ISSN 2522-6398 Vol. 6, Issue 26: 43-48, DOI: 10.25236/FER.2023.062608

Research on Virtual Simulation Experiment Teaching of Concrete Structures Based on Simdroid

Miaomiao Bai[1,a,*], Liyun Tang[1,b], Hongjun Jing[1,c], Zheng Dang[1,d], Hui Liu[1,e], Botuan Deng[1,f], Hailiang Jia[1,g], Xu Duan[1,h]

[1]School of Architecture and Civil Engineering, Xi'an University of Science and Technology, Xi'an, China
[a]jybaimiaomiao@163.com, [b]tangly@xust.edu.cn, [c]jinghongjun@xust.edu.cn, [d]dangzheng@xust.edu.cn, [e]liuhui2006@xust.edu.cn, [f]deng13720412121@139.com, [g]hailiang.jia@xust.edu.cn, [h]duanxu@xust.edu.cn
**Corresponding author*

Abstract: *Virtual simulation experiments have become an important component of experimental teaching in science and engineering, and are increasingly valued by various universities. In response to the characteristics of the concrete structure course and the difficulties in experimental teaching, combined with student feedback and teacher experience summary, an exploration was conducted on the mixed experimental teaching mode of concrete structure based on the Simdroid virtual simulation platform. This paper designs a student-centered teaching mode that combines online and offline practical teaching. This mode breaks the limitations of time and space, increases the fun and flexibility of experimental teaching, enhances students' learning enthusiasm and initiative, and effectively improves the teaching effect of concrete structure experiments.*

Keywords: *virtual simulation; Experiential teaching; concrete structures; Teaching model*

1. Introduction

The concrete structure course is based on experiments and practice, and as a response to the establishment of comprehensive ability cultivation goals in application-oriented undergraduate colleges, concrete structure related experiments have become a scientific experimental training practice course that civil engineering undergraduate students must systematically accept. It is an important step in cultivating the ability and quality of university students in this field and promoting scientific spirit[1-2]. However, due to the monotony of learning concrete structure theory and the singularity of learning methods, most students lack a thorough understanding of the principles of concrete structure experiments. In addition, the pouring process of concrete components is cumbersome and complex, with a long maintenance cycle, and the characteristics of being irreproducible after destruction. Concealed projects are difficult to display on site, combined with the cost of experimental economy and time, which makes it difficult to effectively organize large-scale experiments and prevent everyone from deeply participating in physical experiments. Moreover, given that traditional internship and other practical links are constrained by the production safety requirements of internship units, most of them are visits, and there are few opportunities for hands-on operations. It is difficult for students to gain a systematic understanding of the construction process, organization, and even the entire construction process of concrete structure engineering. Basically, the experimental results in the form of experimental reports and drawings have been difficult for students to gain a dynamic and overall understanding of the construction process, which is seriously disconnected from the development and requirements of higher education informatization, and does not conform to the learning and cognitive laws of college students in the era of "Internet plus" big data, which is difficult to stimulate students' enthusiasm and participation in experiments. Such problems are highlighted due to the limitations of traditional teaching models that no longer meet the training needs of applied, innovative, and comprehensive high-level technical talents, and seriously restrict the improvement of students' comprehensive abilities. Therefore, guided by the spirit of the "Implementation Opinions of the General Office of the State Council on Deepening the Reform of Innovation and Entrepreneurship Education in Higher Education Institutions" and the "Several Opinions of the General Office of the State Council on Deepening the Integration of Industry and Education" documents, we aim to cultivate a group of applied, innovative, and comprehensive senior technical talents that meet the needs of civil

ISSN 2522-6398 Vol. 6, Issue 26: 43-48, DOI: 10.25236/FER.2023.062608

engineering majors [3]. Similarly, improving the quality of teaching and students' practical abilities is an urgent measure to meet the needs of the country. Based on the positioning and characteristics of cultivating civil engineering technical talents in our school, we utilize the Simdroid virtual simulation platform to carry out online and offline hybrid teaching of concrete structure experiment courses, organically integrating classroom theoretical learning, experimental practical operation learning, and online learning. The integration of university experimental courses and information technology has diversified teaching methods, enriched teaching content, and diversified learning methods [4-5].

