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Research on the promotion of digital teaching and learning toward achieving China's dual-carbon strategy

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The dual-carbon strategy of China affects all walks of life, all of which will be affected in realizing these goals. The same is true of the education sector, and China has the world's largest education population. The education sector has a large potential to reduce carbon emissions due to its high carbon consumption. Based on the requirements of carbon emission reduction in education, this paper studied the contribution of digital teaching and learning and the education sector toward reducing carbon emissions and discusses how to promote the mechanism construction of carbon emission reduction in the education sector. The study used a comparative analysis and questionnaire research method to analyze the impact of digital teaching and learning on energy saving and emission reduction in the education sector. Research shows that using the Internet and fully utilizing the advantages of digital teaching and learning could improve the quality of teaching, reduce carbon emissions, and help achieve the goal of dual-carbon.

KEYWORDS

goal of dual-carbon, promotion and implementation, teaching and learning, instructional design, Internet-based learning environments

1 Introduction

As an important strategic decision, the dual-carbon strategy of China is not only an energy and environmental issue but also a social issue that will have a significant impact on people's lives and development. Since 2007, China has become the world's largest emitter of carbon dioxide, accounting for about 30% of the world's total in 2018 (Ren et al., 2021). As of 2019, China's carbon dioxide emissions have still not peaked or shown a slowing trend (IEA, 2021). At the 75th session of the United Nations General Assembly in 2020, China pledged to achieve a "carbon peak" by 2030, when carbon dioxide emissions will stop growing, and then gradually reduce after reaching this peak to achieve net zero carbon emissions, or carbon neutrality, by 2060. However, carbon in the target is bound to bring significant changes to industries (Liu et al., 2022). A large number of people in China's education sector, along with the gradual expansion of schools and the sharp increase in the number of students, has led to a significant increase in energy consumption in schools, leading to a significant increase in China's carbon emissions, yet schools are tasked with spreading social and cultural knowledge, training, and improving the next generation and are one of the most important places to spread the concept of carbon emission reduction. The education sector, therefore, has great potential to reduce carbon emissions and is a key focus for energy saving and emission reduction. Based on this, this paper explores whether digital teaching and learning can contribute to the implementation of dual-carbon goals by promoting energy saving and emission reduction in education.

Digital technology is a modern science and technology based on information and communication technology, with a modern information network as the carrier and digital knowledge and information as the production factors. Through digital technology, the teaching process becomes more flexible. The course teaching and teaching platform are combined and the implementation of digital teaching and learning significantly reduces the impact of the COVID-19 epidemic on normal teaching. School teaching is transformed from "offline" teaching to "online" teaching on a large scale. In September 2007, the Ministry of Education issued the "Notice on Carrying out Actions for Schools that Conserve Energy and Reduce Emissions," requiring local educational administrative departments and schools of all levels and types to creatively work on energy conservation and emission reduction in light of actual conditions. The implementation of energy conservation and emission reduction in colleges and universities can effectively reduce carbon emissions, which is of practical significance in realizing the goal of carbon neutrality (Zhang and Yan, 2021).

However, there is a lack of systematic research on the impact of digital teaching and learning on carbon emission reduction at home and abroad. Based on previous research studies, this paper examines the impact of digital teaching and learning on the education sector in the context of the goal of achieving the dual-carbon strategy. Using comparative analysis and questionnaires, it analyses the advantages of digital teaching and learning and its impact on carbon emissions. First, the advantages of digital teaching and learning in terms of format, teaching capacity, and reduction of carbon emissions are analyzed in comparison with traditional teaching and learning. Second, by comparing and analyzing the carbon emissions of different countries, it is concluded that there is still more room for the adjustment of China's energy structure; thus, the development of the digital economy could better save energy and reduce emissions, and digital teaching and learning, as a form of expression of the digital economy, could accelerate the achievement of the goals of the dual-carbon strategy.

2 A theoretical mechanism for the digital economy to help achieve the goal of dual-carbon

2.1 The positive impact of digital teaching and learning on the goal of dual-carbon

The digital economy takes data as its core, and it is characterized by rapidity, sustainability, and directness (Wang and Wang, 2022). To a large extent, the digital economy can effectively reduce the energy consumption of traditional industries, environmental deterioration, and achieve the sustainable development of society. For example, "forest" ants will pay treasure to users to reduce carbon emissions in daily life on virtual "green energy," to "green energy" after reaching a certain value. The user can choose trees according to their own needs to plant. Ant Forest is a public service initiative to promote low-carbon energy saving and emission reduction, accumulating green energy through low-carbon behaviour.

