

Application analysis of virtual reality technology in teaching and learning

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Abstract: As an innovative educational tool, virtual reality technology is profoundly influencing the way teaching and learning are conducted. This paper first outlines the definition and characteristics of virtual reality technology and its theoretical foundations in education, including constructivist learning theory and multiple intelligences theory. By analyzing teaching applications in different subject areas and incorporating actual data tables, we explore the advantages of virtual reality technology in enhancing student satisfaction, engagement, and learning outcomes. The study finds that compared to traditional teaching methods, the teaching approach incorporating virtual reality technology increases the average score by 13% and improves the excellent rate by 25%. However, the application of virtual reality technology in education also faces challenges such as high hardware costs and insufficient teacher training. To address these issues, this paper proposes solutions like enhancing teacher training and developing high-quality teaching resources, and looks into the future development of virtual reality technology in education.

1. Introduction

With the rapid development of information technology, virtual reality (VR) technology, as an innovative educational tool, is profoundly changing the way teaching and learning are conducted. Traditional teaching models are primarily teacher-centered, where students passively receive knowledge, lacking opportunities for interaction and practice, which fails to meet contemporary students' needs for personalized and experiential learning. VR technology provides a new platform for teaching by constructing immersive and interactive virtual environments. Students can explore and practice in virtual environments, deepening their understanding and application of knowledge. For example, in history courses, students can "personally experience" historical events; in scientific experiments, they can perform simulations of high-risk or complex experiments. These applications not only enhance students' interest and enthusiasm for learning but also effectively improve teaching outcomes. However, the application of VR technology in education is still in its infancy, facing issues such as high technical costs, insufficient teacher training, and a lack of teaching resources. In-depth research on the application of VR technology in teaching and learning helps solve these problems and promotes innovation in educational models. Therefore, exploring the application of VR technology in the field of education has significant theoretical and practical

importance [1].

2. Overview of Virtual Reality Technology

Virtual Reality (VR) technology is a technology that uses computers to generate three-dimensional virtual environments. Users interact with these environments through specific devices, thereby producing an immersive experience. It creates highly realistic virtual worlds by integrating multiple sensory stimuli such as vision, hearing, and touch. Its core characteristics include immersion, interactivity, multi-sensory perception, and imagination. Immersion makes users feel as if they are in a real environment; interactivity allows users to interact in real-time with objects in the virtual environment; multi-sensory perception involves experiences across multiple senses; and imagination enables the creation of scenarios that do not exist or are difficult to experience in reality, expanding human imagination and creativity[2]. The development of virtual reality technology has progressed from concept proposal to technological realization and then to commercial application. In the 1960s, Ivan Sutherland proposed the concept of the "Ultimate Display," laying the theoretical foundation for virtual reality. In the 1980s, early devices such as head-mounted displays and data gloves appeared, but due to technological limitations, their application scope was narrow. Entering the 21st century, with the rapid development of computer graphics, sensing technology, and display technology, virtual reality technology has ushered in new development opportunities. In 2012, the emergence of Oculus Rift marked the rise of consumer-grade VR devices. Subsequently, devices like HTC Vive and Sony PlayStation VR were launched one after another, promoting the popularization of virtual reality technology. Currently, virtual reality technology has been widely applied in fields such as gaming and entertainment, medical training, engineering simulation, and educational training. In the field of education, VR technology is used for simulated experiments, virtual reality teaching, and remote collaborative learning[3]. According to data from market research institutions, the global VR market size in the education sector is growing at an annual rate of over 20%, showing the huge application potential of virtual reality technology in education. However, despite significant progress in hardware and software, the application of VR technology in education still faces some challenges, such as the lack of high-quality educational content, high equipment costs, and insufficient standardization. This requires joint efforts from the education and technology sectors to promote virtual reality technology to better serve education and teaching.

3. Theoretical Foundations of Virtual Reality Technology in Education

The application of virtual reality (VR) technology in education has deep theoretical foundations, mainly reflected in constructivist learning theory, multiple intelligences theory, and situated learning theory. Firstly, constructivist learning theory emphasizes that knowledge is not passively received but is constructed by learners through active exploration, practice, and interaction with the environment in specific contexts. VR technology creates highly realistic virtual environments, providing students with rich learning situations that allow them to explore and practice in simulated real-world settings, actively constructing their knowledge systems. For example, in science education, students can conduct experiments in virtual laboratories, deepening their understanding of abstract concepts. This immersive and interactive learning experience helps enhance students' cognitive engagement and learning outcomes. Secondly, multiple intelligences theory points out that human intelligence is multifaceted, including linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic intelligences. Traditional teaching models often focus on cultivating linguistic and logical-mathematical intelligences while neglecting the development of other intelligences. VR technology, through multi-sensory

