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The Application of Virtual Simulation Training Systems in Digital Construction Teaching

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Abstract: *Modern educational efforts focus on synchronizing theory and practice, with digital construction courses gaining attention in engineering education. Traditional training models face challenges such as high-risk on-site conditions, elevated costs, limited hands-on opportunities, and students' difficulty in intuitively mastering complex construction techniques, making it hard to meet the comprehensive training requirements for engineering talent development in the new era. This paper begins by addressing current shortcomings in construction course instruction, then explores the advantages and methods of virtual simulation training systems in digital construction education. It examines three key aspects: pre-class preparations, in-class applications, and post-class extensions—specifically including system development, in-class group discussions and virtual reviews, and post-class digital extensions. The study investigates implementation pathways for virtual-real integrated teaching models, aiming to overcome traditional training constraints, effectively reduce risks and costs, enhance students' practical engineering skills and digital literacy, and provide a practical reference for future digital construction course activities.*

Keywords: *virtual simulation training system; digital construction; construction course teaching; system construction*

1. Preface

The teaching of construction courses mainly emphasizes the construction operation as the core, conveying the technical methods, management requirements, supervision norms and other contents related to the work to students, attaching importance to the synchronization of theory and practice, in order to enhance students' comprehensive literacy, master the conventional technical and management knowledge and skills of construction engineering. With the development of the times and technological progress, digital technology is gradually being applied in the teaching activities of construction courses, which to some extent addresses the shortcomings of traditional models. Further analysis reveals that digital technology still has drawbacks and is difficult to meet the learning needs of all students, which objectively promotes the application of virtual simulation training systems. Exploring its application advantages, methods, and other aspects has certain practical significance.

2. The current teaching of construction courses is insufficient

2.1 Fragmentation of knowledge

The teaching of conventional construction courses combines theoretical and practical content, but there is a problem of fragmented knowledge. The problem refers to the low knowledge density in the teaching process, which requires students to repeatedly explore and learn in order to absorb sufficient knowledge. Under the usual offline teaching mode, teachers often need to lead students to different sub sites to impart knowledge related to construction technology, safety regulations, and material identification. Knowledge within the same teaching scenario often presents fragmented characteristics and cannot be displayed in a centralized manner. The current digital teaching model has seen some improvement in knowledge concentration, but lacks interactivity and still requires students and teachers to invest more energy in exploration, which reduces learning efficiency[1].

2.2 Safety hazards exist

From the perspective of characteristics, construction teaching has certain peculiarities, and the

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learning complexity of theoretical knowledge is not high. However, practical teaching requires in-depth exploration of engineering sites, which poses certain safety risks. Previously, there was a major accident in Inner Mongolia where multiple students died collectively during their practical learning process, and we need to be vigilant. There are certain safety risks associated with high-altitude construction operations and power system construction activities, and students may be electrocuted or even fall due to a lack of self-protection awareness and ability. In the digital mode, this problem has been somewhat controlled, but students are unable to go deep into the site and personally perceive the construction methods and safety requirements, which limits their growth quality and still needs to seek improvement[2].

2.3 Insufficient extensibility

The conventional teaching of construction courses is insufficient in terms of extensibility. In offline teaching mode, the knowledge provided by teachers is difficult to extend to after class, and when students cannot fully understand the relevant content, they can only learn independently and search for materials, resulting in a decrease in learning efficiency[3].In the digital mode, the knowledge provided by teachers can be extended to after class, but it is too theoretical, and students have a relatively single way of learning and perceiving knowledge, making it difficult to comprehensively improve practical skills. Even if students have deficiencies in their abilities, they cannot independently extend their learning to understand the relevant deficiencies, and the quality of their growth cannot reach the optimal level.

2.4 Restricted Space

From a common perspective, there are certain spatial limitations in the teaching of construction courses, which are reflected in two aspects. Firstly, theoretical content is mainly concentrated in the classroom, and students' learning space is relatively narrow, requiring them to follow the teacher's footsteps to complete knowledge perception and absorption during the classroom stage. Secondly, the space for practical content is not broad. In offline mode, practical content provided by training bases is the main focus. Even with basic digital technology, students' learning is still relatively passive. The expanded virtual space is spacious, but the practicality is insufficient, and the space for providing services to students is still not large, which cannot properly serve their growth.

