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Application of 5G Technology in Education Informatization

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Abstract: The popularity of educational informatization and the emergence of smart learning spaces have significantly increased students' demand for personalized, convenient, and diversified learning content. The fifth generation mobile communication (5G) technology, with its characteristics of large bandwidth, ultra-high reliability, ultra-low time delay, large-scale connection of things, is becoming an enabling technology for perfecting the education network and even realizing education modernization. This paper focuses on the application of 5G technology in education informatization. After the analysis of major characteristics of education informatization, this paper analyzes the technical challenges faced by the education network of China, and demonstrates corresponding 5G application scenarios from the aspects of teaching, teaching research, and education management, thereby forming an overall view of education informatization based on 5G technology. By 2035, the 5G technology will be further promoted, which will constantly enrich the connotation and promote the reform of education scenes; and thus it will become the driving force for the innovation in China's education informatization.
Key words: education; information technology; education informatization; 5G technology; application scenarios

1 Introduction

Education informatization is the core power of educational modernization. Developed countries take the lead in applying information and communication technology to the field of education, opening the tide of education informatization [1]. In 2000 and 2004, the United States issued the National Educational Technology Plan, which promoted the popularization and application of educational technology [2]. Teachers should effectively use information technology (IT) to promote students' learning, and students should gain IT literacy and skills through their teacher's training to promote teaching innovation and application and improve IT educational application efficiency. China has made up for its shortcomings in education informatization. In April 2018, the Ministry of Education issued the *Education Informatization 2.0 Action Plan*, and in February 2019 the State Council issued *China's Education Modernization 2035*, emphasizing the position and role of education informatization in the process of promoting education modernization [3,4]. In the future, education informatization should be based on the construction of an informational environment and the support of software and hardware. It should be closely combined with educational theory and should explore the potential and level of new technological applications, alongside seeking a path that implements the combination of multiple application scenarios, multiple practical fields, and wide technological fields. In this process, intelligent technology—especially 5G, big data, artificial intelligence (AI), cloud computing, and so on—will help innovate and promote the intellectualization of educational services, the contextualization and popularization of educational applications, and provide key support for the revolutionary transformation of education [5,6].

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From the perspective of China's educational field rather than the IT industry, intelligent technology as represented by 5G has great potential to enable technology, and is expected to become the cornerstone in constructing national educational information in the future. With the acceleration of the process of China's education informatization 2.0 and the continuous, increased attention on 5G, the connection and integration of the two will promote the major reform of education and education informatization, and will have a significant impact on traditional education and learning methods. With the support of 5G technology and network environments, sharing and interaction between various sources of educational information, audio-visuals, and other resources will become more convenient, and it may be used to realize a new combination of many elements in education and teaching, establish new teaching methods and forms of presentational content, and even promote the formation of a new educational ecosystem.

At present, 5G research focuses on the key technologies in the fields of communication, the evolution of network architecture, network deployment schemes, and so on [7]. There are relatively few studies concerning the impact of 5G technology on education, while prospective application research of 5G and education informatization remains to be conducted. In the new field of 5G + education, how will the deep integration and application of IT in teaching and management be realized to provide intelligent teaching services and refined management means to meet the needs of educational modernization, and realize the vision of *China's Education Modernization 2035*? It will require the participation of educational practitioners, managers, and decision-makers. This paper analyzes the opportunities brought about by 5G technology for education informatization and discusses how to realize the innovation of educational application scenarios using a 5G network environment to provide basic references for the integrated development of education and information.

2 Basic understanding of education informatization in China

2.1 Main characteristics of education informatization construction

Education informatization focuses on practice. In this process, the progress of IT has brought about significant impacts [8–10] such as the rapid popularization of 4G/5G mobile communication, fixed broadband, and other network technologies, supporting the expansion of information application. With the support of all kinds of high-speed communication networks, cloud computing is reconstructing the competition pattern of the information industry; big data, AI, semantic networks, and other intelligent technologies are reconstructing the organization mode of educational services; and all kinds of educational public service systems are developing toward the direction of general participation and form group intelligence, with the integration of cloud/network/end as the general trend. In addition, intelligent services are accelerating popularization. Informational devices are embedded in the user's environment and daily tools in an invisible way, forming a natural, immersive, intelligent, and educational experience that is supported by a ubiquitous perceptual network.

