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Application of VR Technology in Civil Engineering Teaching in Colleges and Universities

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Abstract: *Based on the construction and application of civil engineering teaching in China, three main stages of research exploration, application, network sharing, systematically expounds the development of VR technology in civil engineering teaching, pointed out that the VR technology has formed a large number of universities, wide range, good project effect, resource cloud sharing, solve the traditional experimental curriculum risk, high cost, long cycle, stimulate learning interest, improve teaching quality,realize education fairness, and achieved good teaching results. However, the application of VR technology has some professional construction, some curriculum construction and some experiments, with the improvement of technology and the increase of application scenarios, these problems will eventually be solved, VR technology will eventually have important reference value and broad application prospects in the field of civil engineering teaching in universities.*

Keywords: *VR Technology, Major in Civil Engineering, Experimental Teaching, Cloud Platform*

1. Introduction

VR technology emerged in the 1980s, covering computer graphics, simulation, multimedia, artificial intelligence and other technologies. It is an advanced computer human-computer interaction technology that can simulate the functions of human visual, auditory, tactile and other sensory organs. It is characterized by multisensory, immersion, interactivity and controllability[1]. In manufacturing, energy, education, military and other fields have been widely recognized and applied.

VR technology has been inseparable from the field of education since its birth. In the 1980s, The University of North Carolina took the lead in applying VR technology in architectural simulation, aviation and other fields, realizing the goal of establishing dynamic realistic scenes in complex scenes, and driving the RESEARCH and application of VR technology in the field of education. In 1996, VR technology was applied to virtual battlefield for the first time in China's 863 Program and preliminary results were achieved. Subsequently, the research boom of VR technology was set off in China[2]. In the same year, Tianjin University took the lead in using VR technology to develop a virtual campus for university curriculum teaching[3].

Civil engineering major is characterized by strong practicality, and various practical courses have problems such as high risk, high cost and long cycle. VR technology has natural advantages in solving these problems due to its multi-sensory, interactive and controllable characteristics. Based on the construction and application status of VR technology in the teaching field of civil engineering specialty in Colleges and universities in China, this paper systematically expounds the development history of VR technology in the teaching field of civil engineering specialty in three major stages: research and exploration, application and promotion and network sharing.

2. Exploration stage of VR technology in civil engineering teaching

At the beginning of the 21st century, a series of problems such as high risk of teaching experiment of civil engineering specialty in colleges and universities became increasingly prominent. Some universities in China tried to combine VR technology with civil engineering experiment teaching in colleges and universities to develop virtual simulation experiment projects suitable for civil engineering teaching in colleges and universities.

In 2008, Jiangxi University of Science and Technology tried to integrate VR technology into the field of civil engineering practice teaching. In 2017, Jiangxi University of Science and Technology developed

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a set of virtual Simulation Experiment system for mechanical Properties of Composite Structural Components using tools using Unity3D[4]. In 2011, Ningxia University began to study and explore the application of VR technology in the experimental teaching of civil engineering major, and established *Virtual Simulation and VR Simulation Laboratory of Civil Engineering Construction Technology under the New Engineering Background*. In the same year, Dalian University carried out research on the application of VR technology in the experimental teaching of road and bridge in the major of civil engineering, and developed a set of *Virtual Simulation Experiment of Bridge Detection and Load Test* by using tools such as Unity3D to deal with the problems of high risk in bridge quality detection and load measurement. Around 2012, Shandong University of Architecture, Lanzhou University of Technology, Beijing University of Technology and other universities carried out research on the teaching application of VR technology in the design principles of concrete structures [5-10].

In 2014, the Ministry of Education established the first batch of national virtual simulation experimental teaching centers nationwide with the guiding ideology of scientific planning, sharing of resources, highlighting key points, improving efficiency and sustainable development[11]. In 2015, the Ministry of Education started to build the second batch of national virtual simulation experimental teaching centers, and established 8 national virtual simulation experimental teaching centers including Tongji University[12]. With the research and exploration of universities and the support of national policies, VR technology has gradually stepped into the application and promotion stage in the teaching field of civil engineering[13].

3. Application of VR technology in civil engineering teaching

3.1. In-class experiments

3.1.1. Professional basic courses

In the basic courses of civil engineering, VR technology is mainly applied in dynamics, materials and structural design courses. Among them, dynamics courses mainly include *Soil mechanics*; Material courses mainly include *Civil Engineering Materials* and *Engineering Geology*. Structural design courses mainly include *Principles of concrete structure design* and *Steel structure*.