2.2 The digital economy can transform teaching and learning

In the era of the digital economy, digital technology is closely related to people's lives. For example, online education, listening to books online, and online knowledge payments are examples of the development of the digital economy in the cultural and educational sectors. Digital technology is also used in the teaching and learning process, and carrying out digital teaching and learning can better help teachers improve the quality of teaching and save energy. In the process of digital teaching and learning, a series of teaching topics can be conveyed, such as setting up a green and low-carbon consumption concept, advocating for students to save resources, and protecting the environment in their daily lives. At the same time, it can control the number of students in class, increase class duration, and implement digital teaching and learning. In addition, as a product of the digital age, digital teaching and learning has changed traditional teaching modes, reduced ineffective energy consumption, and improved the level of education through distance learning, online offices, and the construction of network information platforms. As we often say, "technology has changed our lives." Realizing the goal of dual-carbon can not only improve our overall environment but more importantly, achieve low energy consumption and high efficiency. Therefore, the application of digital technology can not only improve the quality of teaching and help students develop comprehensively, but also reduce carbon emissions and promote the implementation of dual carbon goals.

3 Digital teaching and learning contribute to dual-carbon goals

According to the fifth plenary session of the 19th CPC Central Committee, a new developmental pattern should be established under the guidance of the new development concept, with the domestic cycle as the main body and the domestic and international double cycle mutually reinforcing. The new development pattern should be manifested as green, low-carbon, and involve a mode of sustainable high-quality development. The development of science and technology has been increasingly rapid in recent years, and the emergence of the Internet has had a huge impact on people's clothing, accommodation, households, and transportation. Information technology is gradually being paid attention to by people, and education is gradually becoming closer to information. In order to meet the needs of society for new education, relevant personnel continue to explore and actively innovate on the road of new education, making education gradually enter the digital era. In the digital era, the development of the digital economy is indispensable, among which digital teaching and learning, as one of the products of the digital economy, and plays an important role in promoting the realization of the carbon peak.

Under the impact of the new crown pneumonia epidemic, the digital teaching and learning model has become the best choice for schools to teach. Compared to traditional teaching modes, digital teaching and learning can enhance the flexibility of classroom teaching and improve the enthusiasm of teachers and students to interact. Since the digital teaching and learning mode is based on the Internet, teachers, and students do not have to attend school (Huang, 2020), which significantly reduces the energy consumption and carbon dioxide emissions of the school. Therefore, the digital teaching and learning mode plays a driving role in the realization of dual-carbon goals.

TABLE 1 Comparative analysis of teaching modes.

Serial number	Evaluation index	Digital teaching and learning	Traditional teaching
1	Teaching form	Individualized	Collectivization
2	Teachers' ability	High	High
3	Carbon emissions	Low	High

4 Practical ways of digital teaching and learning to help achieve dual-carbon goals

Following the emergence of the COVID-19 outbreak, schools are taking steps to prevent the further spread of the virus by promoting online courses. (Xinfa and Tian, 2022). Given the impact of COVID-19 on normal school teaching, to effectively solve current practical problems and major dilemmas and effectively improve the quality of teaching, the Ministry of Education proposes the use of the Internet to carry out online teaching during the epidemic prevention and control period to minimize the impact of delayed school opening. Digital teaching and learning can not only fully play to the advantages of online teaching but also reduce energy consumption (Wang, 2019). To accelerate the realization of dual-carbon goals, it is necessary to explore the impact of online teaching during the COVID-19 pandemic (Jiang, 2020).

4.1 Comparative analysis of digital teaching and learning and traditional teaching

Due to the COVID-19 pandemic, traditional teaching models are not enough to meet the needs of teachers and students, and digital teaching and learning models have gained wide acceptance. According to the higher education department of the Ministry of Education, 91% of college courses were offered online in 2020, 80% of teachers approved of online teaching, and 85% of students were satisfied with online teaching (Wei and Zhang, 2022). Digital teaching and learning objectively promote the wide application of an online teaching mode. Based on this case, this paper takes the digital teaching and learning mode and the traditional teaching mode as the analysis object and makes a comparative analysis of the teaching form, teacher ability, and carbon emission in Table 1.

