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Exploration of Hydraulics Experiment Teaching Based on Virtual Simulation Technology

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Abstract

In response to the issues of limited resources and monotonous teaching modes in traditional hydraulics experiment teaching, the hydraulics virtual simulation platform developed by Zhejiang University has been introduced. This platform offers a rich variety of experimental projects and resources, effectively breaking the constraints of time and space, allowing students to conduct experiments and learn anytime and anywhere. Through key steps such as preview, actual teaching, and feedback, combined with operational skills assessment in a virtual environment, a diversified evaluation system has been established in this study. Practical results indicate that this teaching mode significantly enhances students' experimental skills and theoretical knowledge, while also fostering their autonomous learning abilities.

Keywords

Virtual simulation technology, hydraulics experiment, teaching mode, experimental skills, autonomous learning.

1. Introduction

With the rapid development of information technology, virtual simulation technology, as an emerging teaching method, is gradually penetrating into the educational fields of various disciplines. As a fundamental course for many engineering majors such as water conservancy engineering and civil engineering, hydraulics experiment teaching plays an irreplaceable role in cultivating students' practical and innovative abilities. However, traditional hydraulics experiment teaching is often constrained by various factors such as experimental equipment, venues, and time, making it difficult to meet the demands of modern education [1]. Therefore, exploring new modes of hydraulics experiment teaching based on virtual simulation technology has become an important direction for current educational reform.

Virtual simulation technology compensates for the deficiencies of traditional experiment teaching by constructing highly realistic virtual experimental environments, enabling students to conduct experimental operations immersively. The introduction of virtual simulation technology into hydraulics experiment teaching not only breaks through the limitations of experimental conditions, realizes the diversification of experimental content and the visualization of experimental processes, but also enhances experimental safety and efficiency while reducing teaching costs. Furthermore, virtual simulation technology can stimulate students' interest and enthusiasm, fostering their autonomous learning abilities and innovative thinking. Therefore, this study aims to delve into the construction and implementation strategies of hydraulics experiment teaching modes based on virtual simulation technology, providing beneficial references and insights for the reform of hydraulics experiment teaching [2].

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2. The Problems in Traditional Hydraulic Experiment Teaching

Under the framework of traditional hydraulic experiment teaching, despite being regarded as a crucial component for cultivating students' practical abilities and innovative thinking, it increasingly faces issues in meeting the demands and challenges of modern education. These problems become particularly prominent when compared to virtual simulation technology, directly impacting teaching effectiveness and the cultivation of students' abilities.

Firstly, the heavy reliance of hydraulic experiments on physical equipment and specific environments poses a significant obstacle to enhancing teaching quality. In traditional experiments, students are required to personally operate real water flow devices and observe actual hydraulic phenomena. While this process is intuitive, it is constrained by the limited number of devices and laboratory conditions. When multiple classes or students need to conduct experiments simultaneously, equipment shortages and laboratory space limitations often result in some students being unable to obtain timely practical opportunities, or having to rush through experiments within a limited time, making it difficult for them to thoroughly understand and grasp the core principles of hydraulics. This unequal distribution of resources not only affects students' experimental experiences but also restricts their potential to deepen their theoretical knowledge through practice.

Secondly, traditional hydraulic experiments have inherent limitations in terms of safety and repeatability, which stand in stark contrast to the safe and controllable environment provided by virtual simulation technology. In real experiments, potential safety risks include high-pressure water flows, rapidly changing water levels, and possible equipment failures. Despite teachers' strict safety measures, accidents cannot be completely avoided. Meanwhile, some hydraulic experiments under complex or extreme conditions are often simplified or omitted due to their high costs or difficulty in implementation, which compromises the comprehensiveness and depth of the experiments. Virtual simulation technology, however, can simulate various complex scenarios, allowing students to freely explore in a risk-free environment, thereby enhancing the safety and repeatability of experiments.

Lastly, the traditional teaching mode of hydraulic experiments appears inadequate in stimulating students' active learning and fostering innovative thinking. In traditional experiments, students often merely follow predetermined steps, lacking the space for independent exploration and innovation. In contrast, virtual simulation technology provides an interactive learning environment that actively encourages students to take initiatives, adjust parameters, and observe results, thereby effectively cultivating their problem-solving abilities and innovative thinking. This student-centered teaching mode aligns better with the demands of modern education and contributes to the comprehensive development of students. Given the numerous issues in resource allocation, safety, and teaching modes in traditional hydraulic experiment teaching, it is urgent to introduce virtual simulation technology for reform and innovation, with the aim of building a more efficient, safe, and innovative new model for experimental teaching.

3. The Development of Teaching Mode for Hydraulic Experiments Based on Virtual Simulation Technology

3.1. Introduction to the virtual experiment platform

This study introduces the Hydraulic Virtual Simulation Experiment Platform developed by Zhejiang University (hereinafter referred to as the "Platform"), which serves as a model for the deep integration of virtual simulation technology and education, bringing revolutionary changes to hydraulic experiment teaching. Leveraging cutting-edge computing technology and high-precision graphic rendering, the Platform has constructed a multi-dimensional virtual

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experiment environment for hydraulics, ranging from basic to advanced levels, fully catering to the learning needs of students at various stages. The experiment modules are not only rich in content and scientifically designed but also effectively assist students in mastering the core principles and experimental skills of hydraulics.