Based on the above, it can be predicted that the main characteristics of the construction of education informatization at present and in the future will be as follows [11–13]:

(1) The educational environment will be more intelligent and adapt to the needs of individuals. Through ubiquitous communication networks, sensor equipment, and intelligent perceptions of learners' environments and characteristics, a learning environment will be actively created in which they may plan learning paths, push appropriate learning resources, and switch the concept of "people find information" to "information finds people."

(2) All kinds of data and educational information will be realized through a seamless circulation. Data analysis is the basis of realizing intelligent educational services, and the construction of education informatization will establish norms and standards for the collection and analysis of all kinds of data. Through perceptions of the physical environment, we can realize the aggregation and cross-domain transmission of data, strengthen the adjustment function of educational services, and break the limitations of time, space, content, and media.

(3) Educational businesses will realize intelligent collaborations. Based on intelligent technology and a ubiquitous high-speed communication environment, all kinds of educational services will be realized by using full-time, full-domain, multi-mode connectivity, and collaborations will highlight its convenience, rapidity, efficiency, and intelligence. Management, teachers, training, services, and other links in the field of education will be able to intelligently collaborate to promote business reorganization processes and innovate service forms.

(4) High-quality educational resources will be better provided on demand. Under traditional modes, all learners are provided with the same learning resources, while in the intelligent era, network transmission technology will promote the efficient transmission of learning data through its entire process. Intelligent learning service systems will provide high-quality and appropriate educational resources and services through its accurate analysis of the

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specific needs of learning individuals.

(5) It will be possible to provide equal learning opportunities and promote educational equity. Education informatization enables high-quality educational resources and services to communicate through the network, embeds learning into daily life outside of formal education, and creates a situation of "when technology is everywhere, learning is everywhere" in which all people have equal learning opportunities to solve the problem of educational equity from the perspective of IT.

2.2 Challenges of the education network

At present, schools have deployed multiple networks simultaneously, such as cable networks, wireless networks (Wi-Fi), campus networks, Internet of Things (IoT), television networks, and so on, to carry campus businesses that are related to scientific research information sharing, multimedia teaching, electronic reading, and data storage, as well as for other businesses such as administrative management, teachers' offices, school forums, and social networking [14]. With the deepening of digital transformations, intelligent network terminals and increasingly innovative applications are promoting the transformation and upgrade of education informatization. Students and teachers expect to receive better network services and richer multimedia experiences, including online learning, immersive virtual teaching environments, online lesson preparation, intelligent management, and so on; they also hope to achieve efficient and convenient network experiences anytime and anywhere on campus [15].

Compared with current supply and demand, the education network is facing many challenges, as follows: (1) It is difficult to share educational information system resources, and information systems such as teaching, scientific research, management, technical services, and life services are usually constructed separately, resulting in isolated islands of information and a low integration of business processes. (2) The capacity of new educational businesses are insufficient, and new services such as ultra-high definition (UHD) (such as 4K/8K resolution) live classrooms, virtual/augmented reality (VR/AR) classrooms, holographic education, 4K supervision, and school mobile patrol cars put forward higher requirements for the network's bandwidth. (3) The data security risks are large, and the shared resources across campuses and the information of students' parents are at risk of being leaked. The aggregation of educational big data may aggravate data security risks. (4) The construction and maintenance costs are high, and the construction of educational information systems and the direct construction, operation, and maintenance brought about by the integration of multi-networks are high, with expensive subsequent upgrades.

The application of education informatization needs higher requirements for the infrastructural functions of information and communication technology. The existing network's access means, such as its fixed broadband, Wi-Fi, and 3G/4G mobile network provides it difficult to meet innovative application scenarios for education and teaching such as high definition (HD) live broadcasts, VR/AR teaching, holographic classrooms, HD supervision, and so on due to its backward performance in networking convenience, network delay, security management, terminal cost, and so on. For example, the existing 4G educational cloud application can basically meet the requirements of a single channel's full HD (1080p) educational video content's collection and transmission, but cannot meet the requirements of a multi-channel's full HD video's simultaneous return, as well as the return and two-way interaction of higher quality teaching resources such as a UHD video or even a VR panoramic video. There is a huge interactive space in the application demand of educational innovations and new IT capabilities, which are precisely adapted and deeply integrated, and are expected to solve the challenges faced by the existing educational network.

