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Teaching Practice and Reformation of Mechanics Course Based on Virtual Simulation Technology

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Abstract: The fundamental mechanical experiment holds an exceedingly crucial position in modern mechanics research as well as practical engineering. Moreover, fundamental mechanical experiment teaching is an indispensable component in the training of undergraduates in the disciplines of mechanics and civil engineering. Nevertheless, in the existing fundamental experiment courses, issues such as inadequate student preparation and insufficient practical operation time continue to exist. In order to address this challenge, educators have integrated virtual simulated experiments into traditional theoretical mechanics teaching, leading to curriculum reformation and teaching practice. Through this exploration of more flexible and effective teaching methods, educators aim to comprehensively enhance both teaching efficiency and student learning outcomes.

Keywords: mechanics experiment, experiment teaching, teaching reformation, virtual simulation.

1. Introduction

Innovation and entrepreneurship education in universities aims to cultivate highly qualified individuals with solid theoretical foundations and outstanding practical innovation abilities. In order to achieve this goal, experimental teaching serves as a crucial method and is vital for fostering innovative talents at the university level[1-2]. Based on modern information technologies such as cloud computing, internet plus, big data, and virtual reality, virtual simulation offers a fresh and innovative approach to talent development. Experimental teaching through virtual simulation has become an important supplement and form of regular experimental teaching in universities[3-5].

In civil engineering, some experiments related to component testing are expensive in terms of operation costs, have a high degree of risk, and cause major destruction. Owing to the high cost of constructing professional laboratories, most universities cannot afford the exorbitant costs of conducting these experiments, particularly those involving huge investments. However, virtual electrical measurement and simulation experiments possess features of high generality, convenient flexibility, and low cost, thereby enabling the establishment of various types of experimental projects, maximizing the utilization of teaching resources, and making up for the inherent shortcomings of traditional experiments[6]. Hence, strengthening the construction of virtual electrical measurement and simulation experimental teaching projects to truly enhance students' innovation and engineering practical capabilities is an inevitable direction for the reformation and innovation of engineering testing techniques talent development[7-9].

Based on the analysis of the current status of mechanics experiments, this article explores the virtual simulation mechanics experimental teaching mode, and carries out the construction of virtual simulation experimental resources, and strengthens the training of experimental skills and lays the foundation for students to solve complex engineering problems related to mechanics.

2. The present situation and existing problems in mechanics course teaching

In the curricular design and educational plan of civil engineering, the mechanics series of courses holds a paramount and fundamental position, characterized by its rigorous theory, meticulous logic, and adaptable engineering applications. It serves as the foundation for subsequent specialized courses, and the experimental section within the mechanics course serves as a crucial link that allows students to transition from fundamental theories to practical engineering applications within civil engineering. As such, the mechanics series of courses has always been the focal point of educational reformation in civil engineering across various higher education institutions.

Currently, there are several prevalent issues with mechanics experimental instruction, which include:

(1) Limitations on the number of experimental equipment and experimental space

In civil engineering, some experimental tests related to component testing have high operating costs, high danger factors, and high destructive properties. The construction cost of specialized laboratories is enormous, and it is difficult for general universities to bear the high costs of experimental operations. The mechanics laboratory has a limited number of test devices available, and the laboratory space is also restricted. The specimens used in the experiment are disposable consumables, and the processing process of a single specimen is complex and expensive, resulting in high experimental costs. At the same time, the expansion of student admissions in universities has led to an increasing number of students while the availability of instruments and equipment remains limited. This contradiction necessitates grouping students during the experimental teaching process, resulting in low experimental efficiency and an extended experimental teaching time.

(2) Single experimental teaching method

The mechanics experimental projects are interspersed between mechanics courses, forming a comprehensive and organic whole with mechanics theoretical knowledge. Each experimental project is interconnected and self-contained. However, most mechanics experimental teaching contents are relatively independent, and are arranged after theoretical teaching, making it difficult for undergraduate students to discover the intrinsic connections between each experiment. As a result, students are in a passive learning state, lacking a global perspective. In addition, for traditional demonstration-type and verification-type experimental teaching projects, the form is rigid and the teaching methods are single, which is difficult to meet the needs of theoretical teaching, practical teaching, industry development, and student independent innovation in this profession. Furthermore, it is challenging to inspire students' interests and initiative in learning.

(3) Students' proficiency in experimental operation

The time for teachers to explain theoretical and operational methods in the classroom is limited. Students find it challenging to fully comprehend the procedures of device utilization during lessons, and as a result, some students may be unable to execute all experiments successfully. Additionally, the impact of factors such as the limitation of experimental space and time, as well as safety concerns, may hinder some students from following appliance operation specifications during the experiment, leading to possible damage to the machinery and possible safety hazards. This, in turn, lowers the efficiency of the experiments and disrupts their normal conduct, making it impossible to achieve the desired results within the present duration of practical lessons.

3. Significance of mechanics experiment teaching reformation

The traditional teaching model of mechanics courses often separates theoretical instruction from practical experimentation. This results in skill training without timely theoretical guidance, and theoretical instruction disconnected from production or real-life scenarios, causing inadequate mastery of skills. With the rapid development of teaching reformation, new teaching approaches such as “project-based learning” and “integrated teaching, learning, and doing” have emerged. However, the skill training used in these new teaching models typically falls into two categories: the first one offering only a fixed number of experiments provided by lab equipment, where students need only follow the guidebook to complete experiments without engaging in the learning process; the second one relying on producing actual experiment circuits or devices, affording students greater hands-on capabilities. However, this method can be resource-intensive, time-consuming, and costly, constrained by equipment availability and variety. In contrast, virtual simulation teaching affords advantages such as high efficiency, low cost, rich content, effective performance, and safety, leading to its expanding applications and popularization. Thus, combining project-based learning, integrated teaching, learning and doing, and virtual simulation teaching can leverage their unique advantages, achieving better teaching outcomes.

(1) Expand experimental time and space

The virtual simulation experiment makes full use of network space and numerical simulation software resources of mechanics to compensate for the deficiencies of traditional laboratory teaching. It greatly expands the space and time of mechanics experiments, and students can experiment at any time and place. Furthermore, the software developed for virtual simulation projects not only has stepwise operational procedures with prompting functions but also enables students to repeatedly practice and perfect their familiarity and proficiency. Subsequently, the application of virtual simulation projects significantly enhances students’ professional practical abilities in conducting experimental operations.

(2) Improve teaching efficiency

The virtual simulation project has constructed an environment that mimics reality. By conducting experiments in the virtual system, the students have learned and acquired an understanding of experimental principles, methods, specific experimental steps, and precautions. This has provided a preliminary understanding and knowledge of the experimental results, thereby enabling students to conduct offline experiments with a certain degree of inquiry, simplifying the teacher’s instructional process, and enhancing the efficiency and effectiveness of the experiments. It is essential for students to have a thorough understanding of the experimental process to perform accurate operations and avoid reckless behavior, which effectively compensates for the inadequacies of monotonous mechanical experimental teaching processes seen in reality.

(3) Reduce teaching costs

The students engage in interactive activities with virtual experimental objects and materials, which results in reduced offline experimentation time, increased equipment utilization rate, and significantly saves on the cost of equipment and materials. Furthermore, virtual simulation experiments enable students to acquire a deeper comprehension of the experimental content and methodology, thereby enhancing their learning interest and improving learning outcomes.

(4) Sharing teaching resources

By establishing an open website and teaching management platform, it is possible to facilitate wide-scale classroom experimentation and share it with various universities. Additionally, active feedback from universities can be incorporated to continuously improve course