In 2015-2018, southwest university of transportation and other colleges and universities using the VR technology around the super gravity centrifugal simulation experiment in soil mechanics, indoor triaxial test, garbage soil sedimentation tests carried out, such as virtual simulation experiment teaching, under the premise that guarantee the truthfulness of the experiment, solves the long experimental period, consumables, such the problem of high risk[5, 14, 15].

From 2014 to 2018, Shandong University of Architecture and other universities respectively realized the application of VR technology in concrete structure design courses. The virtual simulation experiment platform is developed mainly for bearing capacity test of flexural member, normal section test of simply supported beam, structure and analysis of reinforced concrete beam and slab, beam flexural performance test and structural stress failure test. Various stress and deformation processes of reinforced concrete structures are accurately realized[5, 8].

In 2016-2018, Shanghai university and other colleges and universities to achieve the VR technology in the application of steel structure teaching, involving the semi-rigid steel frame pseudo-static experiment, light portal frame structure design and the design of the medium-duty workshop structure in-class experiment. Through the virtual simulation experiment platform, students can build steel structure buildings and measure the structure correlation coefficient.

For some special structural experimental courses of civil engineering major, VR technology has also achieved good results. In 2017, Jiangxi University of Science and Technology applied VR technology to the teaching of *Principles of Composite Structure Design* and developed the virtual simulation experimental platform for FRP composite beam bending experiment for the first time. In 2018, Nanjing University of Aeronautics and Astronautics applied VR technology to the teaching of *Structural Wind Engineering* and developed a virtual simulation experiment platform for in-class wind tunnel test, presenting the virtual experiment process of pressure measurement, vibration measurement and force measurement of buildings under wind load.

3.1.2. Professional courses

In civil engineering courses, VR technology is mainly applied in water supply and drainage

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engineering, geotechnical engineering, construction engineering, traffic engineering and underground engineering. Among them, water supply and drainage engineering courses mainly include *Water Quality Engineering* and *Constructed wetland sewage treatment theory and technology*; Geotechnical engineering courses mainly include *rock Mechanics and Engineering* and *In-situ Testing Technology of Rock Engineering*. Architectural engineering courses mainly include *prefabricated architecture* and *Architectural construction*. Traffic engineering courses mainly include *Subgrade and Pavement Engineering* and *Bridge Engineering*. Underground engineering courses mainly include *Tunnel engineering* and *underground Engineering*.

In the direction of water supply and drainage engineering, from 2017 to 2018, Qingdao University of Technology and Guangzhou University combined VR technology with water plant design and water treatment coagulation experiment teaching in *Water Quality Engineering* respectively, and developed corresponding virtual simulation experiment teaching platform. The site selection of the water plant, the layout of the water plant plane and elevation, the water treatment and coagulation process and the changes of various parameters are presented in the form of VR.

In the direction of geotechnical engineering, in 2017, Henan University of Technology combined VR technology with the experimental teaching of In-situ Testing Technology of Geotechnical Engineering, and used VR technology to carry out static contact exploration experiment, which overcame the problems of long cycle and high cost of traditional experiment and helped students get familiar with the process and matters needing attention of engineering survey. In 2019, Wuhan University combined VR technology with *rock mechanics and engineering experimental* teaching, and used VR technology to conduct virtual simulation experiment of 3d geomechanical model test of tunnel excavation, explaining the basic properties of rock mechanics and other knowledge points, and showing the complete process of model making, loading, excavation overloading and failure, and data analysis.

In the direction of construction engineering, in 2012, Ningxia University combined VR technology with the construction experiment in *Civil Engineering Construction*, and completed the virtual simulation experiment of domestic construction teaching for the first time. In 2016, Henan University of Technology combined VR technology with the teaching of *Granary Architecture and Structure* to help students complete the design, construction and operation of the park in the virtual simulation space.

In 2018, Lanzhou University of Technology introduced VR technology to develop the corresponding virtual simulation experimental platform for the building tilt rectification experiment of *Analysis and Treatment of Engineering Quality Accidents*, which truly presents the phenomenon of building tilt due to subsidence and salt expansion. In the same year, Hebei University combined VR technology with the experimental teaching of *Foundation Pit and Slope Engineering*, showing the whole process of deep foundation pit design, construction and accident prevention in a virtual environment.

