review process and all editorial decisions related to the acceptance and publication of this article. Peer-review was handled independently by the other editors to minimise bias.

## References

- Anthony, B., Kamaludin, A., Romli, A., Raffei, A. F. M., Phon, D. N. A. L. E., Abdullah, A., & Ming, G. L. (2020). Blended learning adoption and implementation in higher education: A theoretical and systematic review. *Technology, Knowledge and Learning*, (27).
- Bygstad, B., Øvrelid, E., Ludvigsen, S., & Dæhlen, M. (2022). From dual digitalization to digital learning space: Exploring the digital transformation of higher education. *Computers & Education*, (182), 104463.
- Chang, J., Li, B., Chen, B., Shen, Y., Lyu, X., & Liu, J. (2023). Does higher education promote sustainable development? Role of green technology and financial performance. *Environmental Science and Pollution Research*, (41), 94890–94903.
- Dillenbourg, P. (2016). The evolution of research on digital education. *International Journal of Artificial Intelligence in Education*, (2), 544–560.
- Ertmer, P. A., & Ottenbreit-Leftwich, A. (2013). Removing obstacles to the pedagogical changes required by Jonassen's vision of authentic technology-enabled learning. *Computers & Education*, (64), 175–182.
- European Commission (2021). *Digital education action plan (2021–2027)*.

- Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, (3), 275–285.
- Ministry of Education, Culture, Sports, Science and Technology of Japan (2019). *Basic plan for the promotion of education*.
- Ministry of Education of Republic of Korea (2023). *Digital-driven education reform plan announced*.
- Ministry of Education of the People's Republic of China (2022). *Accelerating High Quality Development of Education 2022 National Conference on Education*.
- Ministry of Education of Singapore (2023, September 20). *More support for schools and students to shape the future of learning*.
- Pelletier K, Robert J, & Muscanell N. (2023). *EDUCAUSE horizon report: Teaching and learning edition*. 2023 EDUCAUSE.
- Safonov, Y., Usyk, V., & Bazhenkov, I. (2022). Digital transformations of education policy. *Baltic Journal of Economic Studies*, (2), 127–136.
- United Nations (2015). *Transforming our world: The 2030 agenda for sustainable development*.
- United Nations (2022). *Transforming education summit*.
- U.S. Department of Education (2022). U.S. Department of Education Communicates Vision to advance digital equity for all learners.
- Wu, D., Li, H., & Chen, X. (2023a). An exploration of the impact of generalized big model educational applications of artificial intelligence. *Open Education Research*, (2), 19–25, 45.
- Wu, D., Li, L., Wu, L., & Wei, X. (2023b). An international comparative study of digital transformation in higher education. *Journal of the National Institute of Educational Administration*, (4), 27–36.