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Reflections on the Reform of Engineering Mechanics Teaching in Higher Education Based on Virtual Simulation Technology

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Abstract: *The implementation of virtual simulation technology has significantly impacted the reform of engineering mechanics teaching in higher education. This paper explores the application of virtual simulation technology in engineering mechanics teaching and proposes corresponding reform ideas. Virtual simulation technology provides students with a safe and interactive learning environment, expands teaching content and methods, and encourages exploration and practice. Through virtual simulation platforms, students can engage in designing, operating, and analyzing mechanical experiments without concerns about safety risks or resource limitations. This teaching approach enhances practical skills, fosters innovative thinking, and improves problem-solving abilities. Additionally, virtual simulation technology offers teachers more teaching resources and support, enabling the selection of suitable software and platforms and the design of simulation tasks aligned with teaching objectives. Guided by teachers, students can conduct experimental operations and analyze data in a virtual environment, enhancing their understanding and application of engineering mechanics principles and concepts. However, challenges exist, such as experiential differences between virtual and real experiments and the high costs and technological complexities associated with virtual simulation technology. Despite these challenges, the combination of virtual simulation technology and engineering mechanics teaching in higher education provides students with an interactive and safe learning environment, enriches teaching content and methods, and cultivates practical skills and innovative thinking. Effective integration of virtual simulation technology requires careful consideration of its advantages and limitations, adoption of appropriate teaching models and evaluation mechanisms, and continuous improvement of its application in engineering mechanics teaching. This perspective offers new ideas and approaches for the reform and advancement of engineering mechanics teaching in higher education.*

Keywords: *virtual simulation technology, higher education engineering mechanics teaching, teaching reform, cultivation of practical skills*

1. Introduction

In recent years, with the rapid development and widespread application of virtual simulation technology, the reform of university engineering mechanics teaching based on virtual simulation technology has become an important direction worth exploring and considering. Engineering mechanics, as a core foundational course in engineering disciplines, plays an important role in cultivating students' engineering thinking, solving practical engineering problems, and enhancing practical abilities. However, traditional engineering mechanics teaching methods have limitations to some extent and cannot meet the needs of contemporary university education and students' learning styles. Virtual simulation technology, as a method that utilizes computer simulation and visualization techniques to conduct virtual experiments, has brought about a completely new learning environment and practical opportunities for engineering mechanics teaching. This paper aims to explore the feasibility and effectiveness of university engineering mechanics teaching reform based on virtual simulation technology, and proposes a teaching method based on the flipped classroom model to enhance students' practical abilities and knowledge application skills. Through this research, we aim to provide beneficial reflections and insights for the modernization of university engineering mechanics education.

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2. Concept and Technology of Virtual Simulation

Virtual simulation technology is a method that combines computer technology with engineering mechanics to simulate and analyze the behavior and laws of objects under force through the establishment of mathematical models and the use of technologies from multiple fields such as computer graphics, artificial intelligence, and control theory. In the reform of engineering mechanics education in universities, virtual simulation technology is of great significance. It can provide a visual learning environment, unlike traditional teaching methods that rely mainly on teachers' lectures and students' written notes. Students find it difficult to intuitively understand and experience the behavior of objects under force. However, virtual simulation technology can generate realistic 3D models and animation effects through computer graphics technology, enabling students to visually observe and analyze phenomena such as deformation, fracture, and fluid dynamics under force, thereby enhancing students' interest and understanding. Virtual simulation technology can also provide a safe experimental environment. In traditional laboratory teaching, students need to conduct experiments themselves, and some experiments may involve certain risks or require expensive equipment. Virtual simulation technology can simulate real physical experiments, allowing students to carry out experiments in a safe and cost-effective environment, and adjust and optimize the experiments based on the results, thereby improving students' practical skills and innovation awareness. virtual simulation technology can offer personalized learning experiences. Traditional engineering mechanics education often teaches in groups, making it difficult to meet the individualized needs of each student[1] . However, virtual simulation technology can provide personalized learning content and difficulty levels based on students' learning situations and levels, helping students better grasp the basic principles and application skills of engineering mechanics. Virtual simulation technology can promote the reform of teaching and innovation in educational methods for teachers. Traditional engineering mechanics education mainly relies on teachers' lectures and classroom interactions, with certain limitations on teaching content and methods. Virtual simulation technology can provide more teaching resources and tools for teachers, helping them design and conduct a more diverse range of teaching activities, thus improving the effectiveness and satisfaction of teaching. The reform of university engineering mechanics education based on virtual simulation technology can provide a visual learning environment, a safe experimental environment, personalized learning experiences, and promote the reform of teaching and innovation in educational methods for teachers. Virtual simulation technology will bring about significant changes and improvements to university engineering mechanics education, enhancing students' learning outcomes and innovation capabilities[2] .

