Journal of Innovation & Knowledge

A survey on big data-enabled innovative online education systems during the COVID-19 pandemic

Yuhuan Cui[a,b], Zezhong Ma[a,c,d], Liya Wang[a,c,*], Aimin Yang[a,b,c,d,*], Qiumei Liu[a,c], Shanshan Kong[a,b], Huifang Wang[a,c]

[a] College of Science, North China University of Science and Technology, Tangshan, Hebei, China
[b] Ministry of Education University Mathematics Course Group Virtual Teaching and Research Office, North China University of Science and Technology, Tangshan, Hebei, China
[c] Hebei Key Laboratory of Data Science and Application, North China University of Science and Technology, Tangshan, Hebei, China
[d] Hebei Engineering Research Center for the Intelligentization of Iron Ore Optimization and Ironmaking Raw Materials Preparation Processes, North China University of Science and Technology, Tangshan, Hebei, China

ARTICLE INFO

ABSTRACT

With the spread of COVID-19 around the world, the education industry faces enormous challenges. Some colleges and universities have launched online teaching. Comprehensive online teaching and student health checkups help students complete the set teaching content and return to school as soon as possible. With the development of big data, combined with the epidemic risk we are facing, the rational use of big data and the internet for innovative online education has become a mainstream teaching method. Colleges and universities are not yet familiar with the development prospects and future of online education. Through the research of this paper, we can understand the combination of online education and the development of big data and promote its application in colleges and universities. Not only have innovative online education platforms such as MOOC and DingTalk been widely used, but innovative online education methods such as virtual classrooms also have been created. Based on the current epidemic background, this paper analyzes the development of online education, introduces the impact of the combination of online education and big data, and introduces innovative online education technologies and their effects. It helps online education under the influence of the new coronavirus epidemic, operating big data technology to analyze the current prospects and development of online education, showing the combination of big data technology and online education through the analysis of big data technology, and ending with more expectations on other aspects of the use of big data, which affects the online education industry as well as other industries. Finally, we summarize the combination of big data and innovative online education since the emergence of COVID-19 and introduce the concepts and methods of combining online education and big data technology in detail. The online education platform also makes a reasonable introduction. The thesis can be used to understand the problems and challenges faced by innovative online education in the context of the new coronavirus epidemic and look forward to the future on this basis.

Introduction

From the end of 2019 to the present, coronavirus disease 2019 (COVID-19) broke out worldwide. Due to the highly contagious nature of COVID-19, the rapid outbreak in a short period of time has disrupted the working, living and learning conditions of people around the world. To ensure the privacy protection of COVID-19 patients, lightweight and robust IoT-based secure key establishment protocols have been established accordingly (Masud et al., 2020a). As the epidemic continues to spread, people in some countries and regions must strictly abide by "home isolation" measures to block the spread of the virus, which not only affects the resumption of work and production but also deeply affects the resumption of school (Williams-Buffonge et al., 2021; Bahanshal & Khan, 2021). For schools, students eventually need to return to campus. The impact of the epidemic cannot be the reason for the stagnation of the original teaching content. Instead, it is the pressure and motivation for the school and staff to exhaust their methods to make a difference. Therefore, in the

* Corresponding authors at: College of Science, North China University of Science and Technology, Tangshan, Hebei, China.
E-mail addresses: wangliya@ncst.edu.cn (L. Wang), aimin@ncst.edu.cn (A. Yang).

context of COVID-19, big data also has made a difference in the field of education. After the education industry has shifted from traditional education to online education, it has been further combined with big data and built a data warehouse to generate new innovative online education, which has brought much convenience to students' learning and teachers' teaching work (Onyebuchi A & Matthew U O & Kazaure J S, 2022).

Machines can efficiently learn comprehensive health causal knowledge and relations among diseases, symptoms, and other facts (Yu Hong Qing & Stephan Reiff-Marganiec, 2022). Approximately 1.4 billion learners in nearly 162 countries are faced with the dilemma of being unable to go to school for classroom learning (Selviyanti E & Sardjono W & Mukhlis M, 2021). At the same time, many schools have replaced daily classroom education *with* innovative online education. During the epidemic, the use of innovative online education platforms combined with big data has become mainstream. The innovative online education industry in the United States developed early. At present, there are not only many institutions with innovative online education, but student engagement is also relatively high. It can be said that these education models have already swept the American education industry. When China's innovative online education industry ushered in an inflection point in its development in 2012, almost all top universities in the United States set up online training and learning platforms in the same year. A comprehensive online free course has been established, and a national system of innovative online education has been established (Makrakis V & Kostoulas-Makrakis N, 2021) to apply more educational resources to the application of education teaching, combined with big data and artificial intelligence technology. The literature (Zhao J, Li Q., 2022) now offers a detailed introduction to the integration of big data and artificial intelligence in online education. At the same time as the outbreak of COVID-19, with the widespread application of innovative online education combined with big data, various countries also have promulgated relevant laws and regulations to supervise innovative online education and improve various aspects of traditional online education. Unlike China, in the United States, different states have different educational cultures and legal stripes, so different states have different rules on distance education. "E-Learning Days: Sketching Policies and Guidance Plans" shows that 12 states in the United States have their own online learning policies, and only four states have launched online learning days (Fenny A & Crentsil A & Anyamesem D, 2020). In addition, the methods adopted by different states and counties also are different. For example, states such as New Hampshire and Florida adopt a hierarchical and staged innovative online education method for students. In South Carolina, 3000 buses with mobile Wi-Fi hotspots are being deployed to help children in remote areas learn online. To regulate U.S. primary and secondary education in the context of the epidemic, the U.S. federal government officially passed the "COVID-19 Aid, Relief and Economic Security Act" on March 27. The main purpose of the act is to implement subsidies for catering to students' education. In addition, on April 1, 2020, the U.S. Federal Bureau of Education drafted a guidance bill on distance education for college students, the "Distance Education and Innovation Rules", through which to provide guidance on innovative online education. For example, when COVID-19 hit in 2019, China promulgated the "Implementation Opinions on Regulating Off-Campus Online Training". This normative document addressed issues of public concern, such as teaching content, institutional fees, teacher qualifications, business practices, and information security. At the same time, the Chinese Ministry of Education took the lead in establishing a daily inspection and random inspection system, built a national off-campus online training management service platform, and established a black and white list of applications, which effectively responded to the negative impact of innovative online education and promoted innovative online education in China. In July 2020, the "Opinions on Supporting the Healthy Development of New

Business Forms and New Models" were jointly issued by 13 departments, including the National Development and Reform Commission. The Opinions proposed to vigorously develop integrated innovative online education, build a normalized and integrated development mechanism for online and offline education to form a positive interaction pattern, encourage increased investment and teacher training for pilot classroom teaching based on an online intelligent environment, and deepen the popularization of "three classrooms" applications.

COVID-19 has caused hundreds of millions of teachers and students to embark on a road of online teaching that is completely divorced from the real classroom, which also has brought opportunities for China's innovative online education to develop rapidly. According to data released by the "iiMedia Research" institution, the innovative online education market in 2019 exceeded 400 billion U.S. dollars, and the epidemic has further accelerated market education. It is estimated that by 2025, China's innovative online education market will reach 800 billion U.S. dollars, with a compounded average growth rate of 11.4% (Cheeti S et al., 2021; Kopcha T J & Asino T & Giacumo L A, 2021).

During the prevention and control of COVID-19, innovative online education has developed rapidly, and many new online learning methods have emerged. Big data across time and space provide a feasible solution for the development of virtual online teaching. Under the background of COVID-19, large-scale online teaching is a typical application and prominent manifestation of online internet teaching. Online teaching combined with big data technology has become the main form of schoolteaching during the epidemic. In the context of COVID-19, we have discussed innovative online education developed by the combination of big data technology and online education. In the context of the new coronavirus epidemic, this article combines big data with online education to illustrate the role of big data in promoting online education and explains it in detail. This paper makes several contributions, as follows:

(a) This paper describes the development process of big data in detail. The main purpose of this paper is to express the development and prospects of online education and big data in the development of the epidemic;

(b) The development of the new coronavirus epidemic has had an impact on online education. The promotion, influence, impact and development of big data analysis on online education together make people realize what role and influence online education and big data have in the development of the epidemic;

(c) This article introduces how to use online education methods and online education platforms. Through these methods and platforms, the online education process of colleges and universities during the epidemic is completed. At the same time, online education faces difficulties and problems, and this paper explores how to solve these problems;

(d) More applications of big data in online education in the future also are introduced. More application scenarios also are introduced in detail.

This paper is different from the introduction of online education in the context of COVID-19, which differentiates it from other papers. At the same time, it combines the promotion effect of big data technology on online education during COVID-19.

In this article, Section I introduces the difficulties faced by the education industry since the new coronavirus epidemic, promulgated decrees and measures taken. Section II introduces the development process of big data and the innovative online education formed by the combination of big data and the education industry. Section III mainly compares the advantages and disadvantages of traditional offline teaching and online teaching and analyzes the impact of

educational big data on online education in the context of big data. Section IV introduces the main technologies, platforms, and applications needed for innovative online education and summarizes several innovative online education teaching models and user experiences. Section V mainly discusses the problems and challenges of innovative online education, and Section VI summarizes the content of this paper and looks forward to the future development of innovative online education. A schematic diagram of the structure of the article is shown in Fig. 1:

Analysis of the current situation of innovative online education in the era of big data

With the advent of the era of big data, the operating model is undergoing changes, and these changes involve all aspects of the entire industry chain of exhibitions. Big data and internet technology have forced exhibition data to be made public, and marketing channels also have broken information barriers in the industry, forming a new mode of exhibition information dissemination and operation. The rapid development and progress of the internet and 5 G broadband have made it possible for information coconstruction, sharing and real-time interaction. Especially in special times, online teaching has become an important method and approach to teaching. The concept of big data was first proposed by NASA in 1997 and has developed to this day (Hossain M J & Ahmmed F & Rahman S M A, 2021; Nayak B & Bhattacharyya S & Goswami S, 2022). Its development history is shown in Fig. 2. In 2011, McKinsey & Company believed that big data could independently mine and analyze information with the help of computers and output effective information. With the spread of COVID-19 worldwide, all kinds of schools now use big data for online teaching. Families in remote areas of China have been provided with various preferential policies and measures by the Chinese government to cope with their children's learning problems under the new coronavirus epidemic and to guarantee the convenience of their children's internet classes. These are described in detail in the literature (Feng B, 2022). In terms of school factors, the teaching quality of innovative online education can be improved by improving teaching resources and conditions and enriching teaching

organization and content, and students' abilities can be improved through autonomous learning and team learning. Finally, the online teaching database should be optimized to achieve high-quality innovative online education to obtain better teaching quality and form a virtuous circle (Su B & Hu Q, 2020).

At present, big data processing technology has been widely used in all walks of life, and many countries have combined this technology with artificial intelligence technology to give full play to the advantages of these two technologies. Judging from the current big data technology in China, its application and development are very rapid and have a significant advantage (Merlo A & Hendriksen P A & Garssen J, 2021). Big data plays an increasingly significant role in education.

At present, the application of big data technology in China's education field is generally divided into three aspects: The first is the application in adaptive teaching, the second is the application in the discovery of teaching rules, and the third is the application in campus information management. For example, the use of the Lea spout system based on big data technology can scientifically evaluate preparation for the college entrance examination, determine problems in the students' learning process in time, solve students' learning problems through early intervention, and provide assistance according to the actual situation. It can effectively improve the learning efficiency and quality of students. With the emergence and development of big data technology, the education model also has undergone corresponding changes. The changes in education methods in the development process of big data reform are shown in Fig. 3.