Virtual simulation experimental teaching has developed into an important content of higher education informationization construction [6-7]. It is a product of the deep integration of disciplines and information technology, with advantages such as immediacy, contextuality, participation, and pleasure. It plays an irreplaceable important role in cultivating students' practical ability, innovative spirit, and knowledge expansion. Based on the strong technical strength and engineering experience of Beijing Yundao Intelligent Manufacturing Technology Co., Ltd. in CAE simulation level, our institute has established a concrete structure simulation design practice base based on the Simdroid simulation platform through school enterprise cooperation to jointly build a practice base. Under the principle of adhering to multi-level, multi-channel, multi-form, and practical results, based on our national virtual simulation experimental teaching platform, with concrete structure courses as the main body, improving students' practical ability and innovative spirit as the core, relying on modern information technology, and targeting the information content of concrete structure related professional experimental teaching, we promote the application of information technology in experimental practice teaching in higher education institutions, build a pioneering teaching method that integrates theory practice simulation application, achieve multi-dimensional teaching methods such as online teaching and blended teaching, and condense and construct high-quality concrete structure simulation experimental teaching project results.

As the basic unit of experimental teaching in universities, the construction level of experimental teaching projects directly determines the overall quality of experimental teaching. Given the above analysis, conducting concrete structure simulation experiments based on the Simdroid simulation platform is an important measure to promote the deep integration of modern information technology and experimental teaching projects, expand the breadth and depth of experimental teaching content, extend experimental teaching time and space, achieve digital upgrading of experimental courses, and improve the quality and level of experimental teaching. However, although online virtual simulation teaching has certain advantages over traditional teaching in terms of teaching methods, considering the characteristics of hands-on operation in experimental courses, online virtual simulation experimental teaching cannot completely replace the practical operation training of traditional teaching. Therefore, in the teaching process, multi-dimensional teaching methods such as online teaching and blended teaching should be implemented to integrate and penetrate each other, thereby improving the quality of experimental teaching [8-10], eliminating "water courses", creating "gold courses", optimizing course content, enhancing teaching ability, busy students, and achieving practical learning results, forming a first-class undergraduate course system with professional characteristics, constructing a higher level of talent for concrete structure simulation experimental teaching.

2. Teaching Design for Concrete Structure Experiment

The concrete structure course is a compulsory backbone course for civil engineering majors in universities. In long-term teaching practice, the learning of this course is mainly based on courses such as material mechanics, structural mechanics, and civil engineering materials, with strong comprehensiveness. Based on classroom theoretical learning, concrete structure experiments are a highly practical professional technical course in civil engineering. Using experimental techniques as a means, relevant parameters reflecting the actual working performance of structures or components are measured, providing important basis for determining the load-bearing capacity and safety reserves of structures. The task of this experiment is to combine theoretical courses with practical teaching, so that students can acquire basic knowledge and skills in building structure experiments, be able to design and plan general building structure experiments, and receive preliminary training and practice. However, with the development of mechanical technology, the basic experimental equipment for civil engineering courses is no longer sufficient to meet the needs of course construction. In response to the destructive and non repeatable characteristics of concrete component testing, students find it difficult to explore and learn the stress forms and failure states of structural components under various working conditions in experimental teaching and on-site internships. In order to explore and innovate effective experimental teaching methods and means, the concrete structure simulation experimental teaching is a

ISSN 2522-6398 Vol. 6, Issue 26: 43-48, DOI: 10.25236/FER.2023.062608

specific measure advocated by the Ministry of Education for the reform of new engineering undergraduate education. Our college has established a concrete structure simulation design practice base based on the Simdroid simulation platform through cooperation between schools and enterprises. Combined with the soil and wood engineering structure experimental platform, the experimental teaching design is carried out to achieve theoretical design of concrete structure stress, measurement of actual mechanical properties Multi working condition simulation and comprehensive innovative learning are integrated in all aspects to cultivate students' understanding and mastery of the entire process system of concrete structures. Therefore, adopting a personalized, intelligent, and ubiquitous hybrid teaching model that combines online and offline to form an open, shared, and effective information based teaching model is the direction of teaching reform in this course [11-12]. Simdroid software has powerful simulation capabilities, excellent performance, and good scalability, making it an efficient, reliable, and easy-to-use tool for the deep integration of information technology and education. Unlike other simulators on the market, this platform adopts full system simulation technology, which can fully simulate the entire operating system inside the simulator and seamlessly connect with various hardware devices of the host computer, thus achieving accurate simulation testing of the application program.