3. Application Scenarios of Virtual Simulation Technology in Experimental Teaching of Engineering Mechanics

Virtual simulation technology also has extensive application scenarios in structural mechanics experimental teaching. Here are some specific application scenarios:

Structural Analysis and Design: Virtual simulation technology can help students practice structural analysis and design. By using virtual simulation software, students can build structural models and set parameters such as loads and boundary conditions. Then, students can observe and analyze the deformation, stress distribution, and failure behavior of the structure under load. This practical operation can help students better understand the basic principles of structural mechanics and design criteria, and cultivate students' ability in structural analysis and design.Structural Optimization: Virtual simulation technology can help students optimize structural design. Students can analyze and evaluate the performance indicators of structures, such as strength, stiffness, and stability, by varying and adjusting different structural parameters using virtual simulation software. Through repeated optimization designs, students can master the methods and skills of structural optimization, and cultivate the innovative awareness and problem-solving ability of structural engineers.Fracture Mechanics: Virtual simulation technology can assist students in experimental teaching of fracture mechanics. Students can simulate material fracture behavior using virtual simulation software to explore the effects of different loading methods, material parameters, and other factors on fracture behavior. Students can observe and analyze the crack propagation path, fracture toughness, and other fracture mechanics parameters, and understand the fracture mechanism and reasons for material failure.Nonlinear Mechanics: Virtual simulation technology can help students with experimental teaching of nonlinear mechanics. Students can simulate and analyze the mechanical behavior of materials under conditions such as large deformation, elastoplasticity, and contact problems using virtual simulation software. They can observe and analyze nonlinear phenomena such as stress-strain

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curves and load-displacement curves, and understand the application of nonlinear mechanics theory in engineering practice.Virtual simulation technology has extensive application scenarios in experimental teaching of structural mechanics. Through the application of virtual simulation technology, students can more intuitively understand and master the basic principles and application skills of structural mechanics, improve the safety and cost-effectiveness of experimental operations, and cultivate innovative awareness and problem-solving abilities. Therefore, the reform of university engineering mechanics education based on virtual simulation technology is of great significance in the field of structural mechanics[3] .

4. Advantages and Disadvantages of Virtual Simulation Technology in Engineering Mechanics Teaching

4.1. Advantages of Virtual Simulation Technology in Engineering Mechanics Teaching

4.1.1. Safety

Virtual simulation technology provides a risk-free environment for experimental teaching in engineering mechanics, allowing students to conduct experiments without concerns about safety hazards. This is particularly important for experiments involving hazardous substances, high pressure, or high temperatures, as they can be safely conducted in a virtual environment.

4.1.2. Resource Conservation

Virtual simulation technology reduces the need for actual experimental materials and equipment, thus saving costs and physical space. It allows students to design and analyze experiments without consuming experimental materials, avoiding the common resource waste associated with physical experiments.

4.1.3. Reproducibility and Intuitiveness

Another significant advantage of virtual simulation technology is its high reproducibility and intuitiveness. Students can repeat experiments an unlimited number of times in a controlled environment, exploring different hypotheses and variables. This not only enhances their understanding of mechanical concepts but also improves learning outcomes. Through 3D models and animations, students can intuitively observe the stress and deformation of structures under different loads, which helps them better understand and internalize abstract mechanical concepts[4] .

4.2. Disadvantages of Virtual Simulation Technology in Engineering Mechanics Teaching

4.2.1. Experiential Differences

Although virtual simulation provides an intuitive sense of operation, it cannot completely replicate all sensory experiences of physical experiments. For example, by manipulating real force gauges and material samples, students can gain a direct sense of material properties, which is not currently provided by most virtual simulation tools.

4.2.2. Cost Issues

Implementing high-quality simulation software for virtual simulation technology in engineering mechanics teaching can be costly. Licensing fees, technical support, and software updates pose challenges for institutions with limited budgets. Strategies such as negotiating licensing agreements, exploring open-source options, seeking external funding, and fostering collaborations can help manage costs. These approaches enable institutions to overcome financial barriers and effectively implement virtual simulation technology, enhancing the learning experience for students and improving the effectiveness of engineering mechanics education.