Online education refers to the teaching mode that uses media such as television and the internet. It breaks through the boundaries of time and space and is different from the traditional offline teaching mode in the school classroom. With the vigorous development of information networks, online teaching also has achieved huge development. With the impact of COVID-19, the combination of big data and innovative online education has become more extensive and has attracted the attention of major universities and researchers. The development of big data and innovative online education is a new type of education formed by the integration of modern network science and technology and traditional teaching models. Compared
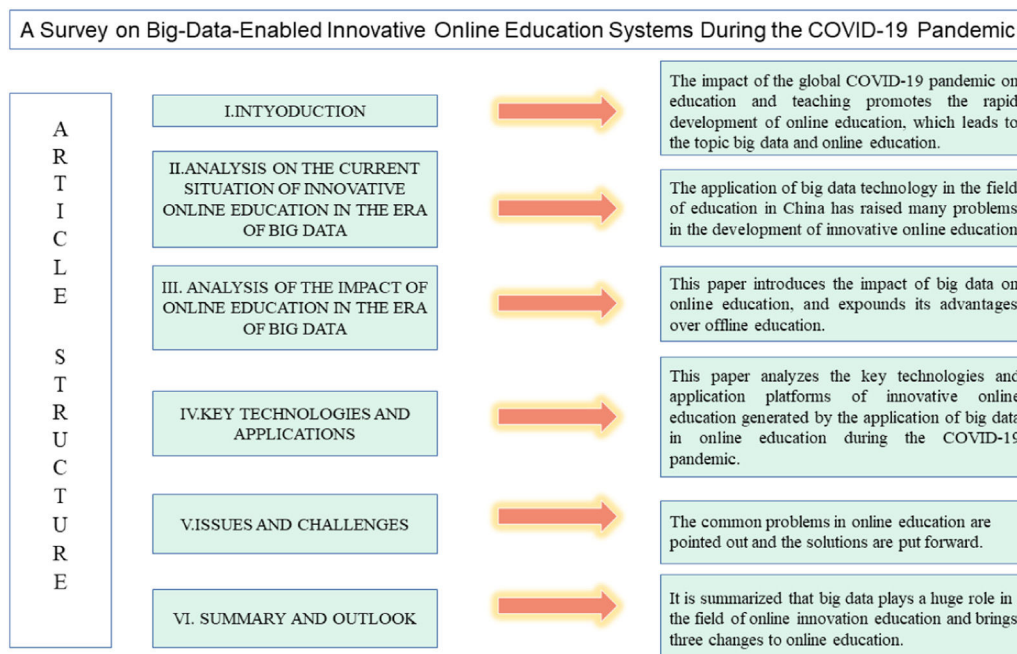

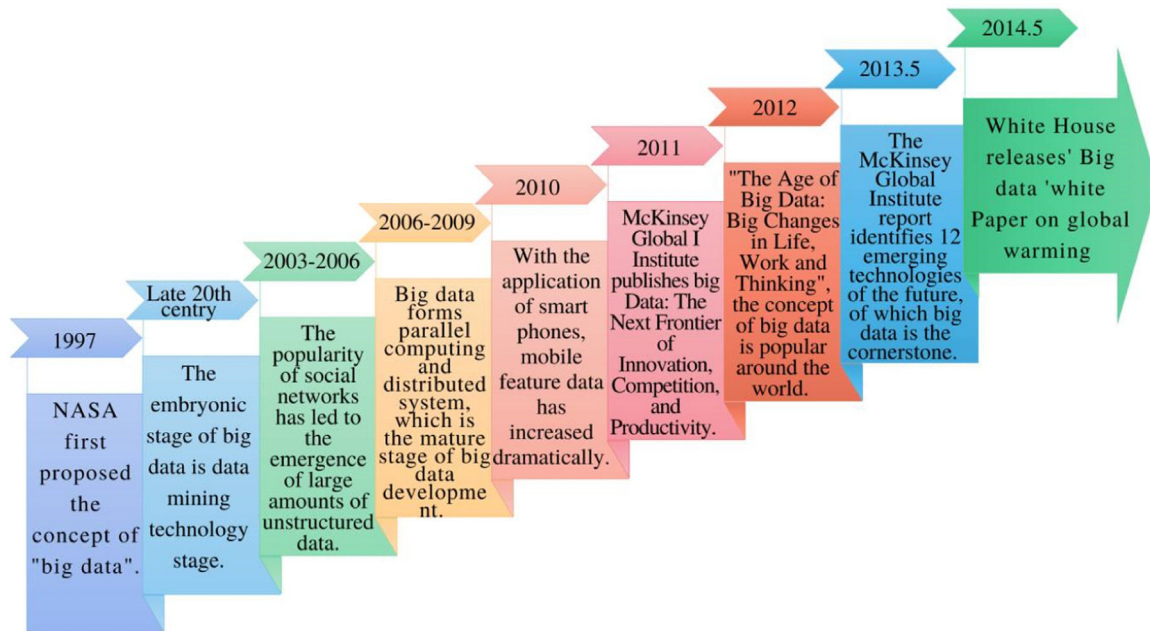**Fig. 1.** Article structure diagram.

Fig. 2. The course of important developments in the development of big data.

with traditional education, innovative online education breaks the limitations of time and space, provides an equal communication platform for teachers and students, and integrates the knowledge imparted by teachers into the daily life of students (Literat I et al., 2021). Second, the innovative online education platform coordinates teaching resources all over the country, which can broaden students' horizons and stimulate their interest in learning (Wang Dan et al., 2020).

In the 21st century, education has developed rapidly. With the high emphasis on combining with information technology, innovative online education has gradually entered people's vision and is accepted by most. This greatly supports and further optimizes the innovative online education industry (Root W B & Rehfeldt R A, 2021). From a global perspective, innovative online education is gaining momentum, but there are still many problems. Phenomena such

as information asymmetry and difficulty in resource matching and docking still hinder the progress of innovative online education in many cases, which are several shortcomings of the industry at present (Alblihed M A & Aly S M & Albrakati A, 2021). On the one hand, the development of big data has made the resources of innovative online education more efficient. The configuration has been optimized, and it displays the high-quality teachers and educational resources of each city on one platform, which to a certain extent makes up for the problem of unbalanced and uneven distribution of educational resources and teachers and greatly improves the distribution of educational resources. On the other hand, under the influence of COVID-19, various regions have carried out innovative online education according to local conditions and rationally used big data to make up for the problem that students cannot come to school for classroom learning. During the epidemic, the practice of large-scale
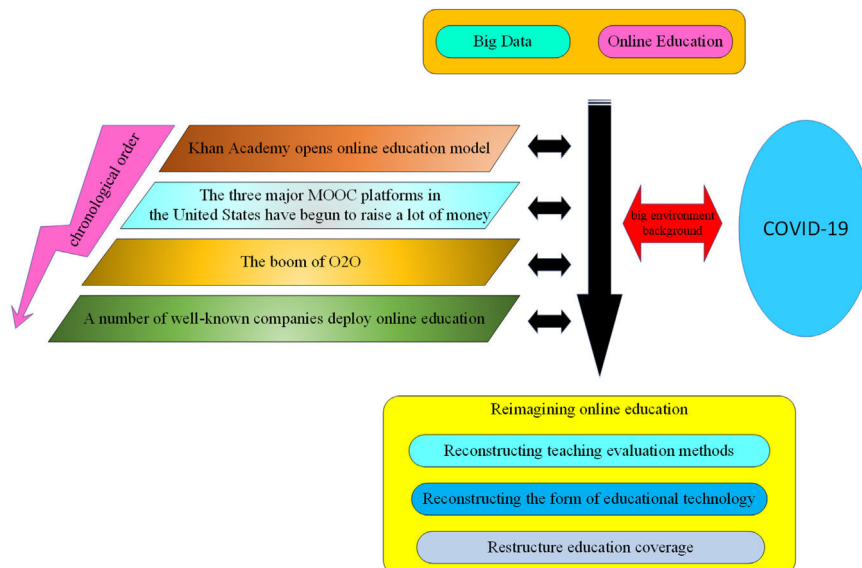

Fig. 3. Innovative online education development process.

"internet + education" presented new features and revealed new problems due to the tight preparation time, large number of participating teachers and students, and uneven teaching environment and teaching resources (Anshari M & Alas Y & Guan L S, 2016). This created the need to analyze and study the practice of "big data education + online teaching" in colleges and universities under the background of COVID-19. It is necessary to adapt to its own characteristics, avoid existing problems, break through development difficulties, innovate the "big data education + online teaching" model and resources, and improve the effectiveness and experience. With the explosion of the internet and mobile internet, the radiation range also is getting increasingly wider. When COVID-19 came, online classes were conducted efficiently, and innovative online education was provided to students to prevent them from being unable to graduate due to insufficient course credits. However, there are still schools that do not have mature innovative online education methods (Al-Kumaim N H & Mohammed F &Gazem N A, 2021). The current relationship between innovative online education and big data education is shown in Fig. 4.

Problems frequently occur in the sudden online education action of colleges and universities caused by the epidemic, and living in the era of big data, we are always accompanied by data (Gaurav A & Psannis K & Peraković D, 2022). Combining online education with big data

is a very important issue in the education industry that must not be ignored, and online education also has made it difficult for some colleges and universities to move forward in the face of the challenge of the epidemic, so we need to pay attention to this problem and make reasonable use of big data technology to further develop online teaching.

Analysis of the impact of online education in the era of big data

The connection between educational big data and online education

The essence of educational big data is the data quantification of the information generated by teachers in teaching, and its production makes teaching change from quantitative expansion to qualitative change. Traditionally, teachers' teaching decision-making is usually based on the deductive method of theoretical guidance and the inductive method of experience summarization. The rapid development of big data and the internet also has led to changes in teaching models. Online teaching and online exhibitions also are emerging. The use of big data to achieve teacher teaching quality assessment also has become a new method. A number of studies also have emerged on the complementary functions of big data in modern education (Fischer C & Pardos Z A & Baker R S, 2020; Baig M I & Shuib L &
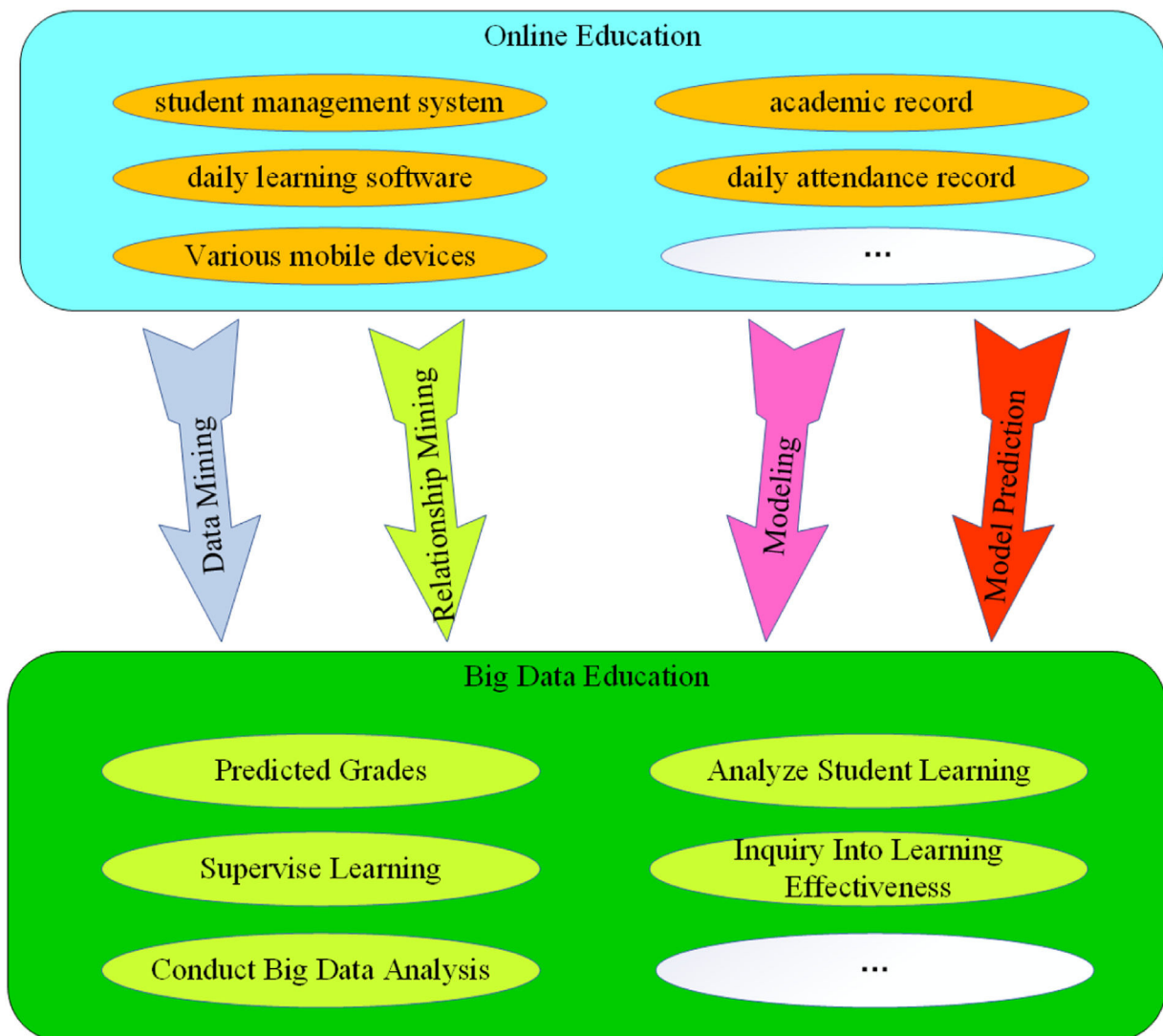

Fig. 4. The relationship between big data education and innovative online education.

Yadegaridehkordi E, 2020). The outbreak of COVID-19 and other epidemics has directly led to the stagnation of offline teaching in various places, which also has made online teaching the main way for school-teachers to teach students. The development and improvement of online education in the future will play a crucial role in assisting this evolution (Paudel P et al., 2021). Therefore, schools should effectively strengthen the application of new technologies, which requires teachers to achieve interconnection and interaction in the promotion of curriculum teaching, and integrate, promote, and create a teaching practice path that combines online and offline methods. Students can learn efficiently and conveniently through online videos that have been recorded.