2.3 5G Technology enables education informatization

The future of education informatization will be closely related to the maturity and practical application of the cutting-edge technologies represented by AI, VR, and big data. By both using and giving full play to the advantages of 5G technology, overcoming the speed, delay, transmission capacity, and other constraints of a traditional network in the process of educational innovation will provide basic and key support for its reform in the field of education to enable future education informatization. The characteristics of a 5G network environment such as its large bandwidth, ultra-high reliability, ultra-low delay, large-scale IoT, and so on, combined with network slicing technology, multi-access edge computing (MEC), AI, and other cutting-edge technologies make the innovative application of smart campuses and smart classrooms possible [16].

The data network of traditional smart classrooms relies on the wired network and Wi-Fi coverage in a campus networks, while the IoT layer is realized through Bluetooth and ZigBee protocols. In contrast, the 5G smart classroom makes full use of the inherent technology and business advantages of the 5G network through hardware

terminals to solve the actual educational needs of campus users and bring better education experiences by: (1) Unifying network bearing, so schools no longer need to deploy multiple networks; (2) using an ultra-high network bandwidth, meaning that the interactive display of terminal equipment, transmission signals, and the processing of terminal equipment can carry a 4K/8K level picture effect; (3) faster speed and lower delay, to support the normal recording and broadcasting of intelligent classrooms, and remote conference rooms for remote teaching can sense and experience the classroom environment of "top teachers and excellent courses" without delay; and (4) supporting new application scenarios of education and teaching such as game based courses, VR experimental environments, VR controlled environments, HD stereoscopic displays, remote examination monitoring, learning behavior tracking and mining, intelligent experiment systems, intelligent teaching systems, and so on.

3 Architecture of 5G educational application

3.1 Demand scenario

The International Telecommunication Union (ITU) has defined three main application scenarios of 5G technology [17,18]: (1) in Enhanced Mobile Broadband (eMBB), which meets the business needs scenario of high peak rates, high-speed mobile medium access, and dense area access to the communication network; (2) in Massive Machine Type Communications (mMTC), which meets the business needs scenario of a low-cost, low-power, small traffic communication network; and (3) in Ultra Reliable and Low Latency Communication (uRLLC), which meets the requirements of ultra-low delay and ultra-high reliable communication networks. Through research and combing as based on 5G's technological capability and the needs of education informatization, the application scenario requirements of the main types of educational institutions for 5G technology are defined (Table 1).

Table 1. Classification of demand scenarios from educational institutions.

	eMBB	mMTC	uRLLC
Primary and secondary schools Training institutions	Remote interactive teaching Teaching effect AI-embedded evaluation	Teaching effect AI-embedded evaluation	Remote interactive teaching Remote listening and evaluation
Vocational colleges Military colleges	VR/AR teaching	Intelligent campus management	VR/AR teaching
Colleges and universities	Teaching effect AI-embedded evaluation	Intelligent campus management Teaching effect AI -embedded evaluation	—

In terms of primary and secondary schools and off-campus training institutions, recent needs focus on the application of remote interactive teaching, remote listening and evaluation, and teaching effect AI-embedded evaluations. In terms of secondary vocational colleges and military academies, recent demands focus on VR/AR teaching and smart campus management applications. For general colleges and universities, recent needs focus on the application of AI assessments in teaching, and intelligent campus management.

3.2 General view

Starting from the three fields of education informatization (teaching, research including educational evaluation, and education management), this paper explores and puts forward a general view of 5G in educational applications (Fig. 1). In the field of teaching, the main requirements of 5G technology include support for remote interactive teaching and VR/AR teaching. In the field of teaching and research, 5G priority application scenarios include remote listening and assessment and teaching effect AI-embedded assessment. In the field of education management, 5G technology application mainly involves intelligent campus management as characterized by the IoT.

