Challenges and Approaches of VR Teaching Applications in the Digitalization Wave

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Abstract. This paper, under the background of the "14th Five-Year Plan" for National Economic and Social Development and the Vision 2035, explores the prospects of Virtual Reality (VR) technology in the field of primary and secondary education. VR technology has brought about significant transformations in education by offering vivid and intuitive learning experiences, thereby stimulating students' interest and motivation in learning. However, its application still faces challenges such as cost, technological maturity, and teacher training. This paper proposes comprehensive solutions including policy guidance, technological research and development, and teacher training. Through this research, new insights are provided for the development of VR technology in the field of education, promoting educational technological innovation, improving teaching quality, and contributing to the cultivation of high-quality talents.

Keywords: Digital Transformation, Virtual Reality, Primary and Secondary School Teaching

1 Introduction

China's "14th Five-Year Plan (2021-2025)" highlights the urgency to build a networked, digitalized, personalized, and lifelong education system. With the ongoing digital transformation, the education sector emphasizes innovation in technology and teaching methods. The recently unveiled "Action Plan for Integrated Development of Virtual Reality and Industry Applications (2022-2026)" specifically emphasizes integrating VR into education. It aims to establish VR classrooms, labs, and simulation bases in schools and vocational institutions. To meet the demand for experimental and associative teaching content, plans include the development of a batch of virtual reality digital courses based on the teaching syllabus to enhance students' interactive practical operations with various virtual objects, complex phenomena, and abstract concepts. These measures aim to promote the upgrading of teaching models towards a more autonomous experiential direction, advocating immersive new classrooms that support autonomous exploration and collaborative learning.

Initially, this paper reviews relevant domestic and international literature to analyze the current application status and development trends of VR in teaching. The research findings indicate that although the application of VR technology in teaching is still in

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its infancy, its potential is enormous and it could potentially revolutionize traditional teaching models. However, due to various constraints such as technological maturity, equipment costs, and teacher skills, the application of VR in teaching has not been widely promoted and adopted.

The focus of this paper is to explore the current application status of VR in teaching, the challenges it faces, and possible solutions. Through in-depth research into these issues, this paper aims to provide new insights and directions for the development of educational technology.

2 Origin and Concept

2.1 History: Technological Evolution

Virtual Reality (VR) is a technology that creates simulated environments, allowing users to immerse themselves in and interact with them through computer technology and sensor devices, simulating real or fictional worlds [1]. The evolution of VR technology has gone through several important historical milestones. The concept of virtual reality was first proposed by Morton Heilig in 1965 and underwent continuous innovation and development over the following decades. In 1968, Ivan Sutherland and Morton Heilig created the first head-mounted display, marking the embryonic stage of virtual reality technology. In 1987, Jaron Lanier published "Virtual Reality: Why Computer Simulation Is the Most Important," providing a thorough explanation of the importance of virtual reality [2].

In recent years, the fusion of virtual reality (VR) technology and deep learning has sparked innovation. Extended Reality (XR) technology, drawing on theories of embodied cognition and experiential learning, transforms abstract knowledge into tangible experiences through multisensory interaction. This enhances learning effectiveness and satisfaction by enabling students to engage in practice, observation, reflection, and real-world application. In education, VR technology is rapidly advancing, providing practical learning experiences through virtual labs, immersive environments, and interactive courses. By integrating VR seamlessly into teaching, companies are offering students vivid and personalized learning experiences, bridging the gap between reality and virtual environments.

2.2 Key Components of VR Technology

Virtual Reality (VR) technology comprises several key components essential for its operation. The cornerstone of VR experiences lies in Head-Mounted Displays (HMDs), which integrate displays and lenses to immerse users in virtual environments. These HMDs are often complemented by sophisticated tracking systems that capture users' head and body movements in real-time, enabling seamless interaction within the virtual space. Various tracking technologies, such as inertial navigation, optical tracking, and magnetic tracking, are employed to achieve precise motion tracking. Additionally, interaction devices like hand controllers and gesture recognition systems facilitate user

input and manipulation within VR environments. Behind the scenes, advanced rendering techniques, including real-time rendering and ray tracing, are utilized to generate immersive virtual worlds with high fidelity graphics. Furthermore, sensor technologies such as accelerometers, gyroscopes, and magnetometers play a crucial role in sensing users' physical movements and orientations, enhancing the realism of VR experiences. Lastly, robust networking technologies are leveraged to support multi-user collaboration in shared virtual environments, ensuring seamless communication and synchronization among participants. These technical intricacies collectively contribute to the immersive and interactive nature of VR technology, revolutionizing its applications across various domains, including education.

