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Conception and Practice of Experimental Teaching System with Combination of Virtuality and Reality in Building Environment and Energy Engineering Specialty Under the Background of Large-Category Enrollment

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Abstract: *Under the carbon peaking and carbon neutrality goal, the development of intelligent buildings will become a new solution for building energy conservation in the new era. The development of intelligent buildings will inevitably put forward new challenges to the training of building environment and energy engineering (BEEE) specialty. At present, many schools adopt the mode of large-category enrollment and professional diversion. In order to better adapt to the cultivation of innovative talents under the situation of large-category enrollment, attract excellent students to choose our specialty, and solve the contradiction between the traditional experimental teaching and talent training mode of BEEE specialty and the demand for new compound talents in the intelligent construction industry, this study proposes the conception of the experimental teaching system with the combination of virtuality and reality in BEEE specialty. Through the complementarity of real experimental teaching and multi-dimensional virtual experimental teaching, the talent training mechanism of BEEE specialty will be improved.*

Key Word*:Experimental teaching system; Combination of virtuality and reality; Building environment and energy engineering specialty; Large-category enrollment.*

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I. Introduction

With the deepening of the reform of higher education and the continuous improvement of the comprehensive quality of higher education in China, the information technology of education and teaching is becoming more and more important in cultivating students' innovative and entrepreneurial spirit and engineering practice ability. Virtual simulation technology and numerical modeling method are the main ways to realize the informationization of education and teaching, and also the important content of the construction of digital intelligent center of experimental teaching[1,2,3].

At present, more and more colleges and universities implement large-category enrollment methods. In order to attract more outstanding students to choose our specialty, high-level laboratory construction is more important. After three years of the epidemic, online education will play an increasingly critical role. According to statistics, in the field of higher education, during the epidemic period, all ordinary undergraduate colleges across the country implemented online teaching. 1.08 million teachers opened 1.1 million courses, a total of 17.19 million courses, and 2.3 billion college students studied online[4]. The development of online education has promoted the sharing of high-quality education resources; it has promoted the balanced development of education; it has broken through the time and space limitations of traditional education; it has served the lifelong learning of the whole people, ; it has innovated the traditional education process, and it has promoted the reform of teaching structure[5]. However, in the talent training system of BEEE specialty, the cultivation of engineering practice ability is particularly important. Therefore, under the reform of national higher education informatization, it is particularly important to establish the experimental teaching system with the combination of virtuality and reality in BEEE specialty.

II. Discussion

1. The background of constructing experimental teaching system with the combination of virtuality and reality in BEEE specialty

In 2012, the Ministry of Education promulgated the "Undergraduate Specialty Catalogue of Higher Institutions" and "Management Regulations for Undergraduate Specialty Settings of Higher Institutions". In these regulations, BEEE specialty is a combination of building energy saving technology and engineering, building facilities intelligent technology and building environment and equipment engineering. There requires senior engineering and technical personnel and management personnel with the ability to design, construct,

debug, operate and manage public facilities systems such as air conditioning, heating, ventilation, building water supply and drainage and gas supply, building thermal energy supply system and building energy conservation, and the ability to formulate building automation system schemes[6]. Building energy consumption accounts for 40-50 % of the total social energy consumption, and the energy consumption of building equipment system can reach 50 %. Therefore, the partial task of carbon peaking and carbon neutrality needs to be undertaken by the relevant talents of BEEE specialty.

In the current large-category enrollment, the BEEE specialty is generally classified as civil engineering, energy, machinery or environment. With the rapid development of science and technology, the cross-integration between different specialties is becoming more and more extensive and in-depth, and emerging technologies are constantly emerging, such as big data, internet of things (IoT), virtual reality and augmented reality (VR / AR), digital twin, which fills the theoretical framework of the development of smart buildings. These emerging technologies make the digitization and intelligence of buildings a reality, and provide a new feasible solution to achieve the carbon peaking and carbon neutrality goals from the field of building technology.

Emerging industries and technologies provide an opportunity for the development of smart buildings, but the real development of smart buildings is inseparable from front-line designers, managers and construction operation and maintenance personnel. So there puts forward a new test for the training of BEEE professionals. The development of smart buildings requires participants to have rich experience in the operation and adjustment of practical building systems. According to the interpretation of the professional certification standards for BEEE specialty, there requires that the graduates of BEEE specialty should have the ability to solve complex engineering problems. In addition to the reserve of basic engineering expertise, engineering practice education is also indispensable. Therefore, experimental education plays a very important role in the training system of BEEE professionals.