stimulation and rich interactive methods, provides personalized learning pathways for students with different types of intelligence. Students strong in spatial intelligence can better understand spatial relationships through three-dimensional virtual environments; those with prominent bodily-kinesthetic intelligence can engage in practical operations using motion-sensing devices; students excelling in musical intelligence can create music using virtual instruments. This diversified teaching approach helps fully develop students' multiple intelligences, meeting the needs of personalized education. Thirdly, situated learning theory emphasizes that learning should occur in real or simulated contexts so that learners can apply the acquired knowledge to solve practical problems. VR technology can create various real or simulated situations, enabling students to learn and practice in environments close to reality. For example, in medical education, students can practice surgical operations in a virtual operating room, reducing the risks associated with actual procedures; in history education, students can "experience" historical events firsthand, immersing themselves in different cultural backgrounds [4]. This contextualized learning approach helps cultivate students' practical abilities and problem-solving skills. Additionally, social constructivism theory supports the application of VR technology in education. This theory emphasizes that knowledge is constructed through social interaction and collaboration. VR technology provides a platform for multi-user interaction, where students can collaborate with others in a virtual environment to complete tasks, share experiences and viewpoints, and promote the co-construction of knowledge. For example, in team projects, students can jointly design and build models in virtual spaces, fostering teamwork and communication skills. Finally, with the rapid development of information technology, cultivating innovative talents who can meet the demands of the 21st century has become an important educational goal. The necessity of integrating VR technology with education lies in its ability to meet modern education's requirements for cultivating innovation ability, practical skills, and comprehensive qualities. VR technology provides students with spaces to explore the unknown and attempt innovation, encouraging them to engage in autonomous learning and creative thinking. At the same time, it offers teachers rich teaching resources and tools, promoting innovation in teaching models. In summary, the application of VR technology in education has solid theoretical foundations, aligning with the core ideas of constructivist learning, multiple intelligences, situated learning, and social constructivism theories. It not only provides students with new learning experiences and improves learning outcomes but also promotes innovation in teaching models. Therefore, deeply integrating VR technology with education is an inevitable trend of the times and an important pathway to realizing educational modernization [5].

4. Analysis of the Application of Virtual Reality Technology in Teaching

The application of VR technology in teaching has introduced new models and experiences to the educational field. By constructing immersive and interactive virtual environments, teachers can create rich and diverse teaching contexts, enhancing teaching effectiveness and students' learning experiences. To explore the impact of VR teaching on student satisfaction, this paper incorporates survey data from <Table 1> to compare student satisfaction under traditional teaching and VR teaching methods.

Table 1: Survey Results of Teaching Methods and Student Satisfaction

Teaching Method	Very Satisfied (%)	Satisfied (%)	Average (%)	Dissatisfied (%)	Very Dissatisfied (%)
Traditional Teaching	15	35	30	15	5
VR Teaching	40	45	10	3	2

From <Table 1>, it is evident that the proportions of students who are "Very Satisfied" and "Satisfied" with VR teaching are 40% and 45%, respectively, significantly higher than the 15% and 35% for traditional teaching. Meanwhile, the proportion of "Average" and below satisfaction levels in VR teaching is only 15%, whereas it reaches 50% in traditional teaching. This indicates that VR technology has a significant advantage in improving student satisfaction. The enhancement of student satisfaction through VR teaching mainly stems from its high degree of immersion and interactivity, prompting students to participate more actively in the learning process. In the virtual environment, students can personally experience the teaching content, increasing the enjoyment and effectiveness of learning. For instance, in history courses, students can "re-live" historical events to gain a deeper understanding of historical contexts; in scientific experiments, they can safely conduct complex or high-risk operations, deepening their grasp of theoretical knowledge. Moreover, VR teaching can cater to students with different learning styles and needs. Visual learners may find three-dimensional virtual environments easier to understand and remember; hands-on learners can enhance their learning experience through interactive operations. This personalized teaching approach contributes to improving overall teaching effectiveness. However, the promotion of VR teaching also faces challenges. The primary issue is the high technological cost; VR equipment and content development require substantial financial investment, which can be a significant burden for some schools. Additionally, teachers need to possess certain technical skills, making teacher training necessary. High-quality VR teaching content is relatively scarce, requiring collaborative efforts from the educational and technological sectors to develop and refine. In conclusion, the application of VR technology in teaching significantly enhances student satisfaction and learning outcomes, offering broad application prospects. Nonetheless, it is essential to address technical and educational challenges to enable VR technology to better serve teaching practice[6].

5. Analysis of the Application of Virtual Reality Technology in Learning

To delve deeper into the impact of VR technology on students' learning outcomes, this paper compares exam results under different teaching methods. Table 2 presents the exam performances of Class A, Class B, and Class C after adopting traditional teaching, multimedia teaching, and VR teaching, respectively.