In the direction of traffic engineering, in 2012, Dalian University combined VR technology with the bridge testing and load experimental teaching of *Bridge Engineering*. Since then, the first batch of traffic engineering virtual simulation experiment platform has been developed in China. Traffic engineering courses mainly include bridge courses and road courses.

From 2015 to 2018, Hebei University of Technology and other universities successively applied VR technology to the teaching of bridge courses, involving the in-class and after-class experimental teaching of such courses as *Bridge Engineering*, *Earthquake resistance and Disaster Prevention of Engineering Structures*, and *Large-span Spatial Structure*. Including cable structure prestress design and construction experiment, pier column explosion test, bridge wind resistance and earthquake resistance test, cable-stayed bridge structure response experiment under earthquake action, long-span bridge construction experiment, cable-stayed bridge stress and strain monitoring experiment, static load test, dynamic load test, bridge detection and load test, etc. It solves the problems of long construction period, high cost and great risk of bridge course experiment.

From 2016 to 2017, Changsha University of Science and Technology and other universities successively applied VR technology to the teaching of road courses, involving experimental teaching of *Roadbed and Pavement Engineering* and *Road Survey and Design*, including mixing station experiment, road field survey experiment and asphalt mixture high-temperature stability experiment. Help students master the key points of material production and material stability control in the process of road construction.

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Figure 1: Changsha University of Science and Technology mixing station simulation panorama

In the direction of underground engineering, From 2015 to 2018, Xihua University combined VR technology with experimental teaching of tunnel construction courses in the direction of underground engineering respectively, overcoming the disadvantages of tunnel experiments that are difficult to carry out and irreversible, and inspiring students' interest in learning tunnel courses .

In 2017, Shandong University combined VR technology with the operation experiment teaching of Seismic wave method, excitation and intensification method and transient electromagnetic method in *Geoelectric and Electrical Exploration*, and developed corresponding virtual simulation experiment platform to simulate real construction scenarios, realizing students' independent operation and increasing students' practice ability.

In 2018, China University of Mining and Technology combined VR technology with experimental teaching of *Urban Underground Engineering* and *Underground Engineering Construction Technology*, including design and analysis experiment of supporting structure in deep foundation pit and tunnel engineering construction experiment, etc., to cultivate students' design and analysis ability of deep foundation pit support.

3.2. Individual laboratory course

3.2.1. Basic individual laboratory course

In recent years, Nanchang University, Tiangong University and other universities have built virtual simulation physics laboratories, and established virtual simulation experiments for more than 30 experimental items such as force, heat, electricity, light and magnetism, such as oscilloscope experiment, Michelson interferometer experiment and multi-purpose meter modification experiment. During the virtual simulation experiment, students operate according to the system instructions, and the system automatically records and summarizes the data, which greatly saves the maintenance cost of experimental materials and corresponding instruments, and improves the teaching efficiency of *College Physics Experiment*.

3.2.2. Professional individual laboratory class

Since 2015, some universities have built a virtual simulation experiment platform for individual experimental courses of civil engineering major. From 2015 to 2018, Southwest Jiaotong University and other universities respectively applied VR technology to the teaching of experimental courses of structural testing. Typical experiments include load-bearing failure experiment of reinforced concrete floor, seismic testing experiment of building structure, practical teaching of load test and state monitoring, and the whole process experiment of beam-type components. The virtual simulation platform shows the load and deformation of the structure synchronously. It also presents the deformation of building structure caused by earthquake or load in front of students, and stimulates students' interest in the research on structural deformation.

In 2015-2019, hebei university successfully applying VR technology to structure design of experiment teaching, involving the design and construction of tunnel experiment, fabricated water retaining wall design, construction and design experiment, large steel frame structure factory building experiment, the subway station construction, etc., the virtual simulation experiment platform to overcome the deficiency of the traditional experimental teaching. The application of theoretical knowledge in

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virtual scenes achieves the fundamental purpose of experimental teaching.

Figure 2: Large scale structural static experiment of Southwest Jiaotong University

On the premise of safety and reality, colleges use VR technology to set up various virtual simulation experiment platforms, which consolidate students' cognition of theoretical knowledge. The continuous promotion and application of VR technology in civil engineering has promoted the teaching quality of civil engineering in some universities under the background of new engineering, and also laid a solid resource foundation for VR technology to enter the stage of network sharing.