Before the rapid development of online education, the traditional experimental education of BEEE specialty mainly includes the following categories: professional basic course experiments which mainly includes fluid mechanics experiments, engineering thermodynamics experiments, and heat transfer experiments, professional experiments and professional cognition and production practice. Among them, the professional experiments of BEEE specialty in University of Shanghai for Science and Technology mainly include building equipment and system experiments, building environment test experiments, building equipment automation experiments and so on. According to the characteristics of their own professional construction and development, different universities have different emphasis on professional experiment setting, but the overall content is basically the same. In addition, cognition practice and production practice are basically the only opportunity for students majoring in BEEE specialty to systematically contact the practical construction equipment system before graduation.

In the above three types of experimental teaching courses, the first type of experimental teaching mainly provides students with a deep understanding of the basic professional theory knowledge. The second type of experimental course mainly provides practical understanding of professional knowledge. And the third type belongs to practical courses, providing students with basic professional practical cognition. However, the three types of experimental and practical courses cannot really provide students with the practical building environment equipment system for practical operation training. If the practical building environment equipment system is provided as a student operation training, the following problems may exist:

(1)Safety: There are many potential safety hazards in the teaching of building environment equipment system, such as the measurement of cooling tower on the roof which needs to climb up, the high-speed rotating equipment such as water pump, fan and refrigeration unit in the equipment room, electrical power installation and the high-temperature equipment such as steam or hot water plate heat exchanger.

(2)Inoperability: The practical equipment system will not exist alone, and can only be an operational part of the building. It must be operated by professional operation and maintenance personnel, and random operation may cause system failure and affect the production and operation of the building. Moreover, the system delay of the building equipment system in the practical building is large, and the operation adjustment under the change of the annual working condition cannot be realized in a short time.

(3)As a major part of building energy consumption, the building environment equipment system needs huge energy consumption to maintain normal operation. If it is provided to students for experimental teaching, the cost of energy consumption will be very huge. Moreover, the current buildings generally have problems such as crowded equipment room area, so it is impossible to specifically establish a building environment equipment system experimental site for experimental teaching.

In summary, at present, there is a serious imbalance between the traditional experimental teaching method and the training mode of BEEE specialty and the rapid development of intelligent construction industry on the demand for high-level talents with rich experience in operation and maintenance engineering of building environment equipment system. The contradiction between supply and demand of this kind of talent training

poses new challenges for the training of BEEE professionals. In order to break this imbalance, it is urgent to establish the experimental teaching and talent training mode of the combination of virtuality and reality.

2. Construction of experimental teaching system with the combination of virtuality and reality in BEEE specialty

The experimental teaching system with the combination of virtuality and reality in BEEE specialty needs to innovate on the basis of the existing real experiment teaching mode reform the existing real experiment teaching, and integrate the virtual experiment teaching mode. And the virtual experiment teaching mode can be carried out in many ways. In addition, the virtual part and the reality part of experimental teaching system with the combination of virtuality and reality in BEEE specialty should have their own emphasis and should not give unequal emphasis.

2.1 Real experiment teaching

The real experiment teaching system is still an indispensable part of the experimental teaching, because the real experiment is a bridge between theoretical knowledge and practical application. The composition of the real experiment should continue the traditional real teaching such as professional basic experiments including engineering thermodynamics, fluid mechanics and heat transfer and professional experiments including building equipment and system experiment, building environment test experiment, building equipment automation experiment. For this part of the real experiment, the experimental system is required to have a high degree of integration, and the practical learning of several knowledge points should be completed through the complete system.

Real experiment teaching is the most direct continuation of theoretical knowledge learning. With the depth of mastery of knowledge, the types of real experiment teaching are also progressive, mainly divided into cognitive, verification and design experiments. And for the real experiment, the operability is required to be well, which can support the cultivation of practical ability. At the same time, the design of the experimental system needs to fully consider the cultivation of innovative and entrepreneurial ability. As shown in Figure 1, it is a modular air-conditioning system experimental device independently developed by the BEEE specialty in University of Shanghai for Science and Technology. Through the integration of the cold source module, fluid conveying module, air processing equipment module and load module of the complete air conditioning system, each module can be tested separately, and each module can be integrated for system experiments. The experimental device is well integrated, and according to the learning situation of students, the cognitive, verification and design experiments can be carried out respectively.