2.3 Current Development Status in China

In the digital era, educational technology has significantly impacted teaching practices and student learning. China, with its vast population, encounters both challenges and opportunities in its education system. The rapid development of Virtual Reality (VR) technology in China, particularly in education, has drawn considerable attention. This paper aims to explore the current status and potential of VR technology in Chinese education, along with its effects on student learning experiences, teaching effectiveness, and models. Through analyzing practical applications comprehensively, we will discuss challenges and future directions.

Construction of Virtual Laboratories and Simulation Environments

VR technology is used to create virtual laboratories and simulation environments for various disciplines such as physics, biology, and chemistry. These simulated environments allow students to conduct experiments and operations in a virtual world without the need for actual equipment or chemicals, reducing costs and increasing safety.

Since 2013, the Ministry of Education has actively promoted the construction of virtualized experimental teaching centers, with hundreds of such centers established in various universities. Utilizing virtual laboratories, teachers can simulate complex equipment and experiments, saving costs and allowing students to practice repeatedly. For experiments with high risks, VR laboratories can be used safely, allowing students to immerse themselves in realistic operations [3].

Interactive Learning

VR technology provides interactive learning experiences, allowing students to participate more deeply in learning. Students can interact with objects, solve problems, or engage in dialogue with virtual characters in a virtual environment.

Learners can actively engage in experiences in virtual scenarios and interact with objects in the virtual environment through specific operations [4]. This interactive learning deepens learners' thinking, exploration, and practice, promoting learning effectiveness.

Personalized Learning

VR technology provides personalized learning experiences based on students' learning progress and interests. Systems can adjust learning content and difficulty levels based on student performance, promoting learning effectiveness and motivation [5].

2.4 Development Status in Other Countries

The rapid development of Virtual Reality (VR) technology has brought about new possibilities in education. In Western countries, particularly in the United Kingdom and the United States, VR has been extensively explored and adopted as a significant pedagogical tool in recent years, sparking widespread attention and yielding significant achievements.

Science Education

VR technology can be utilized to present abstract scientific concepts such as astronomy, biology, and physics. Students can conduct experiments in virtual laboratories and observe phenomena like atomic structures and planetary motion in virtual environments, thereby enhancing their understanding of scientific knowledge.

Research expert Bogusevschi, leading a team during the European Horizon 2020 NEWTON project, designed and developed a computer-based 3D immersive physics education application. Through virtual reality and simulated experiments in virtual laboratories, the application teaches concepts related to the natural water cycle and precipitation formation. This application has been adopted by a secondary school in Dublin, Ireland [6].

History and Geography Education

Through virtual reality technology, students can immerse themselves in historical events or geographic environments, such as the ancient Roman Colosseum, World War II battlefields, or "tour" geographical landmarks like the Egyptian pyramids and the Great Wall. For instance, Google Earth VR on the gaming platform Steam provides robust support for middle school geography teaching, allowing students to explore geographical landscapes and cultural features worldwide as if they were physically present. Similarly, Universe Sandbox is a popular gravity simulation software that helps students better understand celestial motion and the laws of gravity in the universe by simulating the gravitational interactions between stars, thereby enhancing their learning effectiveness and scientific literacy.

Special Education

Virtual reality can support special education, such as social skills training for students with autism spectrum disorder (ASD) and attention training for students with attention deficits. Addressing the challenges of autism spectrum disorder (ASD), a new type of virtual reality-based facial expression system has been developed to monitor eye gaze and physiological signals, exploring effective treatment methods. Research

has shown that adolescents with ASD process and identify emotional faces differently from typically developing peers, providing guidance for the future development of online adaptive virtual reality social interaction systems [7].