Big data statistics show that in actual teaching and education activities, the teaching decisions adopted by teachers often depend on personal past teaching experience and also are affected by external environmental factors such as students and parents (Fu, H & Li, Z. & Liu, Z & Wang, Z, 2018). In the educational big data environment, through data mining, discovering real problems in teaching and optimizing teachers' teaching decision-making is a real need to improve teaching quality. The region establishes a big data processing center through academic data, teaching diagnosis, classroom observation, and deep learning and forms an academic evaluation and teaching platform to serve teachers' education and teaching. On this basis, reasonable statistics and interpretation of the data are carried out to promote and deepen the evaluation of education and teaching based on data. Research shows that improving teachers' teaching quality through big data-related technologies is an ideal way to solve problems.

The basic structures of the two academic evaluation and teaching platforms in Fig. 5 and Fig. 6 show that the academic evaluation and teaching platform based on big data has more teaching evaluation methods. Because of the big data analysis and deep learning algorithm model, the evaluation results are more reasonable, avoiding the interference of human factors. Although there are few practical application examples of big data in the field of education, big data itself has strong advantages. Because the huge amount of data possessed by colleges and universities has not been fully utilized (Sclater N & Peasgood A & Mullan J, 2016; Davenport T H & Patil DJ, 2012), big data-related technologies can make good use of these data to improve college education (Chaurasia S & Kodwani D & Lachhwani H, 2018). The application of big data in the field of education mainly refers to the three major elements of online decision-making, learning analytics, and data mining. Its main role is to carry out the application and research of predictive analysis, behavior analysis, and academic analysis. A large amount of data is generated in the process of students' learning (data sources include two aspects, namely, explicit behavior and implicit behavior), among which implicit behavior includes forum postings, extracurricular activities, online social activities, and other activities that are not directly used as educational evaluation, and explicit behavior includes activities that are used directly as educational evaluation tools. Many studies have shown that big data can theoretically play a positive role in promoting modern education (Xia K & Li Y, 2020; Khamisy-Farah R & Gilbey P & Furstenau L B, 2021). The following describes the basic characteristics of innovative online education in the context of the current big data era from multiple aspects.
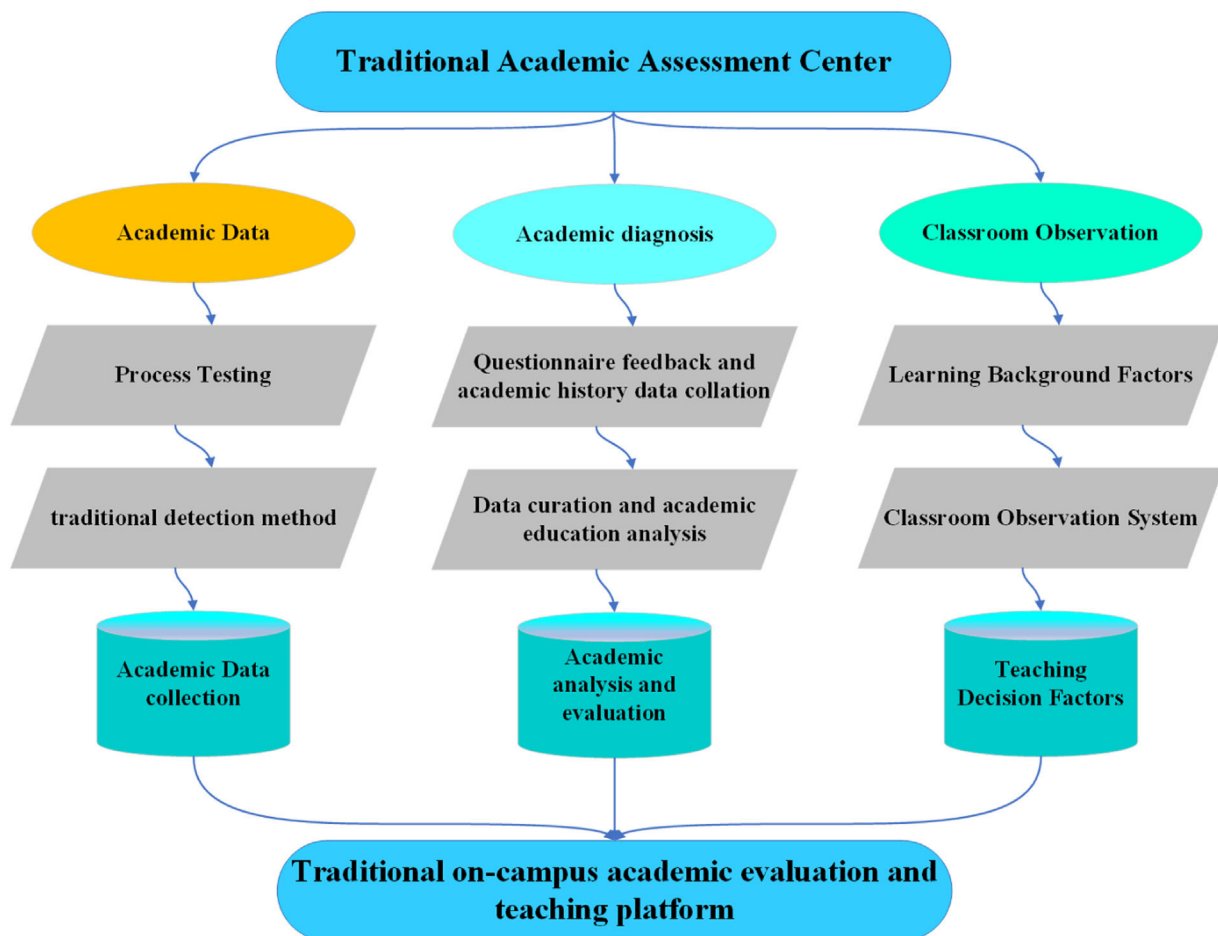

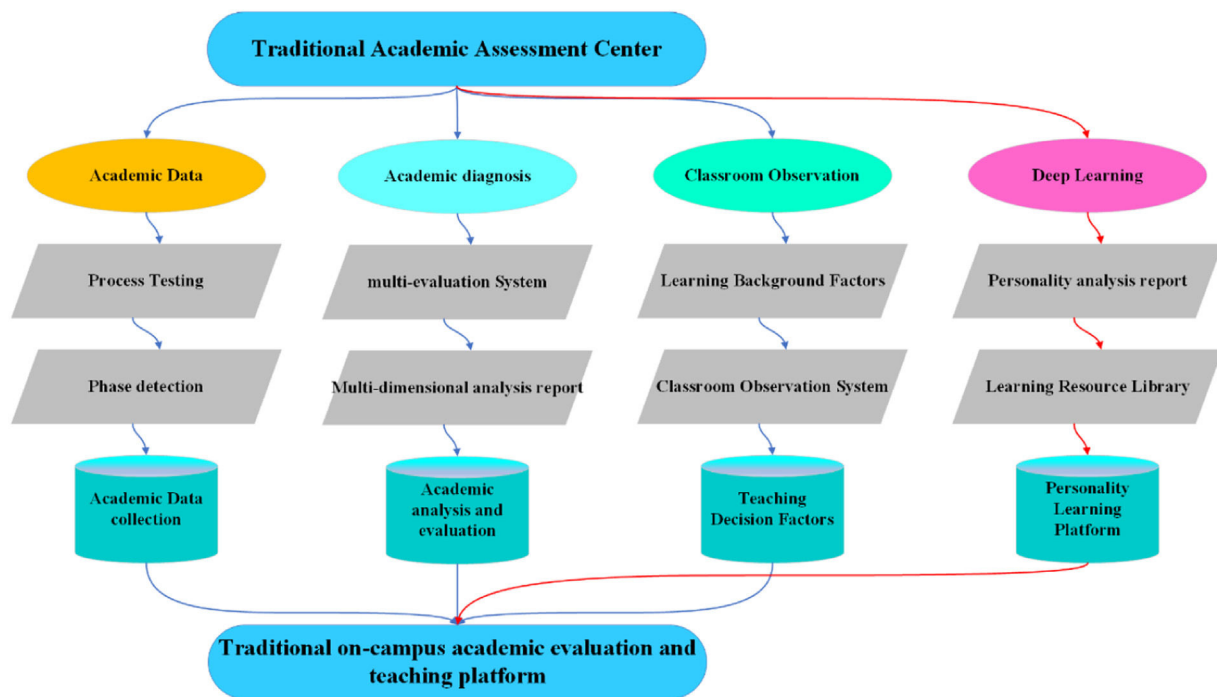**Fig. 5.** Traditional academic assessment and teaching platforms.

Fig. 6. Academic evaluation and teaching platform using educational big data.

Online decision-making: Online decision-making refers to the analysis and processing of data that have always existed in the field of education with relatively complete records, huge inventory, and underutilized data through the relevant methods of big data analysis and uses these to draw a solution that can help complete the decision-making process.

Educational data mining: Upon its creation, educational data mining was mainly the mining of website log data. Currently, interactive learning methods and tools (intelligent tutoring systems, simulations, games) supported by new computer technology have brought new opportunities for quantifying and collecting student behavior data. In particular, more integrated, more modular, and more complex online learning systems provide more types of data, which contain many of the variables required by data mining algorithms. Educational data mining can discover patterns and regularities in these data, explore the establishment of predictive models, and allow us to rediscover and predict how students learn.

Learning analytics: Learning analytics is defined as the interpretation of large amounts of data generated during student learning with the purpose of assessing academic progress, predicting future performance, and identifying potential problems. Data come from students' explicit behaviors, such as completing homework and taking exams, and students' implicit behaviors, such as online socializing, extracurricular activities, forum postings, and other activities that do not directly serve as assessments of students' educational progress. The data processed and displayed by learning analytics models help teachers and schools better understand teaching and learning. The goal of learning analytics is to enable teachers and schools to create educational opportunities that are tailored to each student's needs and abilities. The techniques related to learning analytics have varying degrees of benefit from different perspectives.

From the perspective of students, learning analytics technology, after understanding the current situation of students' learning, analyzes student data, identifies relevant problems, optimizes the students' learning process, and helps students develop good study habits to achieve the purpose of students' self-learning. From the perspective of teachers and administrators, learning analytics technology can evaluate teaching courses and related institutions, help

simultaneously improve the school's established assessment methods, analyze teaching data in depth, and point out teaching deficiencies and better methods for teachers to help students solve practical problems. From the researcher's perspective, learning analytics techniques are an effective tool for studying student and online learning. From the perspective of technical developers, learning and analyzing the different usage frequencies and paths of each module of the technical management system can effectively guide the relevant optimization design of the system interface and can improve the management functions of the system log.

Comparison of offline education and innovative online education

As the name suggests, innovative online education is a teaching method with the network as the medium. Through the network, students and teachers can carry out teaching activities even if they are separated by thousands of miles. In addition, with the help of online courseware, students can study anytime, anywhere, truly breaking the constraints of time and space. Especially under the current background of COVID-19, China is forced to implement measures to restrict the movement of people to control the epidemic, which also has seriously affected the teaching and education work of a large number of schools and made innovative online education, which originally had only an auxiliary role, become the main teaching method. Regarding its actual effect, scholars from various countries have carried out research on the evaluation of innovative online education platforms, including the establishment of a satisfaction evaluation system using the analytic hierarchy process (AHP) and partial least squares. For example, Wilbur (Wilbur K et al., 2016) conducted a structured self-assessment and peer review to evaluate the online component of a blended learning degree program for pharmacists using tools systematically designed according to Moore's transactional distance principles, and they found that many modified course elements could enhance the student learning experience structure, dialog, and autonomy. Chiao H M et al. (Chiao H M & Chen Y L & Huang W H, 2018) built a virtual reality tour guide platform, and 391 students from a university of science and technology in Taiwan participated in the research. The results indicate their learning

effectiveness and technology acceptance in the education system. For innovative online education under the current epidemic situation, some researchers have put forward relevant suggestions on the current innovative online education platform (Chen T & Peng L & Yin X, 2020), and some researchers have summarized and analyzed its impact on society against the epidemic background (Zhou L & Wu S & Zhou M, 2020; Moralista R & Oducado R, 2020).

As a new form of education, innovative online education is subverting the previous form of physical education and promoting all-around reforms of various forms of physical education and training. Innovative online education has begun to change people's traditional learning patterns and learning habits and has been widely recognized by people from all walks of life. The main comparison of innovative online education and offline education is shown in Fig. 7.

From Fig. 7, we can clearly see the advantages and disadvantages between innovative online education and offline education. Analysis from various aspects shows that innovative online education is more flexible. There are problems in the development of education, which makes the advantages of online education more obvious now. Undoubtedly, innovative online education has unique advantages and plays an increasingly important role in education and teaching reform. Compared with traditional offline education at a fixed time and place, the current innovative online education has the following characteristics.

Development and sharing. With the continuous popularization and updating of internet technology, today's learners are completely free from physical conditions and can carry out education and learning activities anytime and anywhere. On the internet, high-quality educational resources are no longer closed and no longer belong to the patents of developed regions. It transcends the limitations of time and space and can bring the best teachers, teaching achievements, and concepts to campuses and geographical areas through the global radiation of the internet. Innovative online education has turned closed education into open education, changed the previous problems of unequal educational resources and information asymmetry in different countries and regions, and promoted knowledge exchange between countries and regions.