4 5G educational application scenario innovations

With the influence of personal computers and the Internet, traditional education patterns have changed significantly. Diversified online learning resources and various types of online schools are now emerging. As the infrastructure of IT, 5G has a huge potential to promote the further innovation of educational applications. 5G technology enables learners to have similar experiences from being present in real classrooms at any time or place

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with the help of IoT and VR technology. High-quality learning fields are everywhere, authoritative education experts are always accessible, and high-quality learning interactions are vivid. In order to effectively track the trends of 5G technologies as coupled with educational applications, we conducted research on 5G technology when applied to the field of education, and especially focused on the innovation of application scenarios and the potential reconstruction of educational main processes.

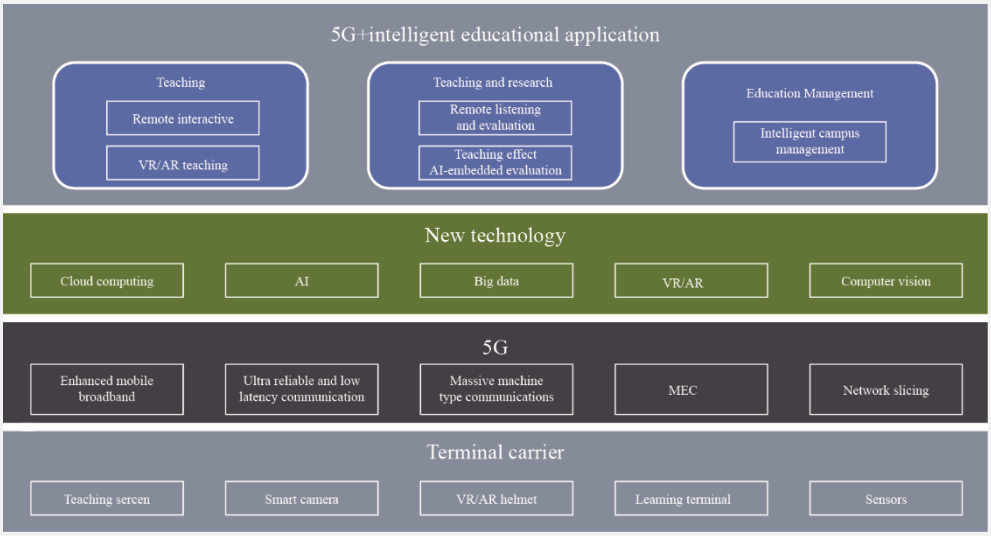

Fig. 1. General view of 5G educational applications.

4.1 Remote interactive teaching

One of the major problems that China's educational reform tries to solve is the imbalanced distribution of educational resources and educational qualities in different areas. As an important part of the construction of national informatization, education informatization has been regarded as an effective measure to alleviate this problem. By using long-distance and real-time interactive teaching systems, areas with low educational qualities can obtain abundant educational content from top teachers which reshapes the offline effect. The most typical application scenario of remote interactive teaching is the dual-teacher classroom, despite it not being a new teaching mode or a new technology. However, the dual-teacher classrooms are low in popularity due to the limitations of the fixed-line network. In order to ensure the effectiveness of a multi-location remote education, most schools or institutions use private line connections which leads to the dual-teacher classrooms being less implemented in undeveloped areas due to a lack of network connections, making it difficult to receive high-quality teaching resources. Even within developed areas, the effectiveness of the interaction of dual-teacher classrooms is also impacted by insufficient bandwidths, high latency, poor stability, low flexibility, and so on. In practice, the mode of dual-teacher classrooms is often degraded to non-interactive teaching by simply back-playing videos.

A 5G network has the characteristics of a large bandwidth and a low latency, which can support the dual-teacher classrooms with its high mobility and on-demand use. It can effectively enhance the interaction experience of traditional dual-teacher classrooms and provide innovative tech support for their further development. An overview of remote interactive teaching as based on a 5G network is shown in Fig. 2. In the multi-location remote teaching overview, 5G communication modules are deployed in the terminal side which makes both the teacher's side and the student's side more flexible when compared with traditional private line modes. Compared with traditional fixed-line networks/Wi-Fi connection modes, a 5G-based remote interactive teaching solution has the following advantages: (1) The use of 5G + cloud deployment can meet the demand of low latency, large bandwidths, and high reliability as required by the real-time interactions of a dual-teacher classroom, solving the problem of audio-visual delays and improving students' participation and learning in the class; (2) a 5G network has the advantage of good flexibility and convenience when compared with a fixed-line connection, and can adapt to the changes in teaching locations and teaching methods; and (3) as estimated, after a large-scale deployment and application of 5G networks, wireless networks (which replace fixed-line connections) can reduce the cost of the construction of education informatization by more than 50%.