2.5 Time limited

The teaching of construction courses often requires a long duration, with undergraduate and vocational programs requiring at least 4 and 3 years of teaching respectively to ensure the integrity of knowledge and technology transmission. Under the traditional teaching mode, the time constraints are worth paying attention to. In the offline practice process, teachers lead students to understand the application methods, inspection requirements, safety supervision methods, etc. of a certain engineering technology. During this process, students follow the teaching timeline and construction timeline to complete information perception and absorb knowledge. After the teaching is completed, even if students cannot fully understand certain content, it is difficult to repeat learning, and the time is irreversible[4].

3. Application advantages of virtual simulation training system in digital construction course teaching

3.1 High knowledge density

The application of virtual simulation training system in digital construction course teaching directly enhances knowledge density. On the one hand, the virtual simulation training system can concentrate a lot of knowledge and solve the problem of knowledge fragmentation[5]. On the other hand, mature integrated technology can serve students to carry out online practice, and students' perception, learning, and application of knowledge are integrated, further improving knowledge density. If the teaching content is concrete crack control, students can acquire theoretical knowledge regularly, and with the support of intelligent tools and equipment, conduct practical learning in an online virtual way, simulate concrete construction activities, further consolidate the learning foundation, and improve the effectiveness of knowledge mastery.

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3.2 Ideal Security

From a practical perspective, the application of virtual simulation training systems in construction course teaching can also enhance safety. Compared with conventional offline teaching, the virtual simulation training system can complete the teaching of students through the establishment of models and virtual practice, without any safety hazards, especially for dangerous practical activities such as high-altitude operations, ensuring safety. Compared with traditional digital teaching models, virtual simulation training systems have higher operability. Students can verify their learned knowledge through interaction with software and teaching tools, enriching learning methods and improving learning quality while ensuring safety.

3.3 Scalable Development

The application of virtual simulation training system in construction course teaching has the advantage of scalability. For the teaching of construction organization related to rivers, after completing classroom education, students can make various attempts in the virtual simulation training system, continuously simulate design schemes, analyze the feasibility and potential risks of construction schemes by adjusting parameters. Repeatedly adjusting parameters and conducting virtual practice to grasp parts that cannot be deeply understood during the classroom stage can also help achieve the correlation between theoretical and practical content. Compared to conventional digital modes, the application of virtual simulation training systems improves the practicality of technology application and enhances the efficiency of extended learning[6].

3.4 Full process visualization

Compared with traditional construction courses, the application of virtual simulation training systems has the characteristic of full process visualization, which breaks the general spatial limitations. On the one hand, the virtual simulation training system is not limited by classroom space, and students can learn at any time during holidays and after class time with the support of information technology and equipment. On the other hand, the operability of the virtual simulation training system is strong, and the spatial boundaries of students' learning can be expanded to some extent. Based on personal learning needs, classroom knowledge characteristics, and thinking, practical learning can be organized at any time, and knowledge practical learning and application can be completed in a visual way without general spatial limitations.

3.5 Information can be reviewed

The application of virtual simulation training system in digital construction course teaching has the advantage of information replayability, which is reflected in two aspects. Firstly, in the case of a stable timeline, students can replicate the entire learning process and use virtual simulation training to repeatedly manage and learn knowledge content at any time node. The second is to use a virtual simulation training system to integrate and adjust certain construction processes and teaching content under the condition of unchanged space, evaluate the impact and feasibility of different parameters by changing them, and improve learning effectiveness through the system, without being limited by time factors, expanding learning boundaries and effects.

4. Application Method of Virtual Simulation Training System in Digital Construction Course Teaching

4.1 Pre class work

In the pre class stage, it is necessary to organize the construction of a work system based on the needs of digital construction classroom teaching and the characteristics of virtual simulation training systems, and to do a good job in resource collection and service teaching activities.

In terms of work system construction, it is advocated to strengthen hardware equipment management and build an IoT work system. Hardware devices include computers, remote management devices, integrated tools, etc. Taking computers as an example, their virtual memory, video memory, and disk space should reach 32GB, 16GB, 2TB or more respectively to meet the needs of collecting and processing large amounts of data, and to provide synchronous learning space for multiple teachers

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and students. The management of other devices also follows this principle, ensuring their performance when conditions permit. In the Internet of Things mode, it is necessary to open multiple interfaces to allow teachers and students to access the teaching system, access databases, download or browse relevant resources, and participate in learning at any time, provided that the connection is legal.