Autonomy and personalization. Innovative online education makes it possible to freely provide a variety of modular and fragmented courses on the internet for students to choose from. Learners can freely choose personal study courses, formulate corresponding study plans according to their own career plans and interests, and use the right study time to study. Innovative online education platforms such as Chuanke.com and Tencent Classroom provide a wealth of free online video tutorials, and these courses are finely classified and have greater autonomy than traditional education. At the same time, teachers can design the teaching process and content according to their own ability structure and can freely arrange a time to organize teaching according to their own time allocation. Innovative online education allows teachers and learners to fully develop their autonomy and personality.

Low cost and fairness. At present, a considerable number of the courses on major innovative online education platforms are free tutorials. Learners can easily obtain the free educational resources they want on the internet or pay a small fee to obtain massive learning resources or teaching services. At present, the relatively expensive online training courses are far less expensive than the physical training courses. Innovative online education platforms (including resource platforms) are not restricted by age, occupation, region, or study area, nor are there any restrictions on identity level, education level, or position. Students in poor areas, rural areas, and students from nonfamous schools also can enjoy the highest-quality educational resources so that everyone has an equal opportunity to receive an education.

Interactive and systematic. Through the innovative online education platform, teachers can teach in units of courses and organize students to form study groups in units of courses. In on-demand courses, students can focus on self-study and conduct interactive learning through online teaching resources. In terms of mandatory assessment, teachers can implement a combination of process assessment and result assessment. This interactive learning process makes students more interested in learning and has a better learning effect. It can realize the teaching guide and answer questions required by learners. The teaching resources include online video tutorials, online courseware, materials, homework, and other massive resources; the learning service system includes a live broadcast system, on-demand system, discussion community, sign-in system, student evaluation system, etc., so that the entire innovative online education system constitutes a well-structured, complete system that is scientific and reasonable and conforms to the laws of education.
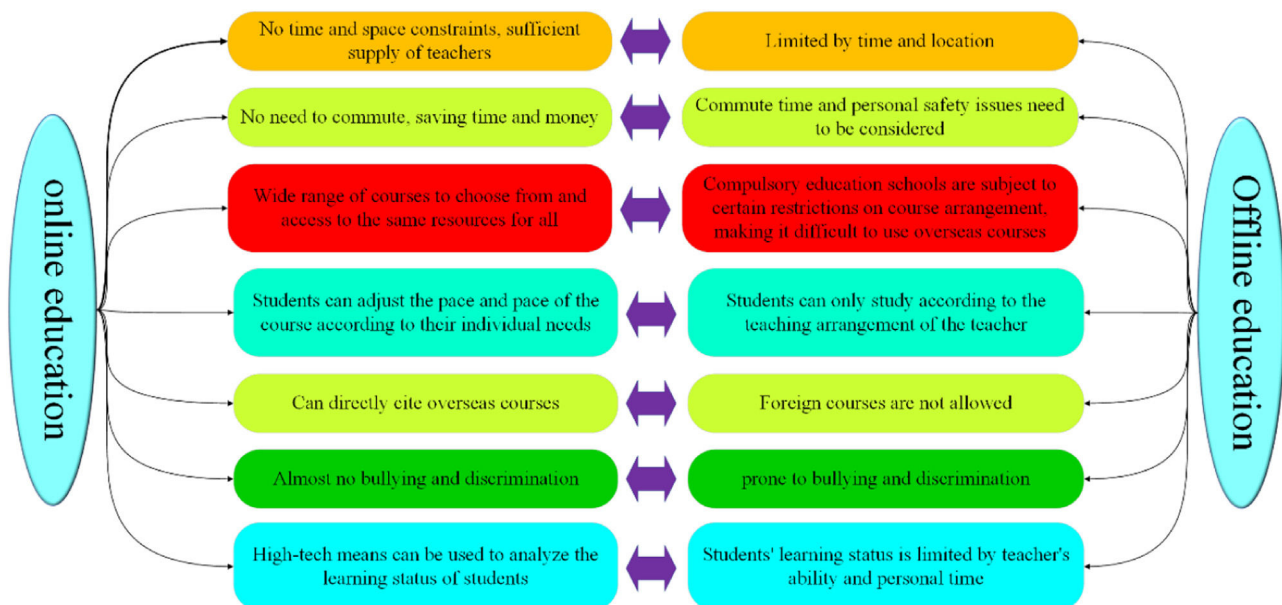

Fig. 7. Comparison of innovative online education and offline education.

Although innovative online education is still faced with various "teaching quality problems", with the impact of globalization and digitization on education and the vigorous development of the open educational resources movement, innovative online education is surging, which will bring earth-shaking changes to traditional education. Even in the face of various problems, innovative online education still produces various positive effects (Doyumgaç I & Tanhan A & Kiymaz M S, 2021; Chakraborty P & Mittal P & Gupta M S, 2021). The organic integration of innovative online education and traditional education is an inevitable trend of development. The development of innovative online education should be carefully planned and integrated from the perspective of complementing traditional education to ensure the quality and advantages of online teaching.

Application and impact of big data in innovative online education

Currently, due to COVID-19, offline education in various places has been seriously affected, which also has prompted many regions to adopt the innovative online education model to continue to complete teaching and education tasks. The previous analysis has shown that educational big data can help better manage innovative online education. The application fields of educational data mining and learning analytics in the context of big data mainly include learner knowledge, behavior and experience modeling, learner documentation, and domain knowledge modeling; more details about them are listed in Table 1.

However, because there are few actual cases of the actual combination of big data and innovative online education, there are certain practical application problems. The following is an explanation of innovative online education from several aspects and how big data can better help current innovative online education.

Combine innovative online education with offline education. With the rapid development of the education industry, many educational institutions have launched innovative online education services, which has significantly accelerated the development of innovative online education. For example, flipped classrooms, MOOCs, etc., all reflect the application prospects of innovative online education, which can make up for the shortcomings of offline education. It also has certain shortcomings, and it does not have the ability to provide face-to-face educational services for students. At the same time, offline education is the main channel for students to learn knowledge. To ensure the learning effect of students, it is necessary to combine innovative online education with offline education to avoid the problem of disconnection between online and offline

education. For example, when using big data to carry out innovative online education activities, one can choose the O2O education model, which mainly integrates online teaching with traditional offline teaching. The information and data of the online learning process can be used to formulate a personalized learning plan, which can make students' learning more effective, provide a reliable reference for students' offline learning, and adjust the content that students need to learn to promote their learning. The improvement of quality reduces the problem of repeated learning of the same knowledge (Chakraborty P & Mittal P & Gupta M S, 2021). In other words, each student's data are different, but these data have certain rules, which can be found with the help of big data, thereby promoting the integrated development of innovative online education and offline education.

Implement personalized innovative online education. Regardless of what kind of education model is adopted, we must adhere to the principle of teaching students according to their aptitude, fully recognize the individual differences among students, and formulate personalized teaching plans based on the actual situation of students to provide more effective solutions for promoting students' all-around development and ground support. Analysis of students' learning processes shows that differences in students' cognitive styles, learning methods, and other aspects have a greater impact on their physical and mental development. It is necessary to carefully understand the changes in students and respect their individual differences. With the help of big data, students' learning data are analyzed, and teaching methods are continuously adjusted to carry out personalized education and teaching activities for them. At present, big data has become an important force in the reform of education and teaching in China. It can not only help teachers carry out personalized teaching activities but also help schools carry out personalized teaching management so that students can be in a good learning and growth environment. For example, it can analyze students' learning preferences through big data, build corresponding models, predict what students will learn, recommend relevant learning content for students in a timely manner, record students' learning process for the reconstruction of the model, and provide a basis for recommending personalized content for each student. However, there are many factors affecting the actual effect of innovative online education (Lockee B et al., 2021), so it is necessary to comprehensively consider the balance of all aspects.

Implement precise innovative online education. With the continuous development of innovative online education, more and more data are generated by students' learning, which makes it difficult for teachers to find useful information and data, and it is difficult to

Table 1
Practical application scenarios of educational big data.

Application of Big Data in Education	Relationship between Data	Data Category
Domain Knowledge Modeling	The relationship between the difficulty level and presentation order of the learning content and the learning outcome	① The learner's correct, incorrect and partially correct response data; the learner's performance data in different difficulty learning modules ② Domain knowledge classification data ③ Correlation data of skills and problem solving
Learning Component Analysis and Teaching Strategy Analysis	The relationship between the functions of learning components in online learning systems, online education teaching strategies and learners' learning outcomes	① The learner's correct, incorrect and partially correct response data; the learner's performance data in different difficulty learning modules ② Domain knowledge classification data ③ Correlation data of skills and problem solving
Trend Analysis	The relationship between learners' current learning behavior and future learning outcomes	① Horizontal and vertical data related to learners' learning behavior in the online learning system ② In the student information management system, the basic information data of learners lasts for a period of time and is relatively stable
Adaptive Learning Systems and Personalized Learning	The realization of learners' personalized learning and the self-adaptive realization of the online learning system	① Horizontal and vertical data related to learners' learning behavior in the online learning system ② User feedback data related to use in the online learning system

implement targeted reinforcement measures for students. Big data can solve this problem. It can determine the information data that teachers need from massive data and make appropriate adjustments based on the actual situation of students to ensure that students' shortcomings in knowledge and skills can be made up in time for the successful completion of learning objectives. Carrying out precise online teaching through big data mainly includes accurate data mining, accurate positioning of students' learning bottlenecks, and accurate prediction of students' future learning to ensure the overall effect of online teaching and enable students to obtain a better learning experience. For example, data mining technology can be used first to analyze massive data and mine valuable information in the data; then, the data information obtained by the data mining tools can be used to analyze students' learning situation, determine the learning bottleneck faced by students; and, finally, targeted teaching guidance can be developed to help students better learn and master relevant knowledge. Studies have shown that when implementing precise innovative online education, setting up a hybrid model of innovative online education and offline education can effectively improve students' learning efficiency (Muthuprasad T & Aiswarya S & Aditya K S, 2021).

Promote the reform and development of innovative online education. The main value of big data applied to innovative online education is prediction, which collects datasets or specific data, conducts data analysis and research, and predicts the possibility of a certain occurrence. By giving full play to the advantages of big data in innovative online education, it can promote the effective interaction of teachers, students, and managers and constantly break through the bottleneck of innovative online education so that it can provide students with better services. As an important part of the current education reform, big data can help teachers clarify the direction of future teaching development, optimize teaching links, and promote the improvement of teaching efficiency and teaching quality. At present, the service demand for online teachers and online students in China has increased significantly. People's life data and physiological data can be recorded and analyzed. To ensure the effective application of big data and promote the reform and development of innovative online education, it is necessary to change the concept over time, including the establishment of a unified data standard to ensure the accuracy and authenticity of data to apply data flexibly and the

realization of the common development of big data and innovative online education. Although studies have shown that the current innovative online education has certain defects, it also has incomparable advantages (Selvaraj A & Radhin V & Nithin K A, 2021), which can be fully utilized to help the reform of modern education.

Key technologies and applications

Key technology

According to the monitoring of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the number of students unable to continue normal school life has hit a record high due to the impact of the COVID-19 pandemic globally. As of April 20, Beijing time, 191 countries had implemented school suspensions nationwide, affecting approximately 1.575 billion students and accounting for 91.3% of the total number of registered students worldwide (UNESCO Statistical Institute, 2020; Masud M & Gaba G S & Alqahtani S, 2020b). At the press conference held by the Chinese Ministry of Education on May 14, 2020, as of May 8, 2020, due to the impact of the new coronavirus pneumonia epidemic, 1454 colleges and universities in China had launched innovative online education, and 1.03 million teachers had opened 1.07 million online courses. Likewise, nearly all U.S. postgraduate institutions and K-12 schools moved classes online in March 2020. The rise of online courses became an unstoppable trend, and Twitter started the model of paying for online learning. COVID-19 led to a payment model, which is detailed in the literature (Alowibdi J S, Alshdadi A, Daud A et al., 2021). Many of them even continued their education online for the fall 2020 semester. As of May 26, 2020, at least 215 countries around the world had discovered the new coronavirus, the number of confirmed infections had reached 5.439 million, the number of deaths had exceeded 347,000, and more than 1.58 billion students were suspended in more than 191 countries, accounting for 91.3% of the total number of students in school. If all U.S. schools are closed for 4 weeks, the low, medium, and high forecast losses are $12.7 billion, $51 billion, and $56.5 billion, respectively, equivalent to 0.06%, 0.24%, and 0.26% of the U.S. GDP. The application of key technologies in online education is shown in Fig. 8.
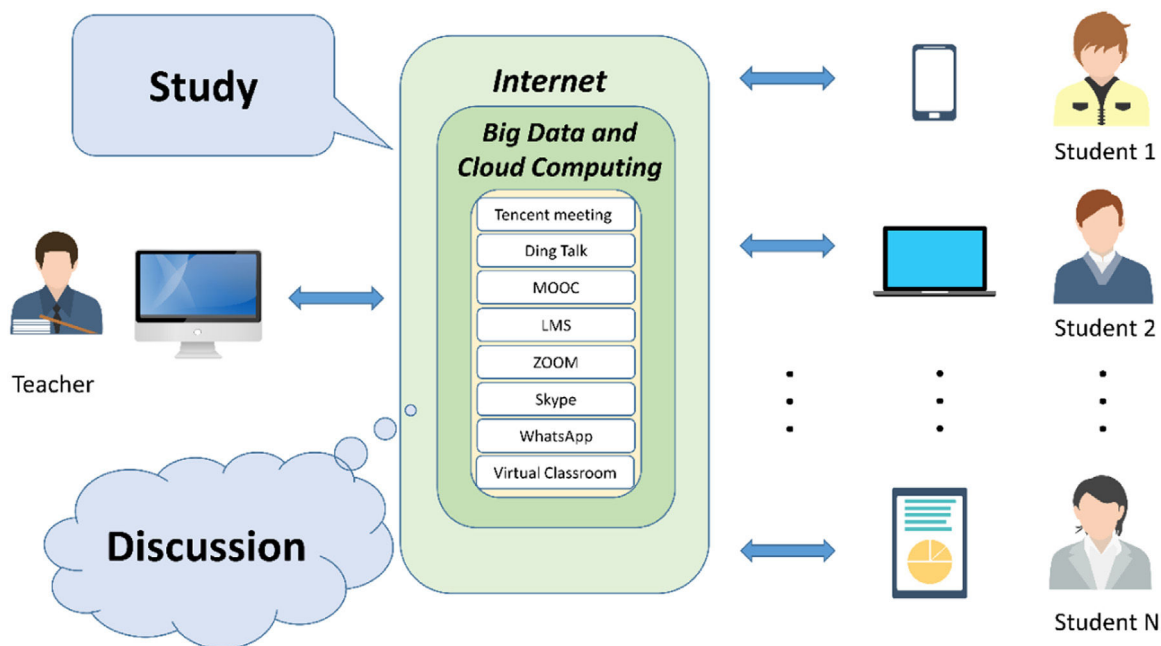

Fig. 8. Application of key technologies in innovative online education.