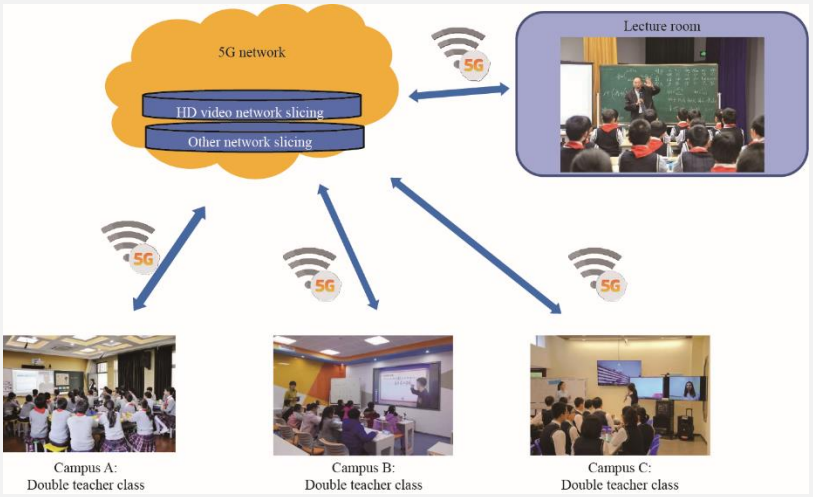

Fig. 2. An overview of remote interactive teaching based on a 5G network.

4.2 VR/AR teaching

The large bandwidth and low latency of 5G technology enables teaching through VR/AR. VR/AR teaching content can be put on the cloud, and the rendering, displaying, and control of the AR application can be run on the cloud by using the cloud's computing power. Then, the VR/AR audio-visual stream, when encoded efficiently, can be transmitted through a 5G network in real time [18]. To meet the needs of the low latency of VR/AR teaching, the deployment of rendering functions on MEC architectures near the customer's side can be used to effectively solve the problems within the former architecture; especially those caused by the limitations of the network's transmission rate and the delay in the cloud's services.

An overview of VR/AR teaching as based on 5G technology is shown in Fig. 3. With the implementation of a VR/AR cloud platform and a VR/AR cloud application, virtual experiment classes, virtual science classes, virtual innovative classes, and other VR/AR classes can be realized. By transforming real things into that which is observable and interactive, digital, and virtual, learners can systematically understand this knowledge in a virtual space.

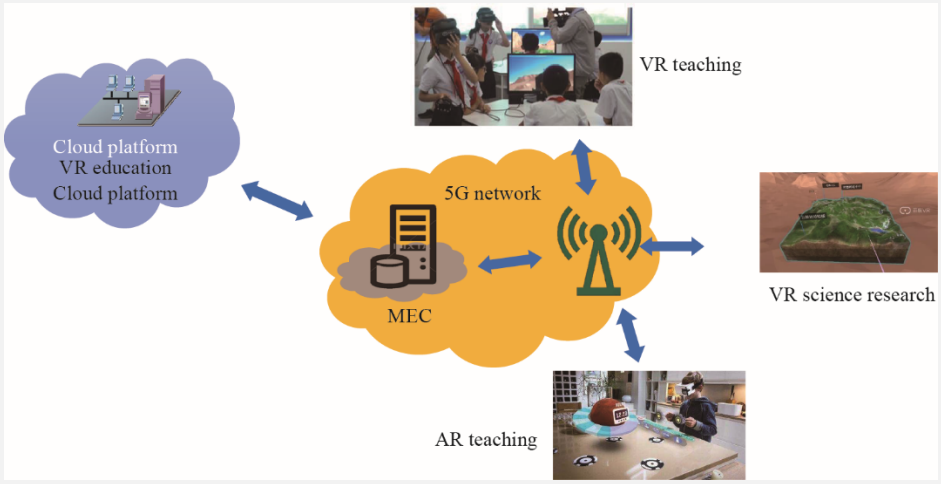

Fig. 3. An overview of VR/AR teaching based on the 5G network.