4.2.3. Technological Limitations

Existing simulation technologies may not fully simulate certain complex or nonlinear mechanical problems, especially when it comes to experiment conditions that are difficult to control precisely or when material behavior is not fully understood. This restricts the application of simulation in teaching, requiring teachers and students to interpret simulation results carefully[5] .In summary, virtual simulation technology brings significant advantages to the teaching of engineering mechanics in terms of safety, cost-effectiveness, reproducibility, and intuitiveness. However, these advantages come with

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associated costs, including experiential differences, cost issues, and technological limitations, which are the main obstacles that need to be overcome in the current application of this technology in teaching. Future engineering mechanics teaching should strive to fully utilize the advantages of virtual simulation technology while seeking ways to address its shortcomings, such as integrating physical experiments to provide a complete teaching experience and reducing software costs through technological innovation.

5. Reform Ideas and Approaches for Engineering Mechanics Laboratory Teaching in Higher Education

5.1. Designing the content of virtual simulation experiments in engineering mechanics

When designing the content of virtual simulation experiments in engineering mechanics, it is important to focus on simulating complex experimental processes to ensure that students can conduct experiments such as multi-body dynamics analysis and mechanical performance testing of composite materials in a virtual environment. These experiments should be closely related to engineering practice and cover cutting-edge technologies and hot topics in the field of engineering mechanics. For example, it is possible to simulate mechanical performance tests such as tension, compression, and torsion for different materials, as well as the deformation and failure processes of composite materials under stress. Through virtual simulation experiments, students can gain a deep understanding of the complexity and diversity of material mechanics. Additionally, various structural scenarios can be simulated, such as beams, columns, and trusses, allowing students to understand the distribution of forces and deformation patterns of different structures under external loads through virtual simulation experiments.

To ensure the scientific and cutting-edge nature of the experimental content, the teaching team needs to maintain close contact with the field of engineering practice, stay updated on the latest developments in engineering technology, and incorporate this information into the design of virtual simulation experiments. Inviting experts from the industry to participate in the review of teaching content and making full use of the resources of research institutions and companies can ensure the integration of virtual simulation experiment content with the latest engineering technology[6] .

5.2. How to utilize virtual simulation technology in teaching engineering mechanics

When implementing teaching in engineering mechanics using virtual simulation technology, a combination of traditional teaching and virtual simulation can be employed, introducing a flipped classroom model and encouraging students to engage in self-study using virtual simulation software before class. Teachers can provide students with learning resources and experimental cases using virtual simulation software in advance, allowing students to perform experimental operations and theoretical learning through the software before class. This approach cultivates students' abilities for independent learning and problem-solving. In the classroom, teachers can explain and guide students on the problems and challenges encountered in virtual experiments, promote in-depth thinking and discussion, and strengthen the integration of theory and practice. At the same time, a virtual simulation laboratory can be established to provide students with opportunities for hands-on experience. In the virtual simulation laboratory, students can engage in experimental design, parameter adjustment, and data analysis, deepening their understanding of engineering mechanics theory through independent software operation, and developing practical problem-solving skills. Teachers can provide timely guidance and feedback during the experimental process, helping students master the application skills of virtual simulation technology and better apply theoretical knowledge to practical engineering problems. By combining the flipped classroom approach with the virtual simulation laboratory teaching model, students' interest in learning can be better stimulated, and their motivation and initiative in learning can be enhanced. Additionally, it helps strengthen students' awareness of teamwork and practical operational abilities, laying a solid foundation for their future engineering practice.

6. Evaluating and Ensuring the Effectiveness of Engineering Mechanics Laboratory Teaching in Universities

6.1. How to Conduct Evaluation

When evaluating the effectiveness of engineering mechanics laboratory teaching in universities, in

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addition to regular online tests and lab reports, more comprehensive evaluation methods can be introduced. For example, student work exhibitions, project demonstrations, and other means can be used to assess students' innovation abilities, teamwork skills, and engineering practice capabilities demonstrated in virtual simulation experiments. At the same time, a comprehensive portfolio of students' overall qualities can be established to provide comprehensive feedback and guidance on factors such as students' professional knowledge, practical skills, and innovation awareness demonstrated in virtual simulation experiments, facilitating the comprehensive development of students' overall qualities. In addition, student feedback can be collected through methods such as questionnaires and focused interviews, incorporating students' opinions and suggestions on virtual simulation laboratory teaching. By analyzing students' feedback, timely adjustments and optimizations can be made to the content of virtual simulation experiments, ensuring that the teaching content is closely aligned with students' needs and practical applications, thus improving the effectiveness of teaching.