In the context of the COVID-19 pandemic, innovative online education is now the norm and will play a very important role. Through the combination of mobile devices and network technology, innovative online education will coexist with traditional education, provide more educational choices, promote educational equity, and promote educational innovation. Different countries offer different technologies for innovative online education. The development of innovative online education requires the support of multiple technologies, and this chapter describes the required network coverage, big data, cloud computing, and various applications for teaching and learning needs.

Network coverage. The Global System for Mobile Communications (GSMA) released the "Global Mobile Internet Connectivity Report 2021″, and despite the new coronavirus epidemic, more than half of the world's population is now using mobile internet; that is, the number of mobile internet users has reached approximately 4 billion, an increase of 2.25% compared to 2020. Only 1/3 of the world's population used mobile internet six years ago. Despite the impressive growth of mobile internet coverage and usage, the report highlights the need to accelerate work to bridge the digital divide. Of the 3.8 billion people who remain unconnected, only 450 million live outside mobile broadband coverage. A bigger challenge is that 3.4 billion people live in areas where mobile broadband is already covered but not used.

The coverage gap has continued to narrow over the past six years. In 2014, nearly a quarter of the world's population did not have access to a mobile broadband network. By the end of 2020, the figure was only 6%. Currently, 94% of the world's population has internet access, with the fastest progress in 2014−2018. In 2020, global coverage increased from 93% to 94%. This brings the number of people living in areas without mobile broadband networks down to 450 million. The number of people using mobile internet is also on the rise: In 2020, 3.4 billion people (43% of the world's population) lived within the coverage of a mobile broadband network but did not use mobile internet services. Low and middle-income countries (LMICs) currently account for nearly 93% of the world's unconnected population. The region with the most significant growth in mobile internet usage in 2019−2020 was East Asia (61%), which increased by 4%. However, despite living within mobile broadband network coverage, 47% of the population in LMIC countries is still not using mobile internet. The coverage of the network is the premise of implementing innovative online education.

Innovative online education requires not only full coverage of the network but also devices such as paper, desktop computers, laptops, speakers, mobile phones, and tablets (Selvaraj A & Radhin V & Nithin K A, 2021).

Tencent Meeting. Tencent Meeting is a high-definition, smooth, convenient, easy-to-use, safe and reliable cloud video conferencing product based on 21 years of experience in audio and video communication. You can use Tencent Meeting for remote audio and video conferences, online document collaboration, screen sharing, etc. It has fast and flexible group discussions and efficient and convenient group meetings and ensures private project bidding.

H Wiranota and T Wijaya (Wiranota H & Wijaya T, 2021) learned about international students' perceptions of online learning through Tencent conferences and found that Tencent conferences were generally well received by students. Online learning using Tencent Meeting makes the learning process well managed and easy to use. A total of 56.7% and 13.3% of students expressed strong agreement and agreement, respectively, with the use of Tencent's meeting and distance learning capabilities. Those who strongly disagreed and disagreed with using Tencent Meeting were 3.3% and 6.7%, respectively.

DingTalk. DingTalk is a product of Alibaba. The name DingTalk comes from Xi Jinping's "promotion of DingTalk", which can book meetings, video conferences, and post tasks. During the epidemic, DingTalk was very popular among students all over the world. Once it was released, more than 19 million schools, enterprises and organizations applied for it. It also has functions such as Ding daily management, group notification, and emergency recruitment, which is convenient for online teachers and students.

However, Nails received a lot of dislike from students at first. Yu L I (Yu L I et al., 2020) investigated the technical characteristics of Ding-Talk, Tencent Meeting and Rain Classroom and concluded that these three software programs all lack reasonable reminders of important terms. These online teaching platforms have been criticized by millions of students due to technical and functional shortcomings (Chen T & Peng L & Jing B, 2020). For example, DingTalk's satisfaction rating quickly dropped from 5 stars to 1 star (Pappano L et al., 2012). The survey found that the user agreements of the three intelligent teaching tools, Rain Classroom, DingTalk and Tencent Meeting, are unequal. The agreement considers the interests of the three parties and, to a certain extent, spies on the user's personal privacy, putting the user in a weak position when accepting the terms (Yu L I et al., 2020).

MOOC. The development of online open courses (MOOCs) (Ebben M & Murphy J S, 2014) has benefited from the open education movement, which aims to create and provide widely available materials and conditions for participatory learning. At the same time, innovative online education has received increasing attention due to its advantages, such as breaking through time and space constraints and improving educational equity. In addition, studies have shown that the MOOC teaching model can promote teachers' professional development and improve teachers' teaching skills (Pappano L et al., 2012). However, at present, due to the limitations of technology, innovative online education mainly focuses on vocational courses and remedial classes and does not involve basic courses and professional courses. Most schools still use traditional teaching methods (Chen T & Peng L & Jing B, 2020). Kimberley et al. (Foley K & Alturkistani A & Carter A, 2019) combined the characteristics of MOOC platforms to compare several evaluation methods to determine their respective advantages and limitations. Wong and Billy (Foley K & Alturkistani A & Carter A, 2019) compared four MOOC platforms, namely, Coursera, edX, FutureLearn, and OpenLearning, and the results showed that courses differed in terms of duration, learning activities, assessment, social interaction, and teacher engagement. Cervi et al. (Cervi L & Pérez Tornero J M & Tejedor S, 2020) used data collected from postevaluation surveys to demonstrate that MOOCs are effective training tools by assessing participants' structure, functioning, and opinions. Kravvaris et al. and Mackness et al. (Kravvaris D & Kermanidis K L & Ntanis G, 2016) found through empirical research on MOOCs that learner autonomy plays an important role in learning. The year 2012 became the "Year of the Massively Open Online Courses" (Shenoy V & Mahendra S & Vijay N, 2020), with well-funded providers partnering with top universities to offer a wide variety of massively online open course environments, such as Coursera, Udacity, and edX. The modern MOOC movement has not only offered more free online courses but also has partnered with universities and colleges to offer fully online degree programs leading to bachelor's and master's degrees. Additionally, a study on predicting learning outcomes in MOOC-based flipped classrooms based on big data analysis is used to help MOOC classroom platforms develop better. The literature (Qian Y, Li C X, Zou X G et al., 2022) describes this in detail.

LMS. Learning management systems (LMSs), such as Canvas, Moodle, and Blackboard, play an important role in innovative online education. An LMS is a software application used to manage, document, track, report, and deliver educational courses, training programs, or learning and development programs. Primarily as a repository for learning materials or the like, when used for innovative online education, the LMS provides the delivery of online course content and acts as a platform for online courses. It can support asynchronous and synchronous innovative online education, providing an online platform for teachers to upload teaching materials and communicate with online students. According to the Instructure website https://www.instructure.com/canvas/highereducation/advancing-the-

institution, Canvas has been adopted by more than 30% of higher education institutions in North America (Ramos R J M & Ramos R G A & Espaldon R N, 2021).

Zoom. Zoom is arguably one of the most popular video conferencing tools. One of the main reasons for Zoom's popularity is its ease of use. When joining an online meeting room, participants do not need to bother signing up for Zoom. Only one conference number (i.e., multiple numbers) is required (Mohanty M & Yaqub W, 2020). Zoom ended the second quarter of 2020 with more than 370,000 customers, representing a staggering annual growth rate of 458% (Ramos R J M & Ramos R G A & Espaldon R N, 2021). Teachers in Pakistan mostly use WhatsApp and Zoom for innovative online education (Rehman N & Zhang W & Iqbal M, 2021). However, Zoom has serious security and privacy issues. A major security issue is poor authentication mechanisms, so unauthorised people can join meetings and cause disruption, leading to Zoom explosions and Zoom eavesdropping (Mohanty M & Yaqub W, 2020).

Skype. Skype is an instant messaging (IM) software that has the functions required by IM, such as video chat, multiperson voice conference, multiperson chat, file transfer, text chat and other functions. It also can provide high-definition chats with other users, make international calls, etc., and has very complete functions for innovative online education.

WhatsApp messenger. WhatsApp messenger is an application for smart mobile phone users. It supports Android, iOS and other operating systems. It has a push notification service and can receive messages from relatives, friends and colleagues.

Virtual Classroom. The construction of virtual teaching and research rooms is a new exploration, new practice and new promotion by the Chinese Ministry of Education for the reform of education and teaching in colleges and universities, and it is of great significance. Construction work must strive to achieve three breakthroughs: first, a breakthrough in the digital development of higher education; second, a breakthrough in strengthening the construction of grassroots teaching organizations; and third, a breakthrough in the mechanism for the continuous improvement of teaching quality. The majority of teachers actively explore new forms of integrated and efficient teaching and research, build a community of teachers' teaching development, and promote the coconstruction and sharing of high-quality teaching resource pools. The virtual teaching and research section should take application as the king, build a multidisciplinary, multitype and multilevel new grassroots teaching organization system, promote the networked and systematic construction of the virtual teaching and research section step by step, take the majority of teachers as the main body of the virtual teaching and research section, and collaborate to build the virtual teaching and research room into a communication community and spiritual home for teachers. Related technologies for innovative online education are shown in Table 2 below.

New technologies such as artificial intelligence. Innovative online education also is benefiting from the development of entirely new technologies such as artificial intelligence and machine learning, the development of embedded computer systems and other technologies, the independent use of humanoid robots and web-based chatbots and other developments. Using these platforms, teachers can perform different administrative functions, such as reviewing and grading student work more efficiently and achieving higher-quality teaching activities. On the other hand, since the system utilizes machine learning and adaptation, the curriculum and content have been customized and personalized according to the needs of students, which promotes absorption and retention, thereby improving the learner experience and overall learning quality (Chen L & Chen P & Lin Z, 2020). Chassignol et al. found that the application of AI in education has been incorporated into management, teaching and learning (Chassignol M & Khoroshavin A & Klimova A, 2018). With the development of education, researchers are trying to apply new artificial intelligence techniques, such as deep learning and data mining, to deal with complex problems and customize teaching methods for each student.

Cloud Computing and Cloud Platforms. Cloud computing and cloud platforms are important branches of innovative online education. The most important thing in the development of innovative online education is the speed of access to the network. We now have many innovative online education apps with complete functions. The focus of improving teaching quality services is how to become more efficient, and cloud computing provides a great platform to enhance teaching practices and productivity. The cloud server stack is used for the terminal, the user is at the front end, and the server is at the back end. These services exist in the middleware of the cloud server stack. The application sits at the top level, which virtually delivers the application to the front-end clients. Higher education institutions can use cloud servers to deploy their own private clouds, or several universities can deploy hybrid clouds together, also known as education clouds. The private cloud can utilize the local network, while the education cloud can use the public network to access the functions provided by the two cloud models (Qasem Y A M & Abdullah R & Jusoh Y, 2019).

Innovative online education mode and user experience

Innovative online education mode. Data from the National Center for Education Statistics (2021) show that, similar to primary and secondary education, higher education has been disproportionately affected by the pandemic. In the spring of 2020, many institutions moved from in-person to online classes. College practices and programs also changed in other ways, from new policies on campus tours and admissions to the economic challenges of falling tuition and room and board revenue and the cancelation of athletic programs. In fall 2020, approximately half (51%) of postsecondary students reported that the coronavirus pandemic was likely to have a negative impact on their ability to complete their studies (Irwin V & Zhang J & Wang X, 2021). This section summarizes several teaching modes of innovative online education, as shown in Fig. 9.