Compared with traditional methods of education, VR/AR teaching has the following characteristics: (1) The three-dimensional teaching content and method can upgrade a student's classroom experience from its previous two-dimensions. The VR/AR content can visualize intangible things which helps learners improve their cognition and understanding. (2) Enhanced interaction and participation of VR/AR teaching can inspire students through deep learning experiences, and may lead them to proactively participate in the teaching process. (3) Active-interactive learning allows students in the class to pause at any time or repeat any of the steps without excessive interruptions or overstress on teachers. (4) By leveraging VR/AR methods, teaching content can be designed into very attractive

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games which makes learning interesting and entertaining for students. (5) By using VR/AR technologies, virtual experiments can be done in virtual environments, which can reduce the risks from experiments in chemistry, physics, electronics, and other disciplines. (6) VR/AR can enable teachers and students from different regions to gather in the same virtual classroom, balancing the equality of educational resources.

4.3 Remote listening and evaluation

For listening and evaluation in traditional classes, the presence of experts in the class may affect the normal status of teaching and listening and therefore the evaluation could be invalid. Remote listening and evaluation in classes can avoid the shortcomings of this situation by having teaching in the classroom and the evaluations held remotely, which would be better than the traditional mode and more human-centric and effective.

An overview of remote listening and evaluation as based on a 5G network is shown in Fig. 4. At its core is a 5G normal recording and broadcasting terminal, a powerful computing ability, and the ability of AI analysis using 5G. The recording and broadcasting terminals relying on a 5G network can create a near-real-time class environment with two-way interaction and intelligent listening and evaluation. Compared with the traditional method of a fixed-line connection or a Wi-Fi network, a 5G network has the advantage of having an ultra-high bandwidth and an ultra-low network latency, which can fully guarantee that the evaluators can fluently receive HD audio-visual teaching to ensure the objectivity and accuracy of the evaluation. The integration of the capability of AI enables real-time analysis and evaluation of teaching and learning behaviors, thus generating big data of all aspects that concerns teaching and learning. By combining classroom data with expert remote listening and evaluation, the feedback of evaluations can be directly generated by an AI algorithm to highlight the content that needs to be improved in the teaching process.

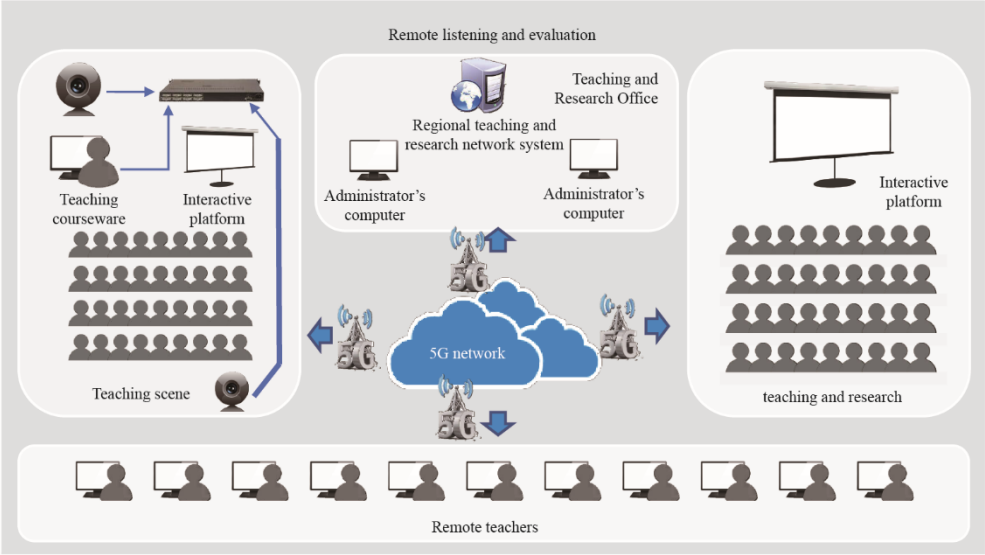

Fig. 4. An overview of remote listening and evaluation based on a 5G network.