4.1.1 Comparative analysis of teaching forms

Traditional teaching mode is a collectivized teaching mode, which can maximize the advantages of classroom teaching, and quickly transmit scientific cultural knowledge to students so that students can systematically accept knowledge and culture, but often neglect the cultivation of students' personalities. Digital teaching and learning modes can integrate audio–visual, image, sound, and video teaching, which not only provides teachers with a variety of choices but also enables the students to be immersive and stimulate students' interest and curiosity in learning. In addition, using digital background records and electronic equipment, the type, number, and frequency of students' questions were statistically analyzed. Thus, teachers can understand students in the study of suspected difficulties and provide more targeted guidance for students. Online education is a process in which teachers and students interact with learning resources in a learning environment (Yu and Z, 2022). In addition, educators are constantly exploring the teaching methods (Allen et al., 2016) that have the most effective positive impact on students' learning and learning attitudes (Armbruster et al., 2009).

4.1.2 Comparative analysis of teachers' abilities

The traditional teaching mode requires teachers to make full use of the platform of classroom teaching to carry out teaching activities, not only to pay attention to students' learning status but also to strengthen their teaching skills and be able to calmly respond to classroom emergencies. For example, when students prepare for exams, they have to decide what to study, how long to study (Bjork et al., 2013), and how to study, and teachers need to provide timely guidance (Kornell et al., 2007). Compared to the traditional teaching mode, the digital teaching and learning mode has higher requirements on teachers' teaching ability. This is because the digital teaching and learning mode is more susceptible to external interference and emergencies or even teaching accidents. The influence of control factors is minimized.

4.1.3 Comparative analysis of carbon emissions

The traditional teaching mode is mainly based on the special equipment provided by the school, which has a certain quality assurance and can avoid most interference factors. However, the campus population density is large, the school teaching area is relatively concentrated, and the diversity of campus buildings leads to high energy consumption on the campus. The daily output of household garbage and harmful gases on the campus will lead to an increase in carbon emissions. The digital teaching model usually utilizes online video conferencing and online teaching platforms, such as Tencent conferencing, Ding Talk, and superstar learning to transmit and display teacher images and voices in real-time. Compared to traditional teaching models, digital teaching and learning not only reduces travel for teachers and students but also reduces energy consumption on campus, thus reducing carbon emissions.

4.2 The way to implement digital teaching and learning

The development of digital teaching and learning mainly involves three aspects: teachers, students, and digital online teaching platforms. This demand for online learning has led to a shift in the way we think about course design, pedagogy, and practice (Salmon, 2014). During the epidemic prevention and control period, teachers and students should choose the appropriate online teaching platform based on the actual situation of their environment. Due to the large volume of concurrent online teaching during the COVID-19 pandemic, teachers and students all have high requirements for online teaching platforms.

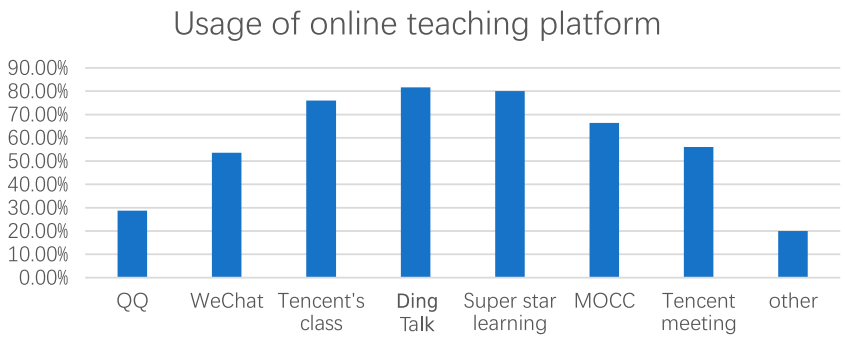

FIGURE 1
Usage of online teaching platforms (data source: online teaching satisfaction questionnaire for college students).

According to a survey of some teachers and students, Ding Talk, superstar learning, and Tencent class have the highest utilization rate as digital online teaching platforms, accounting for 81.6%, 80%, and 76%, respectively, as shown in Figure 1. Enrollment in online learning has steadily increased since 2003, with more than a third of students enrolled in at least one online course as of 2017 (Allen et al., 2017).