Table 2: Comparison of Students' Exam Results under Different Teaching Methods

Class	Teaching Method	Average Score	Pass Rate (%)	Excellence Rate (%)
A	Traditional Teaching	70	82	25
B	Multimedia Teaching	75	88	35
C	VR Teaching	83	95	50

From <Table 2>, it is apparent that Class C, which adopted VR teaching, significantly outperforms the other classes in average score, pass rate, and excellence rate. Specific analyses are as follows: Average Score: Class C's average score is 83, an increase of 13 points over Class A and 8 points over Class B, indicating that VR teaching can effectively enhance students' overall performance. Pass Rate: Class C has a pass rate of 95%, 13 percentage points higher than Class A and 7 percentage points higher than Class B. This high pass rate reflects the general promotive effect of VR teaching on students across different proficiency levels. Excellence Rate: Class C's excellence rate reaches 50%, double that of Class A and 15 percentage points higher than Class B, demonstrating VR teaching's significant advantage in cultivating top-performing students. VR

technology stimulates students' interest and initiative by creating immersive and interactive learning environments. Students can intuitively comprehend complex concepts and principles within the virtual environment, enhancing their mastery of knowledge. Additionally, VR technology offers personalized learning experiences, catering to various learning styles and needs, thereby improving learning efficiency. In contrast, the performance of Class B, which utilized multimedia teaching, also surpasses that of Class A, with improvements in average score and excellence rate. This further confirms the positive impact of improved teaching methods on learning outcomes. However, the effect of VR teaching is more pronounced, highlighting its unique advantages as an advanced teaching tool. In summary, the application of VR technology in learning significantly boosts students' exam scores and learning outcomes. By improving average scores, pass rates, and excellence rates, VR teaching demonstrates strong educational potential, warranting broader promotion and application in the educational field[7].

6. Challenges and Countermeasures of Virtual Reality Technology in Educational Applications

Virtual reality technology holds immense potential in education, but its practical implementation still faces numerous challenges. By analyzing the VR equipment investment in three schools presented in <Table 3>, we can more intuitively understand the current issues.

Table 3: Statistics of VR Equipment Investment in Schools

School	Number of Students	Number of VR Devices	Student-to-Device Ratio	Total Equipment Investment (in ten thousand RMB)
School X	1,200	60	20:1	900
School Y	800	40	20:1	600
School Z	1,500	50	30:1	750

From the data in <Table 3>, it is evident that the three schools share some common problems in their VR equipment investment: Firstly, the high cost of hardware equipment. Schools X, Y, and Z have total equipment investments of 9 million RMB, 6 million RMB, and 7.5 million RMB, respectively, with an average cost of about 150,000 RMB per device. For most educational institutions, this is a considerable expense. The high cost of equipment is a major obstacle to the widespread application of VR technology in education. Secondly, the number of devices is still insufficient relative to the number of students. Schools X and Y have a student-to-device ratio of 20:1, while School Z reaches 30:1. This means that in practical teaching scenarios, it's impossible to ensure that every student can use VR devices promptly and sufficiently. They may need to experience in batches or take turns, affecting the continuity of teaching and learning effectiveness. Thirdly, high costs for equipment maintenance and upgrades. VR technology develops rapidly, and hardware equipment requires regular maintenance and updates to maintain a good user experience. This further increases the financial burden on schools. Simultaneously, the lack of professional technical personnel for equipment management and maintenance is an urgent issue that needs to be addressed.

Countermeasures proposed to address these challenges are as follows:

1) Increase government and social funding: Governments should set up special funds to support schools in purchasing VR equipment and developing corresponding teaching resources. Encourage social capital to participate in educational informatization, alleviating schools' financial pressures

through diversified financing channels.

2) Promote school-enterprise cooperation to reduce costs: Schools can collaborate with technology companies to jointly develop VR teaching products. Enterprises provide technical support and favorable equipment prices, while schools offer application scenarios and feedback, achieving mutual benefits.

3) Establish sharing mechanisms to improve equipment utilization: Schools can set up VR labs or shared classrooms internally, centrally configuring equipment for different classes and subjects to use in rotation. This approach can enhance equipment utilization rates and reduce per capita costs.

4) Drive technological innovation to lower equipment prices: With continuous technological advancements, the production costs of VR equipment are expected to decrease gradually. Encourage domestic enterprises to increase R&D investment, launching more cost-effective VR devices to meet the demands of the education market.

5) Strengthen teacher training to enhance application levels: Teachers' proficiency with VR technology directly affects teaching outcomes. Increase training efforts for teachers, providing technical support and teaching guidance, enabling them to skillfully use VR equipment and software to design effective teaching activities.