2.5 Existing Limitations

Cognitive Load From Immersive Environments

The immersive experience brought by virtual reality (VR) devices may have an impact on users' cognitive load. When using VR devices, users are typically immersed in a virtual environment different from the real world, which can impose significant burdens on their senses, attention, and thinking.

Firstly, immersive experiences may cause sensory overload for users. Since VR technology can provide highly realistic visual and auditory experiences, users may receive a large amount of visual and auditory information in a short period, which may burden the brain. Secondly, immersive experiences may also affect users' attention. In a virtual environment, users may be attracted by various visual and auditory stimuli, leading to distraction and difficulty concentrating on specific tasks or activities. Finally, for some users, adapting to a new virtual environment may require additional cognitive effort. They need to learn how to navigate in the virtual environment, interact with virtual objects, etc., which may increase cognitive load [8].

The High-profile Introduction of Multimedia Teaching Concepts

Despite the many advantages of virtual reality technology, some studies suggest that over-reliance on new technology and devices for teaching may have negative effects. This phenomenon is known as the multimedia effect [9]. The multimedia effect refers to the excessive use of multimedia technology, leading learners to overly rely on the media itself and neglecting deep understanding and reflection on the knowledge.

When learning through VR devices, users can more intuitively experience the learning content, as they can immerse themselves in the situations and scenarios of the virtual environment. This immersive experience can stimulate learners' interest, enhance their engagement and motivation for learning, thereby promoting understanding and memory of the learning content.

Therefore, although virtual reality technology brings new possibilities for teaching, educators need to carefully consider how to use this technology reasonably to maximize learning effectiveness, rather than blindly pursuing the technology itself. From the learner's perspective, when using VR devices for learning, it is still necessary to engage in thinking and processing during the learning process to ensure that the knowledge learned is transformed into long-term memory. Therefore, when designing VR learning environments, it is necessary to consider multiple factors comprehensively to improve the sustainability and practical applicability of learning effectiveness.

3 The Value Implications of Teaching Based on VR Technology

3.1 Wide Range of Available Knowledge

With the continuous development of virtual reality (VR) technology, it has emerged as a highly promising learning tool in secondary education. In geography, students can utilize VR to explore global terrains, observe climates and ecosystems, and simulate natural disasters. In physics, VR allows students to intuitively observe object trajectories in different gravitational fields, experience light phenomena, and explore quantum mechanics. Similarly, in language, arts, and history, VR offers immersive experiences, aiding language learning, historical site visits, and appreciation of artworks. This method fosters interest, exploratory spirit, and enhances learning outcomes.

In physics, VR enables intuitive understanding of abstract concepts and laws [10]. For instance, students can observe object trajectories and light phenomena, enhancing their comprehension. In geography, VR facilitates global exploration, climate observation, and disaster simulation, fostering interest and understanding [11]. In language, VR provides immersive learning, aiding communication skills, confidence, and cultural awareness. Additionally, VR offers rich language resources for better mastery.

In arts and history, VR offers immersive experiences, aiding in site visits and historical reenactments [12]. Students gain intuitive insights into artworks and historical events, fostering interest and awareness. Overall, VR technology revolutionizes secondary education, offering immersive experiences that enhance understanding and engagement.

3.2 Deep Interaction Between Users and Environment

Virtual reality technology enables students to interact deeply with the environment and customize personalized environments based on their needs and learning objectives. Through virtual reality technology, students can immerse themselves in various situations and scenes, interact with objects in the virtual environment, and engage in learning and practice within the virtual world.

Personalized environment design can be tailored to students' learning needs and interests. For example, virtual reality educational applications can adjust teaching content, difficulty, and speed based on students' learning styles and levels, providing personalized learning experiences. Additionally, virtual reality technology can simulate various learning scenarios and contexts, such as laboratory simulations, historical scenes, and art studios, to meet the needs of different subjects and courses.