Based on the characteristics of concrete structure experimental teaching, a concrete structure experimental teaching design based on the Simdroid virtual simulation platform is carried out. The experimental teaching mode adopts a "online and offline" mixed teaching method, combining virtual and physical experiments, as well as a combination of student independent operation and teacher online guidance for teaching. The blended teaching mode of "online and offline" involves the interaction between students and teachers in a single stage before, during, and after class. Generally, theoretical teaching of concrete structures in the classroom will precede experimental and practical teaching, and due to teaching plans, schedule arrangements, and other reasons, there may be a longer time gap between the two teaching methods. Therefore, before carrying out blended teaching, experimental teaching teachers need to review and design according to the characteristics of each part of the teaching content, so as to gradually improve students' understanding and application of theoretical knowledge from shallow to deep, in stages, and gradually. In the pre class guidance stage, students complete login on the platform, conduct "experimental preview" of virtual simulation courses, and complete thinking questions; Classroom students sign in on the platform, the teacher teaches important and difficult content, precautions, raises questions, and students engage in free discussion. During the experiment, the teacher guides students to independently complete the experimental operation and analyze data; After class, the teacher assigns homework, raises questions, and students complete homework on the platform to participate in discussions. After the completion of students' virtual simulation experiment learning, conduct physical experiments to achieve a combination of virtual and real. After completing some physical experiments, the student platform is required to operate independently, and the teacher guides students online to independently complete the entire experimental process in the virtual simulation experiment. For any difficult problems that arise during the experiment, the online teacher provides timely guidance.

Based on the characteristics of application-oriented undergraduate universities and the ability of virtual simulation teaching to combine reality with reality, in order to meet the characteristics of civil engineering and industry needs, combined with the innovative entrepreneurship loading platform, 500T hydraulic loading press, reaction wall and other hardware platforms of our school's Civil Engineering Structure Experimental Training Center, as well as the current situation of testing equipment with automatic collection, Simdroid virtual simulation platform experimental teaching is carried out, which can complete civil engineering materials Various mechanical performance tests such as concrete structural components are carried out to achieve comprehensive and innovative learning of theoretical design, actual mechanical performance measurement, and multi working condition simulation of concrete structures. Through teaching practice activities, the teaching content is continuously improved and improved, further enhancing students' understanding and mastery of the entire process system of concrete structures. For example, in view of the many drawbacks of conducting large-scale concrete structure experiments, such as complex component design and pouring operations, long maintenance cycles, high costs, multiple experimental steps, inability to display some extreme special conditions, and non repeatability after physical structural damage, the Simdroid virtual simulation platform can be used for virtual simulation experiments of concrete structure damage under stress.

3. Implementation Approaches for Concrete Structure Experimental Teaching Design

Based on the above teaching design ideas, in the mixed teaching process of concrete structure

ISSN 2522-6398 Vol. 6, Issue 26: 43-48, DOI: 10.25236/FER.2023.062608

experiments, students need to input offline design parameters through the virtual simulation software platform interface, and generate experimental reports through online experimental operations, data analysis and processing, etc; Teachers conduct comprehensive evaluations of experimental results, design abilities, and other aspects by assessing the quality of online and offline design results. This can establish a complete design concept for students, cultivate their creativity and practical ability, enable them to deeply and systematically understand the working principles of concrete structures, combine physical experiments and engineering practice internships to improve teaching effectiveness, promote effective learning for students, and achieve the goal of online and offline mixed teaching of concrete structure experiments.

The Simdroid mesh generation module provides multiple generation functions and mesh control methods to meet the mesh generation needs of different models, while its structural analysis module provides a rich range of element types and material constitutive relationships, flexible connection and assembly methods, multiple load constraint application methods, and static/dynamic, linear/nonlinear finite element solvers, which can meet the needs of the vast majority of engineering structural analysis. Taking the virtual simulation experiment of the flexural bearing capacity of a reinforced concrete beam as an example, the complete experimental teaching process includes three parts: demonstration, practical operation, and simulation assessment. The main experimental operations include the entire process of component production, component installation, and loading test. Component production includes steel bar cutting, steel bar bending, steel bar strain gauge pasting (including steel bar grinding, positioning, cleaning, strain gauge pasting, connecting wires, welding wires, gluing, waterproofing treatment), binding steel bar cages, pouring concrete (including production of hooks, installation of steel molds, installation of steel bar cages into steel molds, pouring of concrete, vibration of concrete, plastering, and removal of steel molds). Curing of test specimens, brushing white lines on the side of beams, pasting copper columns, pasting concrete strain gauges (including concrete surface polishing, surface brushing, positioning and cleaning, pasting strain gauges, pasting wiring columns and welding wires), etc; Component installation includes installing supports, placing specimens in place, installing distribution beam ammonium supports, placing distribution beams in place, installing load sensors in place, installing magnetic gauge bases and dial indicators, connecting load sensors, strain gauges, etc; The loading test includes opening the strain gauge for preheating, zeroing the strain gauge, preloading, unloading, resetting the strain gauge, recording the initial reading, loading in the elastic stage, loading in the working stage with cracks, crack observation, and loading in the failure stage.