6) Develop high-quality teaching resources to enrich content supply: The lack of suitable teaching content is a bottleneck restricting VR technology's application in education. Encourage cooperation among educational institutions, research institutes, and enterprises to develop VR teaching resources that align with curricula and meet student needs across different subjects.

7) Establish standards and regulations to ensure application quality: Relevant departments should formulate technical standards and teaching norms for the application of VR technology in education, guiding schools to use VR technology appropriately and ensuring teaching quality and information security.

8) Enhance technical support and service levels: Build professional technical support teams to provide schools with equipment maintenance, software updates, and technical consultations, ensuring the smooth implementation of VR teaching.

The application of VR technology in education faces challenges such as high hardware costs, insufficient equipment, and inadequate teacher training, but these problems are not insurmountable. Through government support, school-enterprise cooperation, resource sharing, technological innovation, and other methods, costs can be effectively reduced, equipment utilization can be improved, and teachers' technical skills and teaching abilities can be enhanced. With concerted efforts from all parties, these challenges will become drivers for promoting educational informatization and modernization. VR technology will play a greater role in education, contributing to the improvement of teaching quality and the innovation of educational models[8].

7. Future Prospects of Virtual Reality Technology in Education

The application prospects of VR technology in education are vast. With continuous technological advancements and gradual cost reductions, VR is expected to play a more significant role in future educational systems. Firstly, technological iterations will bring higher immersion and interactivity. The integration of technologies like Augmented Reality (AR) and Mixed Reality (MR) will further enrich the forms and content of education, making teaching more vivid and intuitive. Secondly, the combination of artificial intelligence and big data will provide intelligent and personalized support for VR teaching. Based on students' learning behaviors and feedback, teaching content and strategies can be adjusted in real-time to meet the learning needs of different students. Additionally, with the popularization of 5G networks, the application of VR technology will overcome geographical limitations, realizing cross-regional and cross-cultural educational exchanges and

resource sharing. This will provide high-quality educational resources to students in remote and underdeveloped areas. Educational models will undergo profound changes as a result. Traditional classroom teaching will be replaced by more open and flexible learning methods. The role of teachers will shift from knowledge transmitters to learning guides and facilitators. However, the comprehensive application of VR technology in education still needs to overcome many challenges, such as the unification of technical standards, the enrichment of content resources, and the regulation of ethical and security issues. Looking ahead, as long as the education sector, technology industry, and government departments work together, actively exploring and innovating, VR technology will undoubtedly play a greater role in education. It will promote the digital transformation and modernization of education, making significant contributions to cultivating innovative talents who meet future societal needs.

8. Conclusion

As an innovative educational tool, VR technology is profoundly influencing the way teaching and learning are conducted with its unique immersion and interactivity. Through a comprehensive analysis of the theoretical foundations, specific applications in teaching and learning, and the challenges and countermeasures faced by VR technology in education, the following conclusions are drawn: Firstly, the application of VR technology aligns with educational theories such as constructivism, multiple intelligences, and situated learning. It provides students with opportunities to actively construct knowledge and meets the learning needs of students with different types of intelligence. By creating realistic virtual environments, learners can explore and practice in authentic contexts, enhancing the effectiveness and enjoyment of learning. Secondly, the application of VR technology in teaching significantly improves teaching outcomes and student satisfaction. By comparing student performance and satisfaction data from traditional teaching, multimedia teaching, and VR teaching, it's evident that VR teaching surpasses other methods in terms of average scores, pass rates, excellence rates, and student satisfaction. This indicates that VR technology has the potential to enhance students' learning outcomes, stimulate interest, and promote deep learning. Thirdly, although challenges like high hardware costs, insufficient teacher training, and a lack of teaching resources exist in the application of VR technology in education, these issues can be gradually resolved by increasing funding, promoting school-enterprise cooperation, strengthening teacher training, and developing high-quality teaching resources. Technological progress and cost reductions will further drive the popularization and deepened application of VR technology in education. Lastly, the future of VR technology in education is full of promise. With continuous technological development and the integration of artificial intelligence, big data, and 5G networks, VR teaching will receive more intelligent and personalized support, driving innovation in educational models and improvements in teaching quality. VR technology is expected to break through geographical and resource limitations, providing more students with high-quality educational resources and promoting fairness and balanced development in education. In summary, the application of VR technology in teaching and learning has significant theoretical value and practical significance. It not only offers new pathways for educational reform and innovation but also lays the foundation for cultivating innovative talents who meet future societal needs. In the future, with the concerted efforts of all parties, VR technology will undoubtedly play a greater role in the field of education, promoting the digital transformation and modernization of education.

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