Personalized environment design not only enhances students' learning motivation and engagement but also improves learning outcomes and achievements. By interacting deeply with the virtual environment and learning in personalized environments, students can better understand and grasp subject knowledge, enhance learning efficiency, and develop independent learning abilities and problem-solving skills. Therefore, virtual reality technology has significant application prospects in the field of education, providing students with diverse and personalized learning experiences.

3.3 Breaking the Boundaries of Time and Space in Collaborative Learning

Virtual reality technology to some extent can break the limitations of time and space, assisting students in experiencing cross-temporal and spatial learning. Through virtual reality technology, students can immerse themselves in historical events, cultural scenes, or future worlds, gaining a deeper understanding of related knowledge as if they were traveling through time and space.

For instance, it is possible to create a virtual classroom where all students can join the same classroom virtually, engaging in learning and communication as if they were face-to-face. This virtual classroom can be accessed through head-mounted displays or other virtual reality devices, allowing students to choose their virtual avatars to interact with teachers and other students within the virtual environment.

In the virtual classroom, students can listen to the teacher's explanations, watch teaching resources, participate in class discussions, and interact with other classmates just like in a real classroom. Teachers can design the environment and layout of the virtual classroom according to teaching needs, including the arrangement of desks and chairs, and the setup of blackboards or screens, to provide a more realistic and comfortable learning experience.

The virtual classroom not only facilitates face-to-face interaction among students but also creates diverse and rich learning environments. For example, teachers can set the virtual classroom in different scenes such as historical landmarks, science laboratories, or outer space, allowing students to learn and explore in various scenarios. This virtual learning environment not only provides a more vivid and concrete learning experience but also stimulates students' interest and imagination, enhancing their motivation and engagement in learning [13].

In summary, the virtual classroom is an innovative application of virtual reality technology in the field of education, providing students with a new learning experience that transcends the limitations of time and space. It enables face-to-face interaction among students, promotes knowledge exchange and sharing, and enhances learning effectiveness and achievements.

4 Conclusion

The application of virtual reality (VR) technology in primary and secondary education has attracted widespread attention, bringing about significant changes and opportunities in education. Through this technology, students can experience more vivid and intuitive learning experiences, thereby stimulating interest and enhancing learning motivation. Teachers can utilize VR technology to design diverse and interactive teaching resources and activities, providing personalized and interactive learning environments to meet the needs and abilities of different students. Additionally, VR technology can break the limitations of time and space, allowing students to immerse themselves in various scenarios and contexts, broaden their horizons, and enhance learning effectiveness.

However, despite the enormous potential of VR technology, we must address the challenges and issues it presents. Firstly, the cost of VR technology remains relatively

high, making it difficult for schools and educational institutions to afford the procurement and maintenance costs of equipment and software. Secondly, the content and application scenarios of VR technology are still relatively limited, requiring continuous research and innovation to meet teaching needs and enhance effectiveness. The professional competence and technological literacy of teachers are also crucial factors that require ongoing training and support to ensure they can fully utilize VR technology.

In the process of promoting the integration of VR technology into campuses, some influential institutions and enterprises have emerged in China. The "Virtual Experiment Education System" of the Central Institute of Educational Technology and the "VR/AR+ Education" laboratory of Beijing Normal University represent academic research institutions committed to promoting the application of VR technology in the field of education. Meanwhile, companies such as Judao Technology, Dapeng VR, Wala Laboratory (VIVE of Beijing Weiwu World Entertainment Technology Co., Ltd.), and Zhongjiao Qixing (VR all-in-one machine) have made remarkable progress in the education field. Their continuous efforts and innovations have facilitated the widespread application and popularization of VR technology, providing students with diverse, vivid learning experiences and opening up new possibilities for education and teaching. With the continuous development and maturity of VR technology, it is believed that it will play an increasingly important role in the field of education, making more contributions to the development of education.

As VR technology continues to develop and become more widely adopted, we believe it will play an increasingly important role in primary and secondary education. In the future, we can expect VR technology to become more intelligent and personalized, providing students with diverse and varied learning experiences. Meanwhile, strengthening the sharing and cooperation of educational resources, promoting the widespread application of VR technology in the field of education, and allowing more students to benefit from this innovative teaching method will be necessary.

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