As the main method of digital teaching and learning is to rely on teaching with a network platform, it is not restricted by time and place, meaning that people and people, people and things, and things and things are connected at any time and anywhere, which can broaden the scope of information transmission and speed up information transmission so that teachers and students can communicate in class through the Internet and reduce the spread of viruses. In addition, there is a diversity of knowledge on the web. Students can take the initiative to search for knowledge in the network and expand their knowledge, rather than limiting themselves to the knowledge imparted by teachers (Dyer, et al., 2000). The process of digital teaching and learning has turned the epidemic situation into practical teaching material in the classroom. When teaching knowledge, we must also correctly guide students to understand the epidemic situation, and actively cooperate with epidemic prevention and control so that students can develop physically and mentally in a special period, gain subject knowledge, enhance self-management awareness, and cultivate students' positive attitude. An upward life attitude and tenacity will enhance students' sense of responsibility and patriotism. Furthermore, in the classroom, teachers can use the online education platform to popularize knowledge and concepts related to production, environmental protection, and carbon neutrality to students, stimulating green and low-carbon awareness, and jointly building a green campus.

4.3 Digital teaching and learning reduces energy consumption

There are two main paths for the digital economy to affect carbon emissions through technological innovation. On the one hand, technologies such as big data, cloud computing, the Internet of Things, and the Industrial Internet penetrate the industry. On the other hand, digital technology promotes connection, innovation collaboration, and knowledge sharing among innovation subjects, which has produced the empowerment effect of digital technology. In the process of digital teaching and learning, digital teaching resources are data that can be copied and shared. People can watch excellent teaching cases through the Internet and can make comments or voice communication in time to reduce unnecessary outings, which can not only reduce the impact of the epidemic diffusion but also reduce carbon emissions by traveling. At the same time, through informatization and intelligent management and control, energy waste in digital teaching and learning activities can significantly be reduced.

The main types of energy consumed by the school include electricity, natural gas, gasoline, and diesel. According to the observation of energy consumption in schools, the highest proportion of energy consumption in most schools is electricity, with a maximum of 96.19% and a minimum of 59.57% (Sun et al., 2022). Electrical energy is still the main energy source of school energy consumption. Among them, the calculation shows that the energy consumption in the teaching area is the highest, up to 60%. Under the guidance of the goal of dual-carbon, an effective way to achieve carbon neutrality is to increase the proportion of clean energy and improve energy efficiency. The effective use of digital teaching and learning can reduce energy consumption on campus. Therefore, digital technology plays an important role in reducing energy effects.

5 Digital teaching and learning promotes sustainable development

5.1 Main sources of carbon emissions

Carbon emission is the process of emitting greenhouse gases to the outside world during human production and business activities and is one of the main causes of global warming. In 2020, the total global carbon dioxide emissions will be 32.284 billion tons, of which China, the United States, and India will be the top three countries in carbon dioxide emissions. In terms of the average annual growth rate of carbon dioxide, the United States and India have declined, and China has increased by 0.6%, as shown in Table 2.

China's carbon emissions mainly come from the power sector, construction sector, industrial production sector, transportation sector, and agricultural sector, as shown in Figure 2. Energy and electricity account for the largest proportion, followed by construction (Fu, 2021), and industrial production transportation and agriculture account for the least. China's energy consumption structure is relatively single, and the

TABLE 2 Carbon dioxide emissions by countries in 2020.

Country/region	Emissions (million tonnes)	Average annual increment rate	Emissions per (capitation/person)
China	9,899.3	0.6%	6.9
America	4,457.2	−11.6%	13.5
India	2,302.3	−7.1%	1.7
The Russian Federation	1,482.2	−7.4%	10.2
Japan	1,027	−8.4%	8.1
Iran	678.2	0.2%	8.1
Germany	604.9	−11.5%	7.2
South Korea	577.8	−7.5%	11.3

Data source: Zhiyan Consulting.