Therefore, based on the teaching ideas designed above, the experimental preview, experimental practice, and assessment mode modules are applied to different stages of student learning, including experimental principles and plans, specimen design, teaching demonstrations, practical exercises, and simulation assessments. Firstly, under operational guidance and teacher guidance, students learn experimental principles and plans and choose experimental component design parameters. Then, the teacher conducts operational demonstrations from three aspects: component production, component installation, and loading experiments, guiding students to learn how to use the keyboard and mouse to complete actions such as moving forward, backward, left, right, looking up, leaning down, dragging, connecting wires, buttons, knobs, and loading and pressing, thereby controlling the virtual environment to achieve human-machine interaction. Next, students need to independently conduct online experimental operations, complete all experiments through component design, load testing, analytical simulation, and complete report records based on the experimental situation. Teachers conduct comprehensive evaluations of experimental results, design abilities, and other aspects by assessing the quality of online and offline design results.

4. The significance of virtual simulation experiment teaching mode for concrete structures

The traditional blended teaching mode mainly focuses on video and text learning, but there are many shortcomings in the exercise of students' experimental and practical training abilities. The virtual simulation experimental platform, as a teaching resource, can be added to the blended teaching process, enriching both the teaching resources of blended teaching and the teaching methods of blended teaching. Enable students to engage in practical experimental learning based on virtual reality resources, both online and offline. The realistic experimental scenes created through the virtual simulation experimental platform can not only achieve dynamic and efficient interaction, but also enhance students' sense of participation and immersion, allowing them to engage in problem-solving, practical training, and experimental operations in the virtual environment, stimulate students' learning enthusiasm, improve their interactive and cooperative abilities, and deepen their understanding of tedious theoretical knowledge.

ISSN 2522-6398 Vol. 6, Issue 26: 43-48, DOI: 10.25236/FER.2023.062608

The virtual simulation experimental platform is more suitable for innovative learning and experimental environments where students can explore independently and collaborate, expanding the advantages of blended teaching mode, breaking the limitations of students' learning time and space, allowing students to engage in ubiquitous online learning anytime and anywhere while learning offline, achieving dual classroom teaching both online and offline. In the process of blended learning, students can watch theoretical explanations and experimental operation demonstrations through video during online preview. On the online and offline experimental platform constructed by virtual simulation technology, students can independently set and change experimental conditions for repeated learning in a safe simulation experimental context. At the same time, through interaction with experimental objects in a virtual simulation environment, three-dimensional and intuitive observation and operation, students can more intuitively understand and master knowledge and content, transform from knowledge receivers to knowledge innovators in the learning process, and create conditions for students to reconstruct and create knowledge.

In addition, in traditional experimental teaching processes, most of them involve teacher questioning and guidance, while some students respond and operate through individual interactions. However, introducing virtual simulation experimental systems into blended learning not only has the advantages of traditional blended teaching, but also allows students to interact with virtual objects in the virtual environment, allowing them to have a comprehensive immersive experience through multiple senses such as visual, auditory, and tactile interactions with the environment. As mentioned above, in the virtual simulation experiment of the flexural bearing capacity of the reinforced concrete beam cross-section, students learn and design different experimental parameters, such as reinforcement ratio, reinforcement ratio, shear span ratio, eccentricity, etc., to complete their own experimental reports. Combined with typical physical experimental operation and record reports, the entire complex process of the production, installation, and loading of reinforced concrete components is studied. The mastery and understanding of the internal structure, arrangement of measurement points, boundary conditions for loading, and structural failure characteristics of reinforced concrete components will be more profound.