In terms of resource collection, the main focus is on increasing the total amount of information and improving its structured and semi-structured level through processing, in order to facilitate the use of teachers and students. For civil construction, several different building cases can be selected to form multiple independent learning cases, which are convenient for students to access and view at any time. Alternatively, based on the technical characteristics, specialized technical content such as base compaction and earthquake resistance can be selected, and a case study can be formed and entered into the system for teachers and students to select and apply according to their learning needs and teaching requirements. All resources should be regularly organized and updated, adding new content related to construction technology and management, including technical content, national regulations, and local new requirements, to ensure that teaching content always matches social development trends.

4.2 In class Applications

Entering the in class stage, the application of virtual simulation training system focuses on flexibility and practicality. On the one hand, we should provide students with a basic space for knowledge absorption and application based on their common learning needs. On the other hand, we should ensure that the work is in-depth and specific according to the teaching situation and real-time changes.

If the teaching content is green building construction technology, teachers can access existing resources, provide digital building construction, management, and design related models, and use the models to explain in detail the relevant technologies of green building construction. After entering the practical teaching stage, teachers can ask several questions to guide students' learning ideas. For example:

What technology can be used to control the high cooling energy consumption of Building A? ”

How can Building B cope with the impact of heat island effect and high heating consumption in winter? ”

Students use relevant problems and virtual simulation training systems to analyze and continuously apply various parameters to their personal designs for practical analysis until the problems are resolved. Some construction related content and knowledge are difficult, and the application of virtual simulation training systems is also difficult to ensure the learning effectiveness of all students. Teachers can use group learning or project-based learning methods to divide students into several groups to complete the analysis and learning of difficult and key problems. For knowledge that requires long-term learning to master, project-based learning is used to provide services for students. For example, in the "Design and Construction Plan of Building A", teachers can provide detailed information on the functions, cost goals, and project schedule goals of Building A. After providing it to students, they are required to complete the relevant learning of the project within one month (or other time), including drafting the construction plan, construction process and key steps, building BIM models, and coping methods for safety issues. After all the learning content is completed, teachers will track and evaluate the completion status of each group's project.

Considering that different students have different interests, the application of virtual simulation training system is not singular. Teachers can also encourage students to select learning projects based on their own learning interests, submit the projects to teachers for review, correct any worthless or unnecessary designs, add content related to construction, and provide feedback to students as a usable project. Students can complete the learning of the project as individuals or groups, and complete practical, design, and other work through the virtual simulation training system. The teacher's comments are also based on the completion status of each student's project, and the virtual simulation training system serves as a tool to assist students in learning.

4.3 After class extension

The application of virtual simulation training system in digital construction course teaching can be extended to the post class stage, which includes three aspects: problem inspection and correction, independent learning based on interests, and tracking and teaching after resource aggregation[7].

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Some students have exposed certain problems during the classroom learning stage, and the classroom time is limited, making it difficult for teachers to fully correct them. Relevant issues can be summarized, and students are encouraged to use their after-school time to learn on their own. If the parameters of the concrete pouring strip and foundation reinforcement designed by students are inappropriate, they can be informed of the problem and encouraged to continue design adjustments after class. The virtual simulation training system will be used for design verification until the relevant issues are resolved.

On this basis, students can also independently use virtual simulation training systems for learning. The learning content and methods are relatively free, and modern technology methods are used to assist students in active learning, so that their learning interests are paid attention to and respected, providing support for their long-term growth. Schools can provide necessary network related services, and open computer rooms allow students who lack personal computers to enter the computer room for learning. Finally, the teacher will organize the classroom teaching content and periodically post the content that is prone to problems and errors in the learning group, encouraging students to review and use the virtual simulation training system for repetitive practical learning. If students repeatedly fail to pay enough attention to the completion acceptance after construction, teachers can inform them of the acceptance technical methods and main standards, guide them to use virtual simulation training systems for repeated learning and practice, and enhance their learning effectiveness, knowledge mastery, and application awareness.

5. Conclusion

In summary, the application of virtual simulation training system in digital construction course teaching has certain value and can be given more attention. However, there are certain safety hazards and obvious time and space limitations. The application of virtual simulation training system has alleviated the above problems to a certain extent. In practical work, it is necessary to attach importance to the construction of virtual simulation training systems and resource collection. When entering the classroom teaching stage, it is required to combine common requirements and student learning situations, organize group practice and discussion, pay attention to information collection and review after class, use digital technology to continuously improve students' learning coherence, and provide services for their rapid and stable growth.

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