Figure1:Modular air-conditioning system experimental device

2.2 Virtual experiment teaching based on VR or virtual simulation technology

Under the current technical conditions, virtual reality technology is based on computer technology, through the input and output functions of specific sensing devices, to build a virtual environment in the user visual image[7]. The application characteristics of VR technology include conception, immersion and technicality. Among them, the performance of conception is to carry out innovative activities on the basis of the relatively real environment provided by VR technology, and immersion is manifested as giving users a real experience, creating an immersive illusion, and interacting with the virtual environment through language and action. In addition, from the perspective of the technical factors involved in VR technology, the system composition is complex and requires the help of the Internet and computers[8].

Therefore, VR or virtual simulation technology can be used to virtualize the building environment equipment system, or further establish the digital twin of the real system, so that the operation adjustment can be

carried out in the virtual simulation system, which is almost consistent with the real operation. Then the shortcomings that the real system cannot provide students with real operation will be solved.

Virtual simulation elements are mainly reflected in three aspects:

(1)Virtual simulation of building environmental equipment: The system will actually use the building air conditioning system in the various types of equipment for virtual simulation modeling, such as cooling towers, fans, pumps, chillers, valves.

(2)Simulation of the real operation data of the building environment equipment system : Such as the dynamic load information, equipment capacity, dynamic energy efficiency curve and other data and parameters of the real building are integrated into the virtual simulation system as part of the model. Figure 2 shows the virtual simulation model of the conference room served by the central air conditioning system in the virtual simulation system. The load situation can be changed by adjusting the number of personnel, so as to be closer to the real operation of various load changes.

(3)Virtual simulation of actual operation: Such as the adjustment of the valve, in the virtual simulation system, the valve opening can be adjusted by dragging the valve with the mouse, so as to restore the real operation to the greatest extent, so that students can understand the significance of real operation in the process of virtual experiment.

The virtual simulation experiments that can be set up include outlet water temperature change of cooling tower, parameter change and influence of refrigeration cycle, load rate and energy balance, bypass flow regulation of surface air cooler, flow regulation of pump and other virtual simulation experiments belonging to different modules. In the process of continuous improvement, the virtual simulation intelligent building platform can be gradually formed, and various virtual simulation experiments can be integrated into the digital twin of the real intelligent building, so that students can carry out the operation and management practice of intelligent building environmental equipment and system from the "micro" perspective.

Figure2: Virtual simulation of air conditioning space

2.3 Virtual experiment teaching based on BIM technology

Building information model (BIM) technology is based on computer technology and combines the information of the whole construction project to construct a three-dimensional visual information model, which plays its corresponding role in the whole life cycle of the project from investigation to design, construction, operation and maintenance[9,10].

At present, BIM technology is mainly applied to pipeline synthesis and collision inspection in the field of HVAC system design. Therefore, in the experimental teaching system with the combination of virtuality and reality, BIM technology is introduced to visualize the air conditioning system and air conditioning equipment room and combined with the virtual simulation system to provide the required equipment and system model for the virtual simulation system. As shown in Figure 3, it is the BIM model of the refrigeration equipment room in the virtual simulation experiment system.