In addition to providing rich experimental content, the Platform offers high network accessibility and flexibility. Students are no longer constrained by specific laboratories and time; they can easily log in through a standard web browser to conduct experiments and learn anytime, anywhere. This flexible learning mode breaks the temporal and spatial limitations of traditional experiment teaching, significantly enhancing the convenience and autonomy of learning. The Platform also provides detailed experiment guides, theoretical background materials, and operational videos, ensuring that students can quickly grasp skills and deeply understand principles. Furthermore, the built-in online Q&A and discussion forums facilitate communication and interaction among teachers and students, as well as among students themselves, helping to collectively solve experimental problems and promote knowledge sharing and transmission [3].

The Platform is also equipped with powerful data analysis and processing capabilities, allowing students to collect, process, and analyze experimental data in real-time, generating detailed experiment reports and charts. This process not only deepens students' understanding of hydraulic principles but also enhances their data processing abilities and scientific research literacy. With the assistance of the Platform, students can more comprehensively grasp the skills and methods of hydraulic experiments, laying a solid foundation for their future academic research and career development. The Hydraulic Virtual Simulation Experiment Platform of Zhejiang University, with its advanced technology, rich resources, flexible learning mode, and powerful data analysis capabilities, provides strong support for hydraulic experiment teaching, facilitating the construction of a more efficient, flexible, and innovative new model for experimental teaching [4].

3.2. Design of hydraulic experiment teaching

3.2.1. Virtual simulation experiment project

Table 1. Virtual simulation experiment projects

Numble	Experimental projects	Types of experiments	Class hours
1	Hydrostatic experiment	Verification experiment	2
2	Comprehensive experiment on Bernoulli's equation for steady flow	Comprehensive experiment	2
3	Venturi comprehensive experiment	Comprehensive experiment	2
4	Reynolds experiment	Comprehensive experiment	2
5	Local head loss experiment	Design experiment	4
6	Head loss along the path experiment	Design experiment	4
7	Momentum law experiment	Design experiment	4
8	Orifice and nozzle flow experiment	Design experiment	4
9	Pitot tube velocity measurement and calibration of correction factors experiment	Design experiment	4

Taking the Water Conservancy and Hydropower Engineering major as an example, the virtual simulation experiment platform can provide 9 experiment projects, which are hydrostatic experiment, comprehensive experiment on Bernoulli's equation for steady flow, venturi comprehensive experiment, Reynolds experiment, local head loss experiment, head loss along

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the path experiment, momentum law experiment, orifice and nozzle flow experiment, and pitot tube velocity measurement and calibration of correction factors experiment [5]. The specific hydraulic experiment course projects and their credit hour allocation are shown in Table 1.

3.2.2. The implementation of virtual simulation-based hydraulics experiment teaching

In the pre-class preview session, teachers will assign preview tasks and guide students to utilize the virtual simulation platform to watch explanatory videos on the principles of various experimental projects as well as videos demonstrating experimental operations. These abundant learning resources not only comprehensively cover the background knowledge and core principles of the experiments, but also meticulously present the specific steps and key precautions of the experiments, laying a solid foundation for students' subsequent hands-on operations. Students autonomously conduct experiments through the hydraulics virtual simulation experiment platform and complete the simulation experiment assignments assigned on the learning platform. With the highly realistic simulation operations provided by the virtual simulation environment, students are able to familiarize themselves with the entire experimental process ahead of time, master the use of instruments proficiently, and thus perform more confidently and skillfully in formal experimental operations.

During the classroom teaching phase, we concentrate on the critical and difficult points of the experiments, providing targeted explanations to deeply analyze the core principles and challenging aspects of the experimental theories and operations. Teachers review students' preview situations to identify and address any gaps, ensuring comprehensive mastery of the theoretical knowledge related to the experimental projects. Subsequently, in the experimental operation segment, teachers first demonstrate the experimental procedures on-site, providing a detailed showcase of the process, while students are reasonably grouped (each group consisting of 4-5 members) to collaborate and complete the experiments within their teams. After the experimental operations, the teaching team conducts meticulous evaluations based on the identified issues, clearly pointing out the precautions in experimental operations. This accessible and in-depth teaching approach not only helps students further deepen their understanding of experimental principles but also effectively resolves doubts encountered during their preview process. Furthermore, we have specially arranged a classroom discussion session, encouraging students to actively share their insights, experiences, and encountered problems from the virtual simulation experiment previews. Through collective wisdom and joint exploration, we aim to cultivate students' teamwork spirit and problem-solving abilities.