5. Conclusion

In the context of new engineering, emphasis is placed on students' innovative and practical abilities, which places high demands on innovative and practical teaching. The design and implementation of a mixed teaching mode for virtual simulation experiments such as concrete structures is based on the needs of civil engineering college students Based on modern information technology, applying autonomous and controllable industrial simulation platforms and simulation apps to practical teaching can solve experimental courses that are difficult to operate, high cost, high consumption, irreversible operation, or have large-scale comprehensive training characteristics in experimental teaching. By comprehensively utilizing digital and intelligent technologies such as multimedia, 3D modeling, human-computer interaction, and virtual reality, students' enthusiasm and initiative in participating in experimental teaching can be mobilized, their learning interest and potential can be stimulated. The enhancement of students' innovative and creative abilities is conducive to cultivating a group of high-level technical talents who integrate design, analysis, and application, and promoting the new trend of higher education's transformation towards innovation and creativity.

Acknowledgements

This research was supported by the Xi'an University of Science and Technology's "Student centered Teaching Method Reform" Teaching Reform Project (No. JZ22032); The second round of research and practice project on the comprehensive reform of graduate education in Shaanxi Province: Exploration and practice of cultivating the scientific research innovation ability of civil engineering graduate students facing national needs (No. YJSZG2023091); Ministry of Education Collaborative Education Project: Construction of Concrete Structure Simulation Design Practice Base Based on Simdroid Simulation Platform.

References

[1] Zu Qiang, Wei Yongjun, Xiong Hongqi, etc.(2017). Discussion on the Construction of Provincial Online Open Virtual Simulation Experimental Teaching Project, Experimental Technology and

ISSN 2522-6398 Vol. 6, Issue 26: 43-48, DOI: 10.25236/FER.2023.062608

Management, 34 (10), 153-157.
[2] Liu Xiaojuan, Wu Fengjing, Deng Jiyong, et al. (2018). Exploration of the Construction of Chemical Virtual Simulation Experiment Teaching Project in Applied Undergraduate Universities, Modernization of Education, 5 (45),125-127.
[3] Tang Wenqian, Fang Lu, Xie Zhihua, et al. (2020). Research on the Motivation Mechanism of Industry Education Integration under the Background of Practical Education Reform: From the Perspective of "Double First Class" University Engineering Practical Education, Education Research, 3 (10), 102-104.
[4] Wang Zhihua, Cao Guangsheng, Zhang Ligang. (2017). The Construction of Virtual Simulation Experimental Resources from the Perspective of Educational Informatization, Experimental Science and Technology, 15 (4), 152-155.
[5] Feng Xiaoying, Wang Ruixue, and Wu Yijun. (2018). A review of the current research status of blended learning at home and abroad - an analytical framework based on blended learning, Journal of Distance Education, 36 (03), 13-24.
[6] Chen Qian, Han Ji, Fan Xiang. (2021). Research on the Application of BIM-FILM Technology in the Teaching of "Civil Engineering Construction Technology": Taking the Construction of Collecting Wells as an Example, Southern Agricultural Machinery, 52 (14), 175-177.
[7] Ye Fei, Liao Chengzhu, Zhang Jianbo, etc. (2022). Experimental Teaching of Deep Integration of MOOCK and Virtual Simulation, Journal of Beijing University of Science and Technology (Social Sciences Edition), 38 (01), 67-72.
[8] Hao Zhiqiang, Zhang Xiaoying, Feng Yuling, et al. (2021). Reform and Exploration of the Teaching Mode of "Online+Offline+Virtual Simulation" Diversified Experimental Courses, Shandong Chemical Industry, (50), 186-189.
[9] Lian Wenlei, Yang Lili, Yu Bing. (2022). Exploration of blended online and offline teaching based on virtual simulation, Practical Training and Exploration, 2, 91-94.
[10] Xiong Hongqi. (2022). Construction of an online and offline integration professional experimental teaching system based on virtual simulation, Experimental Technology and Management, 39 (3), 5-9.
[11] Yan Qun, Li Qing, Cui Jiarui, etc. (2021). Research on the blended teaching mode of practical courses in the context of new engineering, Experimental Technology and Management, (1), 198-201.
[12] Jia Peng, Zhao Wen, Wang Shuhong, et al. (2022). A Hybrid Teaching Practice for Tunnel Engineering Driven by MOOC and Virtual Simulation Experiments, China Modern Education Equipment, 381, 72-74.