6.2. Choosing Suitable Virtual Simulation Software

When selecting virtual simulation software, in addition to considering factors such as comprehensive functionality, user-friendly interface, and high computational accuracy, emphasis should be placed on the openness and customizability of the software. Excellent virtual simulation software should have good scalability, supporting user-defined models and experimental content to cater to the teaching needs of different universities and disciplines. Additionally, software updates and maintenance are also crucial factors. It is advisable to select software platforms maintained and supported by professional teams to ensure that the software is always up to date and meets the latest requirements in the field of engineering. Furthermore, schools can encourage collaboration with software development companies to customize virtual simulation software that suits the unique characteristics of their engineering mechanics teaching. By closely collaborating with software development companies, schools can participate in the design and development process of the software, ensuring that the software content aligns with the practical needs of engineering mechanics teaching and provides students with virtual simulation experiences that are closely aligned with real-world engineering applications[7] .

6.3. Developing a Customized Virtual Simulation Platform for the University

To develop a customized virtual simulation platform for the university, schools can invite expert teachers in the field of engineering mechanics to participate in the design and development of virtual simulation software, ensuring that the software content is closely integrated with the curriculum and meets the requirements of engineering mechanics courses. Additionally, schools can actively collaborate with industry partners, leveraging simulation software resources within the industry to share and optimize teaching resources. Through collaboration with industry partners, schools can access real-world cases and data from engineering practice, providing students with more realistic and practical virtual simulation experiences, promoting the integration of theory and practice. Meanwhile, schools can open up and share independently developed virtual simulation software resources, promoting the sharing and exchange of virtual simulation teaching resources in the field of engineering mechanics and facilitating complementary and mutual development of teaching resources within the industry. Through the aforementioned considerations and practices, the evaluation and assurance system for the effectiveness of engineering mechanics laboratory teaching in universities can be continuously improved. This will enhance the application level of virtual simulation technology in engineering mechanics teaching and make positive contributions to cultivating advanced engineering professionals that better meet the demands of engineering practice[8] .

7. Conclusion

Virtual simulation technology provides new methods and means for engineering mechanics laboratory teaching. By applying and optimizing this technology in a rational manner, the quality of teaching and students' practical skills can be enhanced. Universities should actively explore progressive teaching models and utilize virtual simulation technology to cultivate students' engineering literacy and innovation abilities. By enhancing the flexibility and diversity of laboratory teaching, strengthening the integration of theory and practice, promoting interdisciplinary integration and resource sharing, and fostering students' practical and innovative capabilities, the reform of engineering mechanics teaching

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in universities based on virtual simulation technology will provide important support and guarantees for the cultivation of engineering professionals with comprehensive development and strong innovation abilities.

References

[1] Wang Luzhen, Kong Hailing, She Bin, et al. The reform of engineering mechanics experimental teaching and the construction of virtual simulation experimental platform[J]. Laboratory Science, 2021, 24(5):3.

[2] Yu Haoqi, Fang Lu, Luo Wei. Exploration of a new teaching model for "electrical and electronic practical training" based on virtual simulation technology[J]. China Electric Power Education, 2021(003):000.

[3] Zhu Rencheng, Mei Hui, Li Shunyi, et al. Analysis of the teaching reform of "atmospheric pollution control engineering" based on virtual simulation technology[J]. Modern Salt and Chemical Industry, 2021(1):140-142.

[4] Zhu Yating. Practice of college chemistry experimental teaching based on virtual simulation technology[J]. Chemical Fiber and Textile Technology, 2023, 52(2):241-243.

[5] Chen Jia, Deng Xi, Tian Jing. Reform and discussion on the practical teaching of civil engineering construction based on virtual simulation technology[J]. Modern Business and Trade Industry, 2021, 42(35):2.

[6] Wang Luzhen, Kong Hailing, She Bin, Cai Zhongbing. The reform of engineering mechanics experimental teaching and the construction of virtual simulation experimental platform[J]. Laboratory Science, 2021, 24(5):153-155.

[7] Cheng Haonan, Zhou Rong, Wang Zheng, et al. Reflection on the reform of spinning course under the application background of virtual simulation technology[J]. Chemical Fiber and Textile Technology, 2022, 51(9):213-215.

[8] Wang Yanhong, Li Bing, Fan Yanru, Xie Zhaohui. A preliminary exploration of the teaching reform of "human anatomy and physiology" based on virtual simulation technology[J]. Science and Innovation, 2021, 000(009):P.64-65.