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Application of BIM + Virtual Simulation Technology in Road Engineering Construction Technology and Organization Course

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Abstract: We focus on the goal of undergraduate talent training, consider the course features of Road Engineering Construction Technology and Organization, analyze the problems existing in the practical teaching of the course, use the advantages of BIM + virtual simulation technology, design a scientific and reasonable practical teaching content of Road Engineering Construction Technology and Organization, and address the contrast between the strong practical aspect of the traditional Road Engineering Construction Technology and Organization course and the lack of practical instruments in hope to improve students' learning autonomy, enhance the quality of practical teaching, achieve the training objectives of the course, and nurture applied technical talents.

Keywords: BIM + virtual simulation technology; Road Engineering Construction Technology and Organization; Course content integration and implementation

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1. Introduction

Chongqing Engineering College is a general university aiming to cultivate application-oriented technical talents. The knowledge system is mainly designed for the grassroots and the first line of production, while the curriculum of the personnel training program emphasizes more on engineering practice and application, which nurtures students with strong hands-on skills and certain technology development and innovation skills [1].

Road Engineering Construction Technology and Organization is a comprehensive and practical core course focusing on roads and bridges in civil engineering. The course provides the necessary professional skills for road construction, inspection, supervision, and management. Therefore, the corresponding engineering practical skills must be cultivated in the teaching process.

On the one hand, since the course involves a wide range of practical aspects, road construction project volume, complex construction environment, raw materials, and equipment investment, there are certain safety hazards and peculiarities, which might cause difficulties in hands-on practice when completing practical tasks. Moreover, the course has two kinds of classroom practices, one of which is conventional laboratory tests (*e.g.*, asphalt three-index tests, mix design, compaction test, *etc*.), which are usually limited by the type of test and deter students from internalizing and understanding the construction process as a whole (*e.g.*, mix ratio design and mixing); the second is the road and bridge model designed and invested by the school or typical construction processes (such as pile foundations, steel reinforcement cages, and other concealed projects), which are restricted by the quantity and size of the models or physical objects and at a disadvantage of being time-consuming and costly.

Therefore, course instructors are required to introduce more intuitive, realistic, and innovative teaching methods adapted to the development of engineering in traditional practical teaching. After two years, the teachers found that the use of BIM + virtual simulation technology can effectively solve certain problems in the practical teaching of the traditional Road Engineering Construction Technology and Organization course. They are constantly optimizing the teaching design with an aim to improve the teaching effect and quality of the course. Based on the development trend of BIM in foreign countries and China as well as the application of virtual simulation, through the reform, the part that covers the course teaching plan will be removed, while the part that involves the cultivation of knowledge and skills needed by the society will be enhanced, so as to improve the overall quality of talents, enhance the competitiveness of graduates, and provide the society with high-level innovative talents.

2. Basic idea of BIM + virtual simulation technology in the course teaching

With the continuous development of science and technology, BIM and computer simulation technology are widely used in various fields of society. The core of BIM technology is to create a virtual three-dimensional (3D) model of a specific construction project in the computer [2], while using digital technology to ensure that this model is complete and consistent with the actual situation of the building engineering information base through a real simulation software before the building is completed, *i.e.*, a preview of the whole construction process in advance, in order to achieve a foolproof construction process. The intention of using BIM is to establish a model information base, depict the entire life cycle of construction projects, and realize the synthesis and sharing of information based on building models between different stages and different professions. Virtual simulation, also known as virtual environment or virtual reality, is a more advanced computer technology that involves sensing, simulation, microelectronics, and other computer-integrated technology with 3D simulation of the real environment.

The application of BIM + virtual simulation technology can theoretically address the problems of “difficult to see, high risk, and abstraction” in practical teaching to a large extent. BIM + virtual simulation technology can be used to simulate the virtual environment, construction progress, construction plan, construction cost, and virtual scene roaming. The incomparable simulation function is the core feature and advantage of simulation technology. BIM + virtual simulation technology can also be used in road construction, road base construction, road mixing, asphalt pavement surface installation, foundation construction, and other high-simulation activities.

3. Current situation of Road Engineering Construction Technology and Organization course teaching

3.1. Gap in theoretical learning and engineering practice

In terms of economics and operability, it is unrealistic to acquire and operate given the needs of undergraduate teaching. There is a significant time gap between the theoretical learning of this part of knowledge via classroom lectures and the course practice or engineering practice internship, resulting in the fragmentation of the two aspects of learning and the poor effect from the integration of theoretical and practical learning.