After class, we require students to diligently write experiment reports to consolidate their acquired knowledge and enhance their scientific writing and logical thinking skills. Concurrently, we place great emphasis on student feedback, actively collecting and organizing their evaluations and suggestions regarding the effectiveness of the virtual simulation platform, the appropriateness of the experimental content, and the efficacy of the teaching methods. This allows us to continuously optimize our teaching strategies and improve teaching quality. Through this meticulously planned and implemented virtual simulation-based hydraulics experiment teaching process, we have not only successfully enhanced students' experimental operation skills and theoretical knowledge but also cultivated their autonomous learning and problem-solving abilities, laying a solid foundation for their subsequent academic pursuits and career development.

3.3. Assessment of hydraulics experiment

In the design of the assessment content, while retaining the traditional evaluation of experimental skills and theoretical knowledge, we have incorporated an assessment of operational abilities in a virtual simulation environment. Students are required to complete simulated experiments on the virtual simulation platform to test their capabilities in instrument operation, data recording, and analysis. In addition, we comprehensively evaluate students' understanding of hydraulic principles, experimental procedures, and precautions through written exams and built-in test questions on the virtual simulation platform. This diversified design of assessment content not only retains the essence of traditional assessments but also cleverly integrates modern technological elements, thereby significantly enhancing the comprehensiveness and scientific rigor of the evaluation [6].

In terms of assessment methods, a comprehensive tracking strategy is adopted. Before class, the preview function of the virtual simulation platform is utilized to record students' preview progress, evaluating their autonomous learning ability and preview effectiveness. During class, real-time guidance from teachers is combined with the monitoring function of the virtual simulation platform to provide immediate feedback on students' experimental operation processes, ensuring they can accurately grasp experimental skills. After class, students are required to submit experiment reports, and in conjunction with data records from the virtual simulation platform, an in-depth analysis of students' experimental data is conducted to assess their data processing and experimental analysis abilities. This comprehensive tracking assessment method enables a thorough and accurate evaluation of students' learning processes and outcomes, providing a solid basis for teaching improvements.

In terms of assessment criteria, we emphasize comprehensive consideration and have established clear scoring standards. Not only do we quantitatively evaluate students' experimental operation skills, data accuracy, and the quality of their experiment reports, but we also place great importance on their learning process and attitude. By combining factors such as preview performance, classroom participation, experimental operation performance, and after-class feedback, we conduct a comprehensive evaluation from all aspects. This integrated assessment criterion, which focuses on both students' experimental results and their learning process and attitude, can comprehensively and objectively reflect students' actual learning level and effectively motivate them to actively participate in the learning process and cultivate good learning habits. Through the implementation of diversified assessment content, comprehensive tracking assessment methods, and this integrated assessment criterion, we have achieved a comprehensive and accurate evaluation of students' comprehensive abilities, significantly improving the accuracy and comprehensiveness of the assessment. This has promoted a comprehensive enhancement of students' overall qualities and provided new ideas and methods for hydraulics teaching.

4. Analysis of Implementation Effectiveness

4.1. Significant improvement in experimental skills

By introducing virtual simulation technology, students are able to repeatedly practice experimental operations in a virtual environment and become familiar with the usage of various instruments. With the help of the instant feedback function provided by the virtual simulation platform, students can promptly identify and correct mistakes during the operation process, thereby effectively improving the accuracy and standardization of their experimental operations. As a result, students' experimental skills and hands-on abilities are significantly enhanced.

4.2. Further consolidation of theoretical knowledge

The virtual simulation platform not only constructs a highly realistic experimental environment for students but also cleverly integrates built-in features such as question practice. This design enables students to continuously consolidate and deepen their understanding of hydraulic principles during the process of experimental operation. This teaching mode, which tightly combines theoretical knowledge with practical operation, greatly facilitates students' mastery and application of the knowledge, thereby significantly enhancing their learning outcomes.

4.3. Further enhancement of autonomous learning ability

This teaching system places great emphasis on cultivating students' autonomous learning abilities. With the aid of the preview function on the virtual simulation platform, students can familiarize themselves with the specific content and operational steps of the experiments ahead of time, laying a solid foundation for subsequent experimental operations. At the same time, the platform provides a mechanism for submitting and receiving feedback on experimental reports, enabling students to promptly understand their learning status and identify any weaknesses, thereby providing precise directional guidance for their subsequent learning. This student-centered teaching mode greatly enhances students' enthusiasm and initiative for learning, promoting a significant improvement in their autonomous learning abilities.

5. Conclusions

This study conducted an in-depth exploration of the application of virtual simulation technology in hydraulics experimental teaching. By introducing the hydraulics virtual simulation platform developed by Zhejiang University, a diversified, efficient, and safe experimental teaching mode was successfully established. This mode not only breaks the spatiotemporal constraints of traditional experimental teaching and provides a variety of experimental projects and resources but also significantly improves students' experimental skills and theoretical knowledge levels through the close integration of preview, teaching, feedback, and assessment. Furthermore, it cultivates their autonomous learning abilities and innovative thinking. Additionally, this teaching mode provides teachers with convenient teaching tools and precise student learning data, which helps optimize teaching strategies and improve teaching quality. In conclusion, this study provides a useful reference for the reform of hydraulics experimental teaching and has broad application prospects and promotion value.

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