4.4 Teaching effect AI-embedded evaluation

The use of AI technology is a leading trend in the education industry, which involves the multi-dimensional and multi-level intelligent collection, processing, and analysis of massive teaching data. Yet, there are still challenges in its practical applications. A 5G network with its high bandwidth, high speed, low latency, edge computing, and other characteristics makes it possible to collect and transmit more data in unit time, which enables the flexible use of AI. Typical application scenarios of teaching effect AI-embedded evaluation are shown in Fig. 5. The number of AI cameras are fixed in the classroom to record videos and capture images. The detection of facial orientation checks whether the students are facing the front. An analysis of the leaning angles of the faces calculates the proportion of front-facing time from the detection and analysis of students' facial features and micro expressions, and monitors students' non-learning behaviors. The use of a focus analysis model automatically analyzes the learning/focusing level of both the individual and the whole class. Accordingly, 5G technology is utilized to transmit the results of the statistical analysis of various behaviors back to the teachers and the school management system in real time to realize the real-time interaction of the teachers and teaching management. However, we should also pay close attention to

the potential risks and threats of AI technology in educational applications, such as the possible leak of students' private information, the ethical risks of abusing technology, and so on.

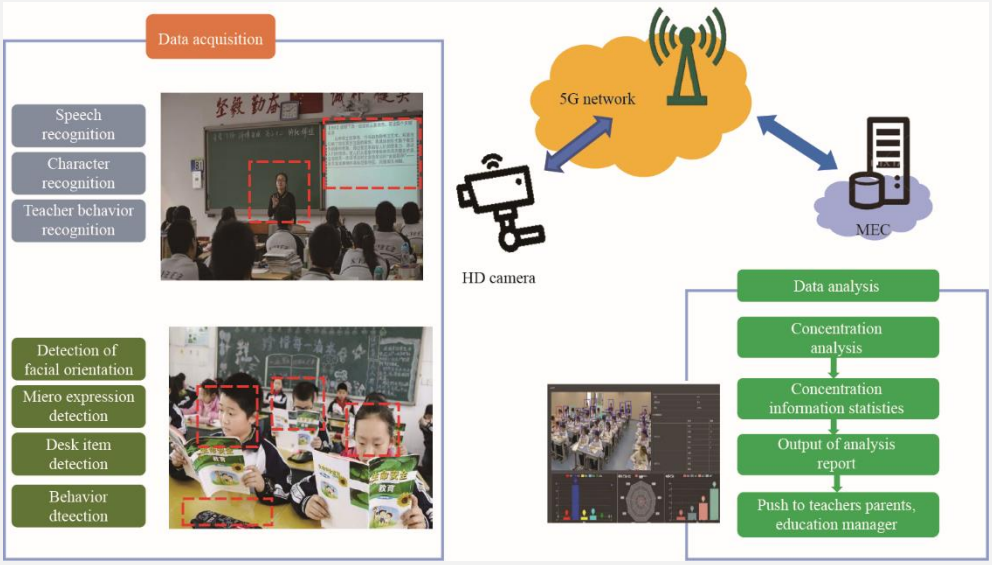

Fig. 5. An overview of teaching effect AI-embedded evaluation based on a 5G network.

The potential benefits of AI's technological application in education and teaching process could be: (1) In the enhanced value of the deep mining of data, which is digitized from the teaching and learning processes and can be applied in supervised and personalized teaching; (2) by automatically analyzing students' uploads of homework, photos, and texts, and automatically correlating important and difficult content, and providing more possibilities for independent learning; (3) in the process of individual learning by making knowledge maps and learning plans according to the correlation of knowledge points; and (4) by accurately judging the level of students, providing suitable learning plans, and providing personalized guidance schemes.

4.5 Smart campus management

Smart campus management mainly refers to the intelligent management of all types of campus equipment. By using intelligent perception technology and IoT technology, devices such as cameras and sensors are used to collect information on campus environments and on people. Then, the collected massive data are intelligently analyzed. The analysis results are applied to school teaching, scientific research, management services, and other works to realize the management of energy consumption, status monitoring, asset management, equipment control, environmental monitoring, security monitoring, vehicle management, and so on to further realize the intelligent operation of a campus. An overview of smart campus management is shown in Fig. 6.