3.2. Difficulty in learning the internal composition of equipment and carrying out practical operations during practical sessions

Due to large road construction equipment and difficulties in loading and unloading, students are unable to visually appreciate the internal composition and functional realization of each part of the equipment during practical sessions. This would affect their understanding of subsequent learnings. At the same time, the high cost and complex control of the equipment deprive students of participating in the operation and control of the mixing plant. As a result, they lack an understanding of the control of the production parameters of the mixing plant. All these would significantly affect students' knowledge about mixing plants, especially when they are exposed to such equipment during an internship.

3.3. Primitive understanding of large equipment composition and lack of engineering experience among university teachers

Road engineering construction processes are complex and diverse. In recent years, with the development of unmanned technology and the intelligentization of construction, these mechanical aspects of knowledge are beyond the conventional knowledge framework of teachers. On the other hand, there are many factors that affect road construction organization and production quality control as well as unforeseen circumstances, which are complicated and evident against the background of new technologies and materials, requiring rich practical engineering experience for students to understand in a comprehensive manner [3]. The above situation has brought about limitations to the teaching of the course.

3.4. Practical teaching limited by time and content

The Road Engineering Construction Technology and Organization course has 32 credit hours (22 hours of theory classes and 10 hours of practical classes). Restricted by class hours and the type of content, such as roadbed compaction test, roadbed pavement leveling test, pavement bending test, asphalt penetration test, asphalt softening point test, and asphalt ductility test, other contents such as road slope operation and slope volume calculation, earthwork construction simulation, asphalt mixture ratio design and road mixing, *etc*., cannot be fulfilled.

4. Application of BIM + virtual simulation technology in Road Engineering Construction Technology and Organization course

In order to address the problems in the practical teaching of traditional Road Engineering Construction Technology and Organization course, the teaching team analyzed the course content based on the civil engineering professional personnel training objectives and course objectives, extracted the practical teaching contents that can be integrated with BIM + virtual simulation technology, used existing BIM + virtual simulation technology for contents that are difficult for students to understand, as well as integrated and optimized the content to stimulate students' learning interest, strengthen the training of students' skills, and effectively improve the practical teaching effect. The teaching team used BIM + virtual simulation technology in three modules.

4.1. Integration Module I: Slope Release Operation and Slope Release Volume Calculation

In the pre-construction stage, the road site needs to be leveled. Through BIM technology, the teaching team can make full use of the advantages of 3D road-level design information modeling technology and students' extracurricular time, thus expanding the hours of practice. In addition, high accuracy and precision of slope volume calculation can be achieved through Civil 3D software [4]. Using Civil 3D, students can apply slope tools and slope commands, set specific slope rules according to the actual situation, create slopes and slope groups automatically, create ground surfaces and design surfaces through the slope groups, further calculate the volume enclosed by the ground and design surfaces, balance the volume of earth, and ensure the quality of the project while pursuing economic rationality, thereby improving students' design capability.

4.2. Integration Module II: Earthwork Construction Simulation

By integrating theoretical knowledge with the embedding point of the engineering project in advance, combining the simulation nodes of BIM technology to sort out and divide the teaching content, helping students further systematize and concretize their understanding of theoretical knowledge, and allowing students to watch the simulation animation, students would have a macro grasp of the virtual environment, construction progress, construction plan, and construction cost. On the basis of perfecting construction drawings, students can use Civil 3D to form the topographical features where the project is located, use Revit to build the BIM model of the main construction stages, which include slope construction and roadbed pavement construction [5], select the content library for the plan layout, and explain in relation to the specific layout of the teacher. In that way, they will be able to better grasp the knowledge as if they were on site. The whole animation process should be in line with the actual construction process of the project. When showing the students the construction process and construction materials of any roadbed pavement engineering construction project, a clear construction visualization simulation of the key process would help students better understand the construction process involved in roadbed pavement engineering.

4.3. Integration Module III: Virtual Simulation Experiment on Construction Principle and Production Control of Intermittent Asphalt Mixing Plant

(i) Optimization of the asphalt mix ratio design, especially the aggregate gradation design. The aggregate occupies more than 90% of the quality of the asphalt mixture; its grade has an influence on the performance of the mixture, such as the high temperature. The design grade is based on the cold material dosage of the mixing station, the hot material sieve specifications, the hot material dosage, and other adjustments.