4. VR technology in the network sharing stage

Universities use VR technology to teach civil engineering are widely distributed in China. Among them, the eastern region is more, accounting for 39%; In northeast China, the proportion is only 10%, and in central China, the proportion is about 24%, mainly concentrated in Henan, Hunan, Hubei and other affiliated engineering colleges. The western region accounted for about 27%, mainly concentrated in Sichuan, Gansu, Shaanxi and other affiliated engineering colleges and universities. The overall distribution of virtual simulation experiment teaching for civil engineering majors in China tends to be balanced, but there is an unbalanced distribution phenomenon within each region, which is concentrated in key universities in each region. There are still gaps in the research and application of virtual simulation technology in ordinary universities.

In recent years, a series of emerging technologies, such as cloud platform, 5G and AI, have emerged at home and abroad. Cloud platform is a service technology that can obtain required resources in an on-demand and easily extensible way through the network, and this technology has created a network sharing platform for virtual simulation teaching. The integration of VR technology and network sharing technology helps the application of VR technology in college teaching gradually step into the network sharing stage.

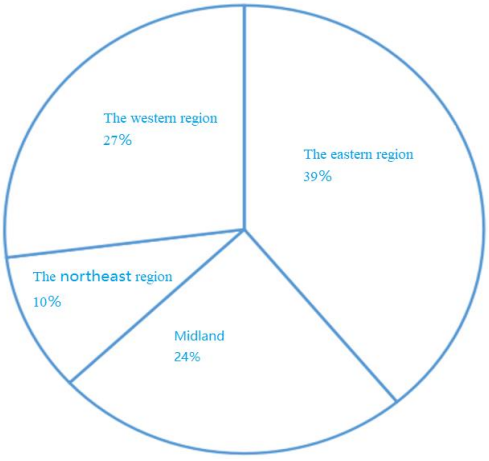

Figure 3: Distribution map of the proportion of colleges and universities in each region

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In 2017, with the continuous emergence of VR technology teaching projects in China, the Ministry of Education selected demonstration virtual simulation projects to build a shared platform for virtual simulation experimental teaching courses based on the fundamental task of moral cultivation. The virtual simulation experiment teaching sharing platform is open to domestic universities. By April 30, 2021, the network platform has received a total of 2,079 virtual simulation experiment projects in 41 majors, including law and civil engineering. Civil engineering is a key major of engineering colleges and universities, and the platform includes 119 experimental courses and separate experimental courses of this professional course.

The construction of network sharing platform not only promotes the development of science and technology teaching, but also realizes the sharing of resources for the society, which drives the innovation of teaching methods and the improvement of teaching level in domestic ordinary colleges and universities.

5. Conclusion

(1) In the stage of research and exploration, some engineering colleges take *Civil Engineering Construction*, *Bridge Engineering* and other practical courses as examples and use VR technology to solve the problems of high risk, high cost and long period in experimental teaching of civil engineering major. Using VR technology and Unity 3D creation and development engine. Through 3D modeling software such as Solid Works, 3D Max and other tools, the virtual simulation platform of relevant experimental courses has been preliminarily built, and a new teaching mode has been created.

(2) At the stage of application and promotion, VR technology has been widely used in the internal and individual experimental courses of civil engineering. In the application and promotion stage, VR technology has been widely used in civil engineering courses and individual experimental courses. Up to now, more than 100 colleges and universities in China have successively developed about 119 virtual simulation experimental teaching projects of civil engineering courses. The application of VR technology covers a wide range of courses, including about 77 courses, such as professional basic courses, professional courses, basic independent experiment courses, professional independent experiment courses and so on. The application of VR technology has a excellent effect. During the implementation of each project, it solves the problems of high risk, high cost and long cycle of traditional experimental courses, arouses students' interest in learning, improves students' participation and achieves a good teaching effect.

(3) In the network sharing stage, the Ministry of Education uses cloud platform and other technologies to create a national virtual simulation experiment teaching course sharing platform, which accommodates virtual simulation experiment projects developed by colleges and universities across the country and is open to use by colleges and universities across the country. Network share phase marked using the VR technology in teaching has entered a new stage, the construction of sharing platform and the use, to avoid the repetitive construction of virtual simulation platform, various colleges and universities to change the present situation of universities teaching resource allocation imbalance, to a certain extent, and so did the universities teaching quality, realize the education fair.

(4) At present, Chinese colleges and universities have made rich research achievements in using VR technology to carry out curriculum experimental teaching, but there are still some problems, such as weak construction of some majors, repetitive construction of some courses, and some experiments that need to be improved. Colleges and universities can rely on the national virtual simulation experimental teaching curriculum sharing platform to develop together, so that VR technology truly serve schools, majors and students.

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