The application benefits of smart campus management by using 5G are: (1) By realizing the interconnection of audio-visual educational equipment, and the interconnection of different resources, services, and platforms to accomplish local direct management or remote indirect management; (2) by realizing the intelligent management of the IoT's equipment to shape the information environment of mutual perceptions between people and the environment, and to comprehensively improve the information level of the school, intelligently save energy, and reduce emissions; and (3) by realizing data collection and optimize management through raising the level of intelligent monitoring, control, and management by long-term collection, data mining, and in-depth analysis of all equipment to improve the overall management efficiency of a campus.

5 Prospects of education informatization in 2035

The top-level design of 5G educational applications, based on the principal of the facts and objective laws of the education industry, takes innovative application scenarios as the starting point to promote the construction and expectations in this area. The next stage of education informatization focuses on the innovation of IT applications in education, as follows: (1) At present, the scope of educational applications mainly includes an educational management platform, teaching resource platform, home-school interaction platform, campus monitoring platform, and so on, and the main role of IT is to change the educational and teaching environment. (2) In the mid-term view

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(until 2025), the role of IT should both penetrate and be integrated into the teaching process. Through leveraging 5G, cloud computing, big data, AI, VR, and other technologies, IT can improve teaching effectiveness more precisely and significantly, and promote the development of education modernization. (3) In the long term view (until 2035), 5G technology will take full advantage of its essential characteristics to solidify the infrastructure of smart campus networks, support the construction of integrated intelligent application systems with many advanced IT technologies, and promote more subversive educational applications.

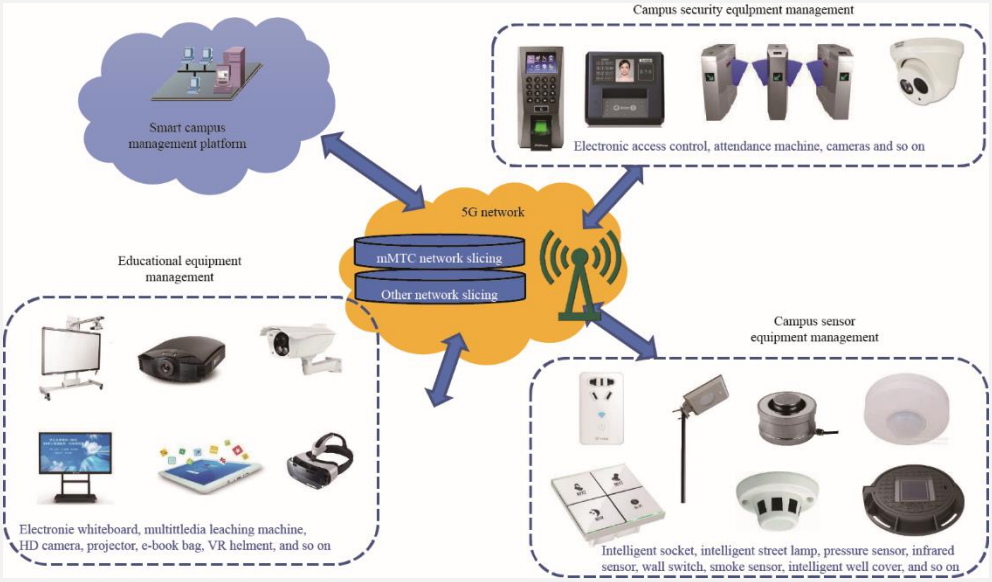

Fig. 6. An overview of intelligent campus management based on a 5G network.

Upon approaching 2035, with the prevalent application of 5G, the construction of education informatization will enter a new stage, as follows: (1) It will support the campus environment to realize the harmonious coexistence of humanistic care and advanced technology. (2) It will support campus governance with IT services to fulfill its governance standardization and structural optimization by using 5G + big data + AI. (3) In the aspects of educational applications, traditional remote broadcast teaching can be upgraded to remote HD interactive teaching, or even holographic interactive teaching. Traditional multimedia audio-visual teaching can be upgraded to VR/AR teaching, and traditional teaching statistical analysis systems can be upgraded to a comprehensive educational and teaching evaluation system based on AI capabilities. Traditionally separated attendance checks/monitoring/security systems on campuses can be upgraded and integrated into smart campus management systems based on IoT and AI technology.

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