(1) 100% innovative online education (or distance learning): From registration to graduation, all steps and learning activities take place online, without the need to visit a university campus.
(2) Blended education: Combines online and on-campus activities to optimize learning by leveraging the strengths of both modes.
(3) Individual online courses: While these courses are offered over the internet and also may be part of a degree program, you can study at your own pace to master a course or acquire a skill.
(4) Massive open online courses (MOOCs): Refer to online courses with unlimited participation and open access through the internet.
(5) Webinars can be delivered by using video conferencing tools to stream online synchronized courses, seminars or events from anywhere in the world.

Table 2
Related technologies for innovative online education.

| Application	Model
Tencent Meeting	Video conference
DingTalk	Live video, task assignment
MOOC	Online courses, unlimited participation and open access
LMS	Learning management system, for administration, documentation
Zoom	Video conference
Skype	Instant message application
WhatsApp	Mobile phone application
Virtual Classroom	Educational management system
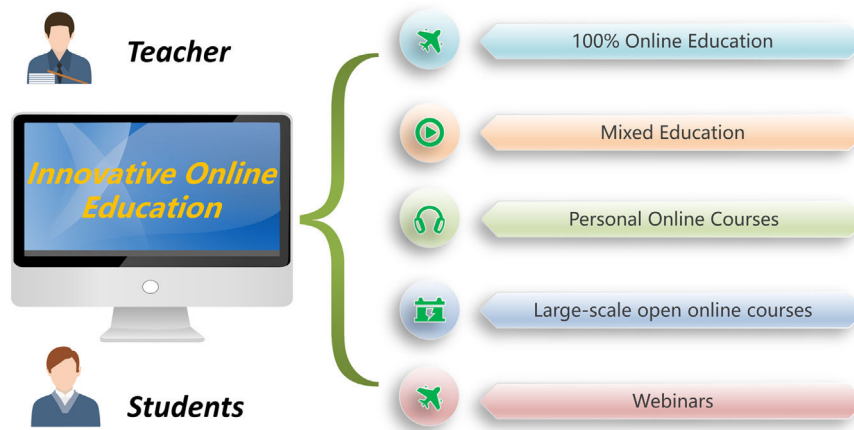
Fig. 9. Class Mode of Innovative Online Education.

Innovative online education user experience. Not only did students and teachers comply with government mandates not to go to school, but social distancing rules may have solved the problem (Kravvaris D & Kermanidis K L & Ntanis G, 2020). There are advantages and disadvantages of innovative online education. The advantages include flexibility, information accessibility, global reach, equity, innovation, and efficiency. The disadvantages include network instability and technical constraints, lack of belonging and connectivity, presence of interference, lack of contact, lack of electricity, slow internet speeds, disrespect of parents and students, overburdened teachers, etc. Universities in India (Shenoy V & Mahendra S & Vijay N, 2020; Chakraborty P & Mittal P & Gupta M S, 2021), the Philippines (Ramos R J M & Ramos R G A & Espaldon R N, 2021), Bangladesh and Nepal (Ibrahim F & Susanto H & Haghi P K, 2020), Pakistan and Afghanistan are poorly prepared for online or distance learning. For most students from low-income families, access to internet data is the largest obstacle to their success, especially in rural areas (Murphy M P A et al., 2020), as shown in Table 3 below.

(1) Survey of innovative online education

Daniel S J et al. (Daniel S J, 2020) proposed a flexible approach to repairing damage to students' learning trajectories after the outbreak with a list of resources. Zhao J et al. (Zhao J & Xiao H & Li Y, 2020) surveyed 1747 teachers and 7223 students through two rounds of questionnaires with a total of 56 questions, involving a total of 741 courses. The survey results were compared and analyzed. It was concluded that the good effect of large-scale distance innovative online education and the satisfaction of teachers and students with the performance of the teaching platform indicate that innovative online education can be used as the main means to replace traditional classroom education in emergency situations. Chakraborty P et al. (Chakraborty P & Mittal P & Gupta M S, 2021) asked undergraduate

students at a university in India their views on different aspects of innovative online education during the current pandemic and received responses from 358 students. The students believe that physical education (65.9%) and MOOCs (39.9%) are better than innovative online education. However, the students also believe that professors' innovative online education has improved during the COVID-19 outbreak (68.1%) and that innovative online education is currently useful (77.9%).

Brem A (Brem A & Viardot E & Nylund P A, 2021) promoted and accelerated the development speed of innovative online education and changed the development direction, from originally a teaching aid to an equally important position as offline teaching. Xie X et al. (Xie X & Siau K, 2020) proposed that innovative online education has many advantages: (1) elimination of the limitation of learning space and time, as innovative online education is open to everyone, no matter when and where they want to learn; and (2) synchronous teaching provides online students with more opportunities to engage in real-time interaction and communicate with offline students. Innovative online education provides flexibility in course schedules, allowing students to progress based on their own understanding, mastery, and internalization of knowledge of course materials, providing more people with access to education and promoting educational equity.

Innovative online education also has its shortcomings: (1) the purpose of online courses may not be to cultivate collective consciousness by emphasizing individual activities, and it is difficult to establish a sense of belonging in online courses; (2) the learning process requires students to have strong self-discipline and be easily socialized, as they can be attracted and distracted by chatting, news, games, etc.; and (3) there is a lack of emotional investment between teachers and students and between students. Those with access to the right technology can take advantage of innovative online

Table 3
Worldwide experience with innovative online education.

Reference	Country/Region	Class mode	Equipment	Application	User experience
(Rehman N & Zhang W & Iqbal M, 2021)	Pakistan	Innovative online education	Computer, Mobile phone	WhatsApp, Zoom	General
(Wiranota H & Wijaya T, 2021)	China	Innovative online education	Computer, Mobile phone	Tencent Meeting	Good
(Ramos R J M & Ramos R G A & Espaldon R N, 2021)	North America	Innovative online education	Computer, Mobile phone	LMS, Canvas	
(Mohanty M & Yaqub W, 2020)	–	Innovative online education	Computer, Mobile phone	Zoom	Good
(Shenoy V & Mahendra S & Vijay N, 2020)	India	Virtual classroom	Computer, Mobile phone	–	Good
(Shenoy V & Mahendra S & Vijay N, 2020)	–	Innovative online education	Computer, Mobile phone	–	Good
(Daniel S J, 2020)	–	Innovative online education	Computer, Mobile phone	–	General
(Zhao J & Xiao H & Li Y, 2020)	–	Innovative online education	Computer, Mobile phone	–	Good
(Chakraborty P & Mittal P & Gupta M S, 2021)	India	Innovative online education	Computer, Mobile phone	MOOC	Good
(Ramos R J M & Ramos R G A & Espaldon R N, 2021)	Philippines	Innovative online education	Computer, Mobile phone	LMS	Good
(Shrestha S & Haque S & Dawadi S, 2021)	Bangladesh and Nepal	Innovative online education	Computer, Mobile phone	–	General

education to improve learning efficiency. While innovative online education is a trend, it is not the only form of education for the future. Xie X et al. (Xie X & Siau K & Nah F H, 2020) provide educational instruction to students through computers, smartphones or mobile devices. Even before the COVID-19 pandemic, innovative online education was experiencing high growth and adoption. Learners can choose from a variety of innovative online education services to acquire new knowledge or enhance existing knowledge. Ramos R J M et al. (Ramos R J M & Ramos R G A & Espaldon R N, 2021) explored students' perceptions of online learning and employment during the COVID-19 pandemic at a state university in the rural Philippines, and based on students' experience with innovative online education and the parameters of this study, they concluded the following: People found that eLearning is easy to use, accessible, works online and offline—anywhere and everywhere—and improves performance, competency, interactions related to improving competency skills, limited interactions, communication problems and network connectivity. The LMS (used in this study) is not optimized because it functions mainly as a repository for learning materials, etc. A comparison of innovative online education research is shown in Table 4.

(2) The problem of innovative online education

Shenoy V et al. (Shenoy V & Mahendra S & Vijay N, 2020), during the blockade of India due to COVID-19, examined the technology adoption, teaching and learning process, student participation and teacher experience of virtual classrooms. Using inductive reasoning and qualitative research methods, data were collected from higher education institutions and teaching courses in Bangalore, such as PGDM, MBA, MMC, MCA and other relevant departments. The study's findings show that during the lockdown, teachers experienced a process of technology adoption, and students engaged in various modes of online learning. Students and teachers have a lot of fear, anxiety, and awareness about COVID-19. This research is limited to the positive aspects of COVID-19 and the changes in the education sector by adapting to technology and engaging students in various virtual meetings. The study is based on qualitative data collected from 20 fraternity teachings in higher education institutions in Bangalore. Telephone interviews were conducted with respondents. The open-ended questions that teachers were asked were divided into four categories, namely, technology adaptation, teaching and learning, student engagement and teachers' experience with virtual classrooms during the COVID-19 lockdown. Students' virtual participation is better than in regular classes, with attendance at nearly 100%.

The findings of Ibrahim F et al. (Ibrahim F & Susanto H & Haghi P K, 2020) show that there is a lack of positive effects on end users, such as a lack of readiness to undergo organizational change in education and uncoordinated communication and information exchange

Table 4
Comparison of innovative online education research.

Time	Author	Survey results
2020	Daniel S J et al.	Proposed a flexible approach to repairing damage to students' learning trajectories after the outbreak
2020	Zhao J et al.	Innovative online education can be used as the main means to replace traditional classroom education in emergency situations
2021	Chakraborty P et al.	Students believe that professors' innovative online education has improved during the COVID-19 outbreak
2021	Brem A	Promoted and accelerated the development speed of innovative online education
2020	Xie X et al.	Proposed that innovative online education has many advantages
2021	Ramos R J M et al.	People found that online learning is easy to use, accessible, works online and offline—anywhere and everywhere—and improves performance and competency

between stakeholders and end users. Shrestha S et al. (Shrestha S & Haque S & Dawadi S, 2021) explored the main challenges and constraints they encountered during the transition to innovative online education, including poor networks, lack of digital skills, lack of technical support from institutions, economic stress, etc. Based on a binational study of English as a foreign language (EFL), teachers and students in higher education institutions in Bangladesh and Nepal examine how teachers and students can prepare for teaching transitions. A qualitative approach was used by Sá M J & Serpa S et al. (Sá M J & Serpa S et al., 2020) to conduct a sample survey of 30,383 students from 62 countries, and the technique for analyzing the collected data was content analysis, concluding that there was a need for improvement. To make digital teaching sustainable in higher education, higher education institutions need to face and overcome profound challenges if they are to succeed at the forefront of the international education market. In China, during the new coronavirus epidemic, the use of big data technology for the design and implementation of the system of online education helps to ensure the normal operation of online education, and reasonable planning for the education of people during the epidemic will not stop. The literature (Li C, Zhang K, 2022) provides a detailed description of online education operations in China. Chen T et al. (Chen T & Peng L & Jing B, 2020) obtained user reviews of seven major innovative online education platforms before and after the epidemic, combined sentiment analysis and hot mining technology, and constructed a reasonable evaluation index system to determine the changes in users' attention to innovative online education platforms. From the aspects of video information access speed, reliability, timely transmission technology, course management, communication and interaction, learning and technical support, etc., this paper discusses the support ability and response level of innovative online education platforms in the COVID-19 epidemic and aims at the functions of these platforms. Corresponding improvement measures have been proposed. For online education, we will face more challenges, including the lack of education for poor areas and not reaching the network speed of the mountainous areas. These are limitations for online education. For big data online education, we may collect data distribution with more for the relatively good economic students, which will cause our data analysis for students to have bias and misunderstanding. Then, we also should change these difficulties due to the future lack of big data online education. The state should support the construction of network penetration for regional economic development relative to the tilt. These are the basic conditions under which we should develop big data online education in the future and solve the influence of big data online education physical factors so that students can truly enjoy the benefits brought by big data online education.

(3) Contribution to innovative online education

A qualitative approach was used in Sá M J, Serpa S et al. (Sá M J & Serpa S et al., 2020) to conduct a sample survey of 30,383 students from 62 countries, and the technique for analyzing the collected data was content analysis, concluding that there was a need for improvement. The findings of Ibrahim F et al. (Ibrahim F & Susanto H & Haghi P K, 2020) show that there is a lack of positive effects on end users, such as a lack of readiness to undergo organizational change in education and uncoordinated communication and information exchange between stakeholders and end users. To make digital teaching sustainable in higher education, higher education institutions need to face and overcome profound challenges if they are to succeed at the forefront of the international education market. Chen T et al. (Chen T & Peng L & Jing B, 2020) obtained user reviews of seven major innovative online education platforms before and after the epidemic, combined sentiment analysis and hot mining technology, and constructed a reasonable evaluation index system to determine the changes in users' attention to innovative online education platforms. Shrestha S et al. (Shrestha S & Haque S & Dawadi S, 2021) explored the main challenges and constraints they encountered during the

transition to innovative online education, including poor networks, lack of digital skills, lack of technical support from institutions, economic stress, etc. Based on a binational study of English as a foreign language (EFL), teachers and students in higher education institutions in Bangladesh and Nepal examine how teachers and students can prepare for teaching transitions. From the aspects of video information access speed, reliability, timely transmission technology, course management, communication and interaction, learning and technical support, etc., this paper discusses the support ability and response level of innovative online education platforms in the COVID-19 epidemic and aims at the functions of these platforms. Corresponding improvement measures have been proposed. This paper mainly analyzes the key technologies and application platforms of innovative online education generated by the application of big data to online education during the COVID-19 period and provides a reference for future research on online education. It is believed that the fields of big data and online education will be more closely linked and combined to promote the development of innovative online education and make the future teaching life one of more informatization.