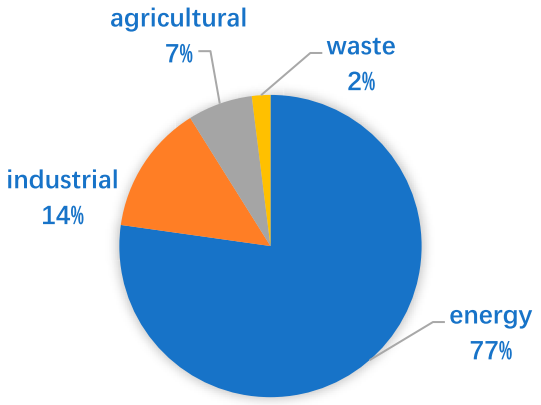

FIGURE 2
China's 2020 carbon emissions (data source: China's Academy of Information and Communications Technology).

energy industry is based on coal carbon combustion that generates carbon dioxide. Due to the position of coal in China's energy consumption structure, coal consumption is the main source of greenhouse gas emissions. The most direct reason for China to achieve carbon neutrality is that carbon emissions are too high. With the rapid development of urbanization, the demand for electrical energy supply is gradually increasing, and the supply and demand situation is changing dramatically (Xinfa et al., 2022). In the long run, it will not only pollute the environment and destroy the ecological environment but also cause harm to people's physical and mental health. Therefore, there is still much room for China to adjust its energy structure and strengthen environmental protection (Li Ji Gang, 2014).

5.2 Vigorously developing digital economy to reduce carbon emissions

China, the world's largest developing country, has achieved rapid economic growth at the cost of serious environmental pollution (Yao and Shen, 2021). According to the White Paper on the development of China's digital economy (2020) released by the China Academy of Information and Communications Technology, the scale of China's digital economy has increased from 2.6 trillion yuan in 2005 to 39.2 trillion yuan in 2020, accounting for 38.6% of the GDP from 14.2%, as shown in Figure 3 (Zhang et al., 2021). On 7 September 2021, China's digital carbon neutrality forum released the green and low-carbon action proposal in digital space, which proposes to build a new engine for the green development of the digital economy. In the digital age, the rapid development of digital technology can also reduce carbon emissions in energy, manufacturing, industry, and other fields by 15%. For example, the use of "green power" to power the Winter Olympics venues in Beijing in 2022 is seen as a successful example of energy saving and emission reduction, accelerating the pace of carbon neutrality.

However, China is constantly faced with the dilemma of how to achieve economic growth and environmental protection at the same time (Guo et al., 2022). High carbon industries significantly contribute to the increase in carbon emissions, while low and medium carbon industries are more effective in suppressing carbon emissions (Zhang et al., 2022). Some scholars outlined that as China's industrialization and urbanization levels increase, whilst urban enterprises reduce carbon emissions, rural areas have huge potential to become carbon sinks, meaning the construction of an urban–rural mutual aid model to reduce carbon emissions can be explored from the perspective of the value of carbon sinks (Tang et al., 2022). In addition, consider the construction industry as an example. In July 2020, the Ministry of Housing and Urban–Rural Development, the National Development and Reform Commission, and other departments issued the Green Building Action Plan, which proposed that by 2022, the green building area in new urban buildings will account for 70%. To achieve this goal, digital technology such as BIM has wide applications. The rate of building informatization in China is only 0.11%, about 1/9 of that in developed countries. Digital technology still has a large application space in the construction industry. It is expected that by 2025, the output value of the construction information industry will reach 100 billion yuan. This will make a significant contribution to building energy conservation. The development of a strong digital economy can therefore effectively reduce carbon emissions.

5.3 Digital teaching and learning accelerates the realization of the goal of dual-carbon

In the digital era, the development of the digital economy is driving continuous innovation in the field of education. Educators should use digital information technology to accelerate educational reforms and

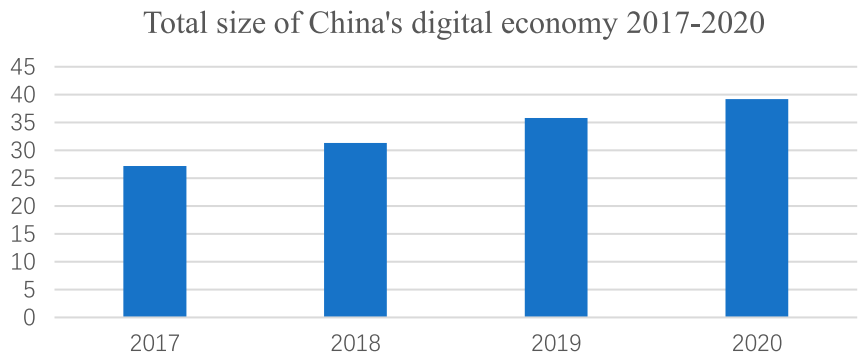

FIGURE 3
Total size of China's digital economy 2017–2020 (data source: China Academy of Information and Communications Technology and China Business Industry Research Institute).