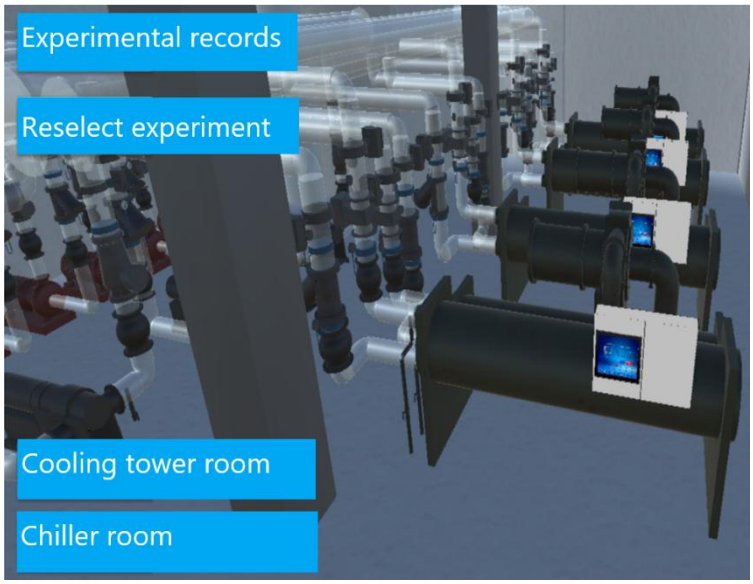

Figure 3: BIM model of equipment room

2.4 Virtual experiment teaching based on numerical simulation

Numerical simulation technology is widely used in the related research of BEEE specialty. In the experimental teaching, numerical simulation technology can be used to visualize the abstract fluid motion, flow field and other problems. Specifically, it can include the following knowledge points: the air distribution form of the air conditioning space and the flow and pressure distribution of the fluid in the pipeline in different systems such as refrigeration system, air conditioning system and heating system. So it can give students an intuitive understanding of the characteristics of pipeline flow under different systems and different fluids and their influence on system operation.

Therefore, the virtual simulation experiment teaching system of the BEEE specialty can be constructed from three perspectives: VR or virtual simulation technology, BIM technology and numerical simulation technology. Together with real experiments and cognition and production practice, it constitutes an experimental teaching system with the combination of virtuality and reality. Figure 4 shows that the real experiment and practice part of the experimental teaching of the experiment teaching of the BEEE specialty can provide theoretical basis, real model and operation data for the virtual experiment teaching part, and the virtual experiment part can be reproduced and verified by numerical simulation. Through BIM technology, the virtualization of field prototype is combined with virtual simulation technology to form virtual simulation experiments of different modules, covering different dimensions of ability training in the operation and management of intelligent building air conditioning systems.

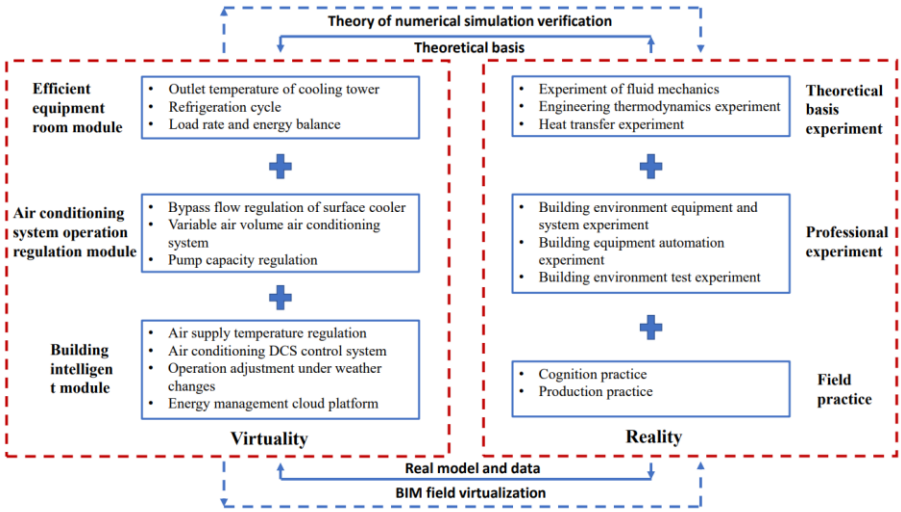

Figure4: Experimental teaching system with the combination of virtuality and reality in BEEE specialty

III. Conclusion

Under the carbon peaking and carbon neutrality goals, smart buildings have developed rapidly with the help of emerging science and technology industries, but it also poses new challenges for the training of BEEE professional. In order to solve the imbalance between the supply and demand of traditional experimental education and the demand for high-level compound talents in the intelligent building industry, this paper proposes a new experimental teaching system with the combination of virtuality and reality which is suitable for the BEEE specialty. On the basis of continuing the traditional real experimental teaching and making corresponding innovations, combined with VR or virtual simulation technology, BIM technology and numerical simulation technology, the complementary of real experiment and virtual experiment is used to form a more complete experimental teaching system, so that the talent training of the BEEE specialty can meet the needs of industry development.

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