(ii) The actual project mixing plant production parameters, including aggregate heating temperature, asphalt heating temperature, hot material sieve specifications, and many other mixing plant parameters, are determined, as they play an important role in determining the quality of the mixture. It can be seen that on the basis of mastering the construction of an intermittent asphalt mixing plant, the asphalt mix ratio design is optimized, and the targeted mixing plant production parameters are determined so that the mixing plant can produce asphalt mixes with stable quality in accordance with the design purpose. This is of great significance to ensure the pavement quality [6].

Through the virtual simulation experiment platform, students can build a highly simulated model of intermittent asphalt mixing plant with an interactive operation mode, relying on virtual simulation, multimedia, human-computer interaction, database, and network communication technology, so as to achieve the following experimental purposes:

(i) master the principle of asphalt mixing plant construction;
(ii) master the asphalt mixture production process;
(iii) master the asphalt mixture production ratio and target ratio content;
(iv) master the key production control parameters of the asphalt mixing plant.

The introduction of virtual simulation experiments not only helps students understand the steps in the design and the specific implementation process of the mixing plant but also supports them in optimizing the design and mixing parameters to obtain the results and corresponding scores, thereby effectively improving their enthusiasm for learning. Online virtual simulation experiments can achieve what actual teaching has found difficult to implement, namely the asphalt mixing plant workflow and quality control operations, resolving issues such as the inability to meet teaching requirements and the restriction of student participation in field practice. Through independent interactive learning, students may be more motivated, and they can enhance their professional skills by completing virtual simulation experiments independently [7].

5. Advantages of using BIM + virtual simulation technology to integrate the course content

5.1. Realize virtual construction using BIM

The intuitive image of virtual construction allows students to gain familiarity with construction aspects in advance and realizes the integration of theory and practice. In addition, virtual construction using BIM technology that displays hidden details in a project [6] or components that cannot be practiced on the basis of guiding theoretical learning enables students to fully understand the construction intention and details, as well as the safety hazards and construction difficulties. Virtual modeling technology provides comprehensive data support and real-time information feedback for engineering construction, provides detailed and accurate information to participants, and improves the development efficiency and construction quality of engineering construction.

5.2. BIM visualization simulation application

In order to help students learn the content of road engineering in the construction of sub-projects, students can be led into the virtual site, walking them through the entire process of a project from construction site planning to its completion [7]. Through this, students would gain experience and learn the specific construction plan of each sub-project, and master relevant operational skills in the course.

5.3. Addressing the insufficient practical class hours

By making use of extracurricular time and the learning modules based on BIM + virtual simulation technology, students can spend more time practicing as well as learning and understanding the impact of different parameters on materials and construction processes in road engineering construction projects through independent exploration by using different parameters or adjusting the construction process. This would save time and reduce the cost of trial and error.

5.4. Cultivate students' comprehensive design and innovation skills

According to the principle of "strengthen the foundation, improve skills, and provide comprehensive training," we should start by cultivating students' practical skills and innovation consciousness, put forward personalized and innovative BIM + virtual simulation experiment projects, and build a step-by-step BIM + virtual simulation practical teaching system. Then, we can strengthen the training of professional skills for students and cultivate their comprehensive design and innovation skills. By adhering to the needs of industrial development, we should make full use of BIM + virtual simulation technology to help students achieve comprehensive and systematic development as well as nurture new talents that can truly meet the development needs of the industry.

6. Conclusion

(i) Integrating the Road Engineering Construction Technology and Organization course content using BIM + virtual simulation technology creates a deep integration between the theoretical aspect and the practical aspect of teaching and renders the practical teaching content consistent with the development of construction technology, thereby ensuring that the practical teaching content and the needs of frontline enterprises and the society are synchronized.

(ii) The use of BIM + virtual construction, with visualization simulation and information expression, effectively enhances students' perceptual understanding of engineering, aids students in visualizing the construction intention, details, and process, as well as motivates students to learn actively.

(iii) A lot of time and effort are required to build a BIM library and create virtual simulation experiments. However, the quality and quantity have yet to reach the ideal state. In the teaching process, students can only complete the relevant tasks during lessons held in ordinary smart classrooms or computer rooms, resulting in a low assignment submission rate. In addition, due to energy, time, and economic constraints, it is impossible to design and build more virtual simulation experiments to carry out different practical training tasks, which would be assigned to each student simultaneously [8].

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Disclosure statement

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