The proposed industrial significance of this paper is to propose the application of big data technology to the online education industry, analyze the impact and development of online education in the context of the new coronavirus epidemic, and simultaneously combine the two to analyze big data technology in the context of the new coronavirus epidemic. For the impact of online education, we look forward to more application scenarios of big data technology in the future and the development of big data technology.

Issues and challenges

At present, the popularity of online education continues to rise. Students have a wide variety of online learning courses, and office workers have many required training courses and related learning tasks. Although the popularization of online education provides convenience for students and office workers, many problems and challenges also have been exposed in the process of innovative online education.

First, feelings towards online courses are mixed and difficult to distinguish. On the one hand, parents of students tend to listen to the rhetoric of poor-quality training institutions on the internet. When they heard online courses are better, they went around buying online courses and forcing students to watch them. China has developed a series of institutions and proposals to ensure the proper operation of online education in response to the COVID-19 online education initiative, which is described in detail in the literature (Xue E, Li J, Xu L., 2022). In fact, this kind of course does not have targeted tutoring but instead increases the student's learning burden, resulting in poor innovative online education (Brdesee H S & Alsaggaf W & Aljohani N, 2022). On the other hand, innovative online education lacks unified management and different charging standards. Most online education companies are private enterprises (George G & Lal A M, 2021). General online education courses often have difficulty educating according to the characteristics of students, and students who do not understand the difficulties of the classroom often have difficulty learning through innovative online education platforms. Now, some online education websites provide one-to-one services, and the fees are too high. Moreover, the definition of teachers' qualifications and

abilities also is insufficient, and it is difficult to reflect the educational effect of students.

For the above problems and challenges, our research found that we can start from the following aspects. First, unified platform management, led by the relevant education authorities, should establish a formal innovative online education evaluation platform on the internet and manage the uploading of teaching videos on online education websites in a unified manner; at the same time, it should restrict the relevant charges for content, such as course prices. Second is the famous teacher teaching system. The education and teaching videos of nationally famous teachers and leaders in key fields should be retrieved first, and innovative online education platforms should pay more attention to the collection and release of teaching resources of these famous teachers. Finally, online training supervision and management methods should be strengthened. For example, the training video can be forced to the top and cannot be covered; video surveillance can be turned on when watching the teaching video. When the students' eyes are not on the computer screen, it can be considered that the students are not paying attention to the class. Challenges and countermeasures of online education are shown in Table 5.

Summary and outlook

In summary, in the context of big data, innovative online education not only solves the problems of incomplete data and slow processing. With the continuous development of big data technology, the application of big data in online education becomes more extensive, which makes the advantages of innovative online education more obvious than those of traditional education. Therefore, the role of big data in the field of innovative online education is more prominent. A recognized authority in the field of big data, the author of the million-level super best-selling book "The Age of Big Data", Professor Viktor Mayer-Schonberger from the Internet Research Institute of Oxford University (Lei Y & Jia F & Lin J, 2016; Qin S J, 2014), in his book "Walking with Big Data", listed cases such as MOOC, Khan Academy, and Duolingo, illustrating that big data has brought great changes to education (Bienkowski M & Feng M & Means B, 2012; Manyika J & Chui M & Brown B, 2011).

For education, especially innovative online education, with the increasingly accurate probability prediction of data collection, statistics, and analysis, big data plays a huge role in the field of innovative online education through three changes: feedback, personalization, and probability prediction (Calvet Liñán L & Juan Pérez Á A, 2015). Innovative online education is not just a change at the technical level but also has a real impact on the development pattern of the education industry. Likewise, big data brings three major changes to online education: first, we can collect data that could not be gathered in the past; second, innovative online education realizes individualized learning of students, rather than general rigid teaching methods; and third, innovative online education can optimize learning content, learning time and learning methods through probabilistic prediction.

As shown in Table 6, to better adapt to the background of COVID-19, online education research is facing the reform needs of management, education and other levels. Only in this way can it be better integrated with big data and improve the teaching level to improve the quality of education. Based on the above research, I will summarize and look forward to the full text.

Table 5
Challenges and countermeasures of online education.

Problem aspect	Issues and Challenges	Responses
Charges	Fees vary	Constrained course fees
Course content	Online courses are mixed and difficult to distinguish	Unified platform management
Student's result	Difficult to improve student performance, Inadequate targeting	Strengthen online training supervision and management methods

Table 6
The reform direction of online education.

Reform direction	Group	Measures
Management	Educational administrative department School management	Update management concepts Provide policy support Choose online teaching programs according to local conditions
Education	Teacher group	Exposure to the latest educational technology Master the latest educational tools Prompt self-learning and working ability
Others	Parents, Students	Parents should cooperate with students' online learning in thought and action Students should actively participate in online teaching

First, big data is entering all aspects of online education and will have a profound impact on learning in this world. Big data can tell us what is most efficient and reveal previously undiscovered mysteries. In the future, innovative online education also will become more popular.

Second, big data has further stimulated large-scale modern education-related industries. According to GSV Advisors, a well-known education technology market research organization, the value of innovative online learning time exceeds 100 billion U.S. dollars, and it continues to soar at a rate of 25% every year. In the future, big data also will have a greater impact on its soaring rate.

Finally, big data promotes the integration of online education and technology, stimulates the imagination of application citation platform entrepreneurs, and attracts investors' funds. In 2012 alone, more than $1 billion in venture capital was poured into the online education industry, a figure that doubled from five years earlier, while traditional education companies such as Pearson and Kaplan have invested billions of dollars in R&D and acquisitions in education technology (De Mauro A & Greco M & Grimaldi M, 2015). Therefore, the improvement of future innovative online education technology and platforms also is the focus of many scholars' research.

In summary, in the context of the era of big data, this paper introduces the analysis of the current situation of online education in the era of big data, expounds the influence and application of big data and online teaching in the field of modern education, and then summarizes the online innovations in the era of big data. It aims to express the application scenarios of big data and online education and what kind of role and impact will they have, analyze the current state of education, compare the various tools and platforms of online education at this stage and determine the development direction of online education. Then, the key technologies and application platforms of innovative online education generated by the application of big data to online education during the COVID-19 period were analyzed. We believe that in future research, the field of big data and online education will be more closely integrated, promoting the development of innovative online education and making future teaching life more information-based.

The novelty of this thesis lies in proposing the use of big data technology in the online education industry, analyzing the impact and development of online education in the context of the new coronavirus epidemic, and at the same time, combining the two to analyze the impact of big data technology on online education in the context of the new coronavirus epidemic, and looking forward to more scenarios of the future use of big data technology with the development

of big data technology. Online education will affect the effect of online education due to social factors, such as regional poverty caused by social development and unbalanced network development. These are the novel ideas and innovations presented in this paper. Therefore, this thesis concludes with an outlook that combines big data technology and online education more together, not only because of the impact of the novel coronavirus epidemic, but also in the future, when the epidemic has passed, education and teaching will be more informative and connected to people's lives. This article has searched for relevant research on online education in an all-around way. However, with the advancement of science and technology, there are still innovative developments in school online teaching during the epidemic, and all information cannot be collected at one time. Education does not compare with offline education during the epidemic. With the development of artificial intelligence technology, the combination of online education and offline education also will develop. These are areas that we have not been able to cover. Development and research will enable big data technology to be applied to more scenarios. This article simply introduces the development and promotion of big data to online education during the epidemic.

Abbreviation table:

Name	Explanation
COVID-19	Coronavirus Disease 2019
AHP	Analytic Hierarchy Process
UNESCO	United Nations Educational, Scientific and Cultural Organization
LMS	Learning Management Systems
EFL	English as a Foreign Language
GSMA	Global System for Mobile Communications

References

Alblihed, M. A., Aly, S. M., Albrakati, A., et al. (2021). The effectiveness of online education in basic medical sciences courses during the COVID-19 pandemic in Saudi Arabia: Cross-sectional study. *Sustainability, 14*(1), 224. doi:10.3390/su14010224.

Al-Kumaim, N. H., Mohammed, F., Gazem, N. A., et al. (2021). Exploring the impact of transformation to fully online learning during COVID-19 on Malaysian university students' academic life and performance. *International Journal of Interactive Mobile Technologies, 15*(5). doi:10.3991/ijim.v15i05.20203.

Alowibdi, J. S., Alshdadi, A. A., Daud, A., et al. (2021). Coronavirus pandemic (covid-19): Emotional toll analysis on twitter. *International Journal on Semantic Web and Information Systems (IJSWIS), 17*(2), 1–21. doi:10.4018/IJSWIS.2021040101.

Anshari, M., Alas, Y., & Guan, L. S. (2016). Developing online learning resources: Big data, social networks, and cloud computing to support pervasive knowledge. *Education and Information Technologies*, 21(6), 1663–1677. doi:10.1007/s10639-015-9407-3.

Bahanshal, D., & Khan, I. (2021). Effect of COVID-19 on education in Saudi Arabia and E-learning strategies. *Arab World English Journal (AWEJ) Special Issue on CALL*, (7). doi:10.24093/awej/call7.25.

Baig, M. I., Shuib, L., & Yadegaridehkordi, E. (2020). Big data in education: A state of the art, limitations, and future research directions. *International Journal of Educational Technology in Higher Education*, 17(1), 1–23. doi:10.1186/s41239-020-00223-0.

Bienkowski, M., Feng, M., & Means, B. (2012). Enhancing teaching and learning through educational data mining and learning analytics: An issue brief. *Office of Educational Technology, US Department of Education*.

Brem, A., Viardot, E., & Nylund, P. A. (2021). Implications of the coronavirus (COVID-19) outbreak for innovation: Which technologies will improve our lives? *Technological Forecasting and Social Change*, 163, 120451. doi:10.1016/j.techfore.2020.120451.

Brdesee, H. S., Alsaggaf, W., Aljohani, N., et al. (2022). Predictive model using a machine learning approach for enhancing the retention rate of students at-risk. *International Journal on Semantic Web and Information Systems (IJSWIS)*, 18(1), 1–21. doi:10.4018/IJSWIS.299859.

Calvet Liñán, L., & Juan Pérez, Á. A (2015). Educational data mining and learning analytics: Differences, similarities, and time evolution. *International Journal of Educational Technology in Higher Education*, 12(3), 98–112. doi:10.7238/rusc.v12i3.2515.

Chakraborty, P., Mittal, P., Gupta, M. S., et al. (2021). Opinion of students on online education during the COVID-19 pandemic. *Human Behavior and Emerging Technologies*, 3(3), 357–365. doi:10.1002/hbe2.240.

Chassignol, M., Khoroshavin, A., Klimova, A., et al. (2018). Artificial Intelligence trends in education: A narrative overview. *Procedia Computer Science*, 136, 16–24. doi:10.1016/j.procs.2018.08.233.

Chaurasia, S. S., Kodwani, D., Lachhwani, H., et al. (2018). Big data academic and learning analytics: Connecting the dots for academic excellence in higher education. *International Journal of Educational Management*. doi:10.1108/IJEM-08-2017-0199.

Cheeti, S. S (2021). Twitter based sentiment analysis of impact of COVID-19 on education globaly. *International Journal of Artificial Intelligence and Applications (IJAIA)*, 12(3). doi:10.5121/ijaia.2021.12302.

Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access : Practical Innovations, Open Solutions*, 8, 75264–75278. doi:10.1109/ACCESS.2020.2988510.

Chen, T., Peng, L., Jing, B., et al. (2020). The impact of the COVID-19 pandemic on user experience with online education platforms in China. *Sustainability*, 12(18), 7329. doi:10.3390/su12187329.

Chen, T., Peng, L., Yin, X., et al. (2020). Analysis of user satisfaction with online education platforms in China during the COVID-19 pandemic. *Healthcare Multidisciplinary Digital Publishing Institute*, 8(3), 200. doi:10.3390/healthcare8030200.

Chiao, H. M., Chen, Y. L., & Huang, W. H (2018). Examining the usability of an online virtual tour-guiding platform for cultural tourism education. *Journal of Hospitality, Leisure, Sport & Tourism Education*, 23, 29–38. doi:10.1016/j.jhlste.2018.05.002.

Cervi, L., Pérez Tornero, J. M., & Tejedor, S (2020). The challenge of teaching mobile journalism through MOOCs: A case study. *Sustainability*, 12(13), 5307. doi:10.3390/su12135307.

Daniel, S. J (2020). Education and the COVID-19 pandemic. *Prospects*, 49(1), 91–96. doi:10.1007/s11125-020-09464-3.

Davenport, T. H., & Patil, D. J (2012). Data scientist. *Harvard Business Review*, 90(5), 70–76.