promote the implementation of digital teaching and learning in schools, which in turn will promote energy saving and emission reduction in schools. According to the U.S. Department of Environmental Protection Agency, colleges and universities account for 2 percent of the total U.S. emissions. Schools not only disseminate knowledge and improve students' comprehensive quality but also serve as an important place for disseminating the concept of carbon emission reduction and undertaking various social functions in the wide-ranging economic and social changes caused by carbon peaking and carbon neutralization. First of all, in epidemic prevention and control, digital teaching and learning can replace the traditional teaching mode. For example, the high-definition online conference teaching mode can replace the original offline teaching mode so as to reduce the transportation of teachers and students and reduce carbon emissions. During the COVID-19 pandemic, teachers can use digital teaching and learning modes to communicate through videos even in isolation, which not only achieves the purpose of epidemic prevention but also improves students' learning efficiency (Tang et al., 2023). Second, the more faculty and students are on campus, the more likely it is to cause energy consumption and greenhouse gas emissions in daily campus life. For example, the unreasonable use of computers, printers, and other electrical equipment can result in excessive energy consumption. Water resources are wasted and water discharge pollution is caused by water rooms, dormitory areas, and teaching areas. People often forget to turn off the lights, resulting in energy consumption and waste. The digital teaching and learning mode can reduce the energy consumption of the school to the greatest extent because of network teaching. With the aid of digital technology, such as the Internet, artificial intelligence, and cloud computing to build a big data platform, can promote each link to realize digital, maximize the ascension of education resources use of efficiency, reduce the waste of paper resources, promote the education industry using green renewable resources, to carry out the green environmental protection, and high-quality teaching resources sharing. Finally, digital teaching and learning can also create a learning platform for students, open carbon neutral general courses, provide more energy saving and emission reduction materials, integrate the concept and practice of being "carbon neutral" into the curriculum system, and let students pay attention to sustainable development together. Digital teaching and learning enable students' acquired knowledge to be put into practice, reducing carbon emissions and accelerating the pace of dual-carbon goals.

The optimal path toward achieving the goal of carbon neutrality involves considering multiple factors (Tang and Luo, 2022). As a new education model, digital teaching and learning combine data with sustainable development, which not only helps to improve the informatization and intelligence level of the whole of society and the efficiency of resource allocation but also helps to reduce greenhouse gas emissions and play a positive role in energy conservation and emission reduction (Jin et al., 2022).

6 Conclusion

China aims to peak its CO_2 emissions by 2030 and be carbon neutral by 2060 (Zhong, 2020). Ecological civilization construction is one of the main approaches to achieving this dual-carbon goal. In order to pursue high-quality and high-speed development to achieve dual-carbon goals, colleges and universities should actively advance digital teaching and learning, taking full advantage of the aid of digital technology, such as the Internet, artificial intelligence, cloud computing to build big data platforms, realizing every digital possibility, maximizing the efficiency of education resources usage, reducing the over-use and waste of paper resources, promoting the green and circular utilization of university resources, sharing of high-quality teaching resources, implementing green environmental protection, reducing carbon emissions, and accelerating the pace of the goal of dual-carbon. This paper studied the role of digital teaching and learning under the background of these double carbon targets and explained how digital teaching and learning could reduce energy consumption and carbon emission reduction, promoting sustainable development in theory and practice.

There are still many shortcomings in this paper. The selection of data is too macro, and some data lack detailed information on carbon emissions, which affects the depth of the analysis. In terms of the literature materials collected, this paper mainly analyzed of the public range within the scope of the relevant materials and research literature but because of a personal research level and the influence of the new champions league pneumonia outbreak, it cannot be in more countries worldwide digital teaching and learning mode of comparative analysis and on-the-spot investigation, and these deficiencies will be in the future learning process that is continuously strengthened to be explored and practiced.

In future research studies, it is suggested to further study the specific details of digital teaching and learning models in different countries and regions and explore the main factors affecting carbon emissions from the details to further reduce carbon emissions, achieve

the goal of dual-carbon, and promote the sustainable development of the society.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

Author ZC was employed by the company State Grid Jiangxi Electric power Co., Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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