De Mauro, A., Greco, M., & Grimaldi, M. (2015). What is big data? A consensual definition and a review of key research topics. *AIP Conference Proceedings American Institute of Physics, 1644*(1), 97–104.

Ebben, M., & Murphy, J. S. (2014). Unpacking MOOC scholarly discourse: A review of nascent MOOC scholarship. *Learning, Media and Technology*, 39(3), 328–345. doi:10.1080/17439884.2013.878352.

Fenny A., Crentsil A., Anyamesem D. POLICY BRIEF COVID-19 and education: Emerging challenges and way forward. 2020.

Feng, B. (2022). Research on family education in remote chinese areas impacted by COVID-19. In *Proceedings of the international conference on education, language and art (ICELA)* (pp. 1035–1040). Atlantis Press. doi:10.2991/assehr.k.220131.187.

Fischer, C., Pardos, Z. A., Baker, R. S., et al. (2020). Mining big data in education: Affordances and challenges. *Review of Research in Education*, 44(1), 130–160. doi:10.3102/0091732×20903304.

Foley, K., Alturkistani, A., Carter, A., et al. (2019). Massive open online courses (MOOC) evaluation methods: Protocol for a systematic review. *JMIR Research Protocols*, 8(3), E12087. doi:10.2196/12087.

Fu, H., Li, Z., Liu, Z., & Wang, Z (2018). Research on big data digging of hot topics about recycled water use on micro-blog based on particle swarm optimization. *Sustainability*, 10(7), 2488. doi:10.3390/su10072488.

Gaurav, A., Psannis, K., & Perakovic, D. (2022). Security of cloud-based medical internet of things (miots): A survey. *International Journal of Software Science and Computational Intelligence (IJSSCI)*, 14(1), 1–16.

George, G., & Lal, A. M. (2021). A personalized approach to course recommendation in higher education. *International Journal on Semantic Web and Information Systems (IJSWIS)*, 17(2), 100–114. doi:10.4018/IJSWIS.2021040106.

Hossain, M. J., Ahmmed, F., Rahman, S. M. A., et al. (2021). Impact of online education on fear of academic delay and psychological distress among university students following one year of COVID-19 outbreak in Bangladesh. *Heliyon*, 7(6), E07388. doi:10.1016/j.heliyon.2021.e07388.

Ibrahim, F., Susanto, H., Haghi, P. K., et al. (2020). Shifting paradigm of education landscape in time of the COVID-19 pandemic: Revealing of a digital education

management information system. *Applied System Innovation*, 3(4), 49. doi:10.3390/asi3040049.

Irwin, V., Zhang, J., Wang, X., et al. (2021). Report on the condition of education 2021. NCES 2021-144. *National Center for Education Statistics*.

Khamisy-Farah, R., Gilbey, P., Furstenau, L. B., et al. (2021). Big data for biomedical education with a focus on the COVID-19 era: An integrative review of the literature. *International Journal of Environmental Research and Public Health*, 18(17), 8989. doi:10.3390/ijerph18178989.

Kopcha, T. J., Asino, T., Giacumo, L. A., et al. (2021). Preface to the special issue. *The Journal of Applied Instructional Design*, 10(4). doi:10.1080/13803610701626093.

Kravvaris, D., Kermanidis, K. L., & Ntanis, G. (2016). How MOOCs link with social media. *Journal of the Knowledge Economy*, 7(2), 461–487. doi:10.1007/s13132-014-0219-2.

Literat, I. (2021). Teachers act like we're robots": TikTok as a window into youth experiences of online learning during COVID-19. *AERA Open*, 7. doi:10.1177/2332858421995537 2332858421995537.

Li, C., & Zhang, K. (2022). Design and implementation of online education system based on big data technology. *International Conference on Multi-modal Information Analytics*959–965. doi:10.1007/978-3-031-05484-6_128 Springer, Cham.

Lockee, B. B (2021). Online education in the post-COVID era. *Nature Electronics*, 4(1), 5–6. doi:10.1038/s41928-020-00534-0.

Lei, Y., Jia, F., Lin, J., et al. (2016). An intelligent fault diagnosis method using unsupervised feature learning towards mechanical big data. *IEEE Transactions on Industrial Electronics*, 63(5), 3137–3147. doi:10.1109/TIE.2016.2519325.

Makrakis, V., & Kostoulas-Makrakis, N. (2021). Responsibility and Co-responsibility in light of COVID-19 and education for sustainability through an aristotelian lens. *Sustainability and Climate Change*, 14(3), 158–165. doi:10.1089/scc.2020.0075.

Manyika, J., Chui, M., Brown, B., et al. (2011). Big data: The next frontier for innovation, competition, and productivity. *McKinsey Global Institute*.

Masud, M., Gaba, G. S., Alqahtani, S., et al. (2020). A lightweight and robust secure key establishment protocol for internet of medical things in COVID-19 patients care. *IEEE Internet of Things Journal*, 8(21), 15694–15703. doi:10.1109/JIOT.2020.3047662.

Masud, M., Gaba, G. S., Alqahtani, S., et al. (2020). A lightweight and robust secure key establishment protocol for internet of medical things in COVID-19 patients care. *IEEE Internet of Things Journal*, 8(21), 15694–15803. doi:10.1109/JIOT.2020.3047662.

Merlo, A., Hendriksen, P. A., Garssen, J., et al. (2021). Transition to online education during the COVID-19 pandemic: Impact of changes in alcohol consumption and experiencing hangovers on academic functioning. *Journal of Clinical Medicine*, 10(22), 5332. doi:10.3390/jcm10225332.

Mohanty M., Yaqub W. Towards seamless authentication for Zoom-based online teaching and meeting. arXiv preprint arXiv:2005.10553, 2020. 10.1109/BigMM50055.2020.00026

Moralista, R., & Oducado, R. C. (2020). Faculty perception toward online education in a state college in the philippines during the coronavirus disease 19 (COVID-19) pandemic. *Universal Journal of Educational Research*, 8(10), 4736–4742. doi:10.13189/ujer.2020.081044.

Murphy, M. P. A. (2020). COVID-19 and emergency eLearning: Consequences of the securitization of higher education for post-pandemic pedagogy. *Contemporary Security Policy*, 41(3), 492–505. doi:10.1080/13523260.2020.1761749.

Muthuprasad, T., Aiswarya, S., Aditya, K. S., et al. (2021). Students' perception and preference for online education in India during COVID-19 pandemic. *Social Sciences & Humanities Open*, 3,(1) 100101. doi:10.2139/ssrn.3596056.

Nayak, B., Bhattacharyya, S. S., Goswami, S., et al. (2022). Adoption of online education channel during the COVID-19 pandemic and associated economic lockdown: An empirical study from push−pull-mooring framework. *Journal of Computers in Education*, 9(1), 1–23. doi:10.1007/s40692-021-00193-w.

Pappano, L. (2012). The year of the MOOC. *The New York Times, 2*(12), 2012.

Paudel, P. (2021). Online education: Benefits, challenges and strategies during and after COVID-19 in higher education. *International Journal on Studies in Education*, 3(2), 70–85. doi:10.46328/ijonse.32.

Onyebuchi, A., Matthew, U. O., Kazaure, J. S., et al. (2022). Business demand for a cloud enterprise data warehouse in electronic healthcare computing: Issues and developments in E-healthcare cloud computing. *International Journal of Cloud Applications and Computing (IJCAC)*, 12(1), 1–22. doi:10.4018/IJCAC.297098.

Qasem, Y. A. M., Abdullah, R., Jusoh, Y. Y., et al. (2019). Cloud computing adoption in higher education institutions: A systematic review. *IEEE Access : Practical Innovations, Open Solutions*, 7, 63722–63744. doi:10.1109/ACCESS.2019.29162.

Qin, S. J. (2014). Process data analytics in the era of big data. *AIChE Journal*, 60(9), 3092–3100. doi:10.1002/aic.14523.

Qian, Y., Li, C. X., Zou, X. G., et al. (2022). Research on predicting learning achievement in a flipped classroom based on MOOCs by big data analysis. *Computer Applications in Engineering Education*, 30(1), 222–234. doi:10.1002/cae.22452.

Ramos, R. J. M., Ramos, R. G. A., Espaldon, R. N., et al. (2021). Online Education in the midst of CoViD-19 Pandemic: Evidences from the Lenses of IT Students. *Turkish Online Journal of Qualitative Inquiry*, 12(7), 5193−5201.

Rehman, N., Zhang, W., & Iqbal, M. (2021). The use of technology for online classes during the global pandemic: Challenges encountered by the schoolteachers in Pakistan. *Liberal Arts and Social Sciences International Journal (LASSIJ)*, 5(2), 193–208. doi:10.47264/idea.lassij/5.2.13.

Root, W. B., & Rehfeldt, R. A. (2021). Towards a modern-day teaching machine: The synthesis of programmed instruction and online education. *The Psychological, Record*, 71(1), 85–94. doi:10.1007/s40732-020-00415-0.

Sá, M. J., & Serpa, S. (2020). The COVID-19 pandemic as an opportunity to foster the sustainable development of teaching in higher education. *Sustainability*, *12*(20), 8525. doi:10.3390/su12208525.

Sclater, N., Peasgood, A., & Mullan, J. (2016). Learning analytics in higher education. *London: Jisc. Accessed February*, *8*(2017), 176.

Selvaraj, A., Radhin, V., Nithin, K. A., et al. (2021). Effect of pandemic based online education on teaching and learning system. *International Journal of Educational Development*, *85*, 102444. doi:10.1016/j.ijedudev.2021.102444.

Selviyanti, E., Sardjono, W., Mukhlis, M., et al. (2021). Model of developing key performance indicator to increase the quality of education during the Covid-19 pandemic. *Journal of Physics: Conference Series. IOP Publishing*, *1832*,(1) 012030. doi:10.1088/1742-6596/1832/1/012030.

Shenoy, V., Mahendra, S., & Vijay, N. (2020). COVID 19 lockdown technology adaption, teaching, learning, students engagement and faculty experience. *Mukt Shabd Journal*, *9*(4), 698–702.

Su, B., & Hu, Q. (2020). Research on improving the quality of online teaching based on big data under the COVID-19 coronavirus epidemic. *Journal of Physics: Conference Series. IOP Publishing*, *1616*,(1) 012018. doi:10.1088/1742-6596/1616/1/012018.

Dan, Wang (2020). *Limitations and countermeasures of the development of online education in the basic education stage*. Jilin University. doi:10.27162/d.cnki.gjlin.2020.003885.

Wilbur, K. (2016). Evaluating the online platform of a blended-learning pharmacist continuing education degree program. *Medical Education Online*, *21*(1), 31832. doi:10.3402/meo.v21.31832.

Williams-Buffonge, N. A. G (2021). COVID 19 and education:The untold story of the barriers to technology adoption from a tertiary viewpoint. *Technology*, *12*(10). doi:10.7176/JEP/12-10-02 (Elmsford, N.Y.).

Wiranota, H., & Wijaya, T. T. (2021). The international students' perception towards online learning using the tencent meeting during Covid-19 outbreak. *Journal of*

Physics: Conference Series. IOP Publishing, *1823*,(1) 012011. doi:10.1088/1742-6596/1823/1/012011.

Xia, K., & Li, Y. (2020). Exploration on big data education for computer majors in applied colleges and universities. In *Proceedings of the 5th international conference on mechanical, control and computer engineering (ICMCCE)* (pp. 1846–1849). IEEE. doi:10.1109/ICMCCE51767.2020.00405.

Xie, X., Siau, K., & Nah, F. F. H. (2020). COVID-19 pandemic−online education in the new normal and the next normal. *Journal of Information Technology Case and Application Research*, *22*(3), 175–187. doi:10.1080/15228053.2020.1824884.

Xie X., Siau K. Online education during and after COVID-19 pandemic. 2020

Xue, E., Li, J., & Xu, L. (2022). Online education action for defeating COVID-19 in China: An analysis of the system, mechanism and mode. *Educational Philosophy and Theory*, *54*(6), 799–811. doi:10.1080/00131857.2020.1821188.

Yu, Hong Qing (2022). Stephan Reiff-Marganiec. Learning disease causality knowledge from the web of health data. *International Journal on Semantic Web and Information Systems (IJSWIS)*, *18*(1), 1–19. doi:10.4018/IJSWIS.297145.

Yu, L. I (2020). Analysis and enlightenment of user agreements based on the three smart teaching tools of rain classroom, Dingtalk live broadcast and Tencent classroom in the post-epidemic Era. *Management Science and Engineering*, *14*(1), 44–48. doi:10.3968/11904.

Zhao J., Xiao H., Li Y., et al. Experience of massive distance online education for medical colleges and universities in China to counter the COVID-19 pandemic. 2020. 10.21203/rs.3.rs-29678/v1

Zhao, J. J., & Li, Q. (2022). Big Data−Artificial Intelligence Fusion Technology in Education in the Context of the New Crown Epidemic. *Big Data*. doi:10.1089/big.2021.0245.

Zhou, L., Wu, S., Zhou, M., et al. (2020). School's out, but class' on', the largest online education in the world today: Taking China's practical exploration during The COVID-19 epidemic prevention and control as an example. *Best Evidence of Chinese Education*, *4*(2), 501–519. doi:10.2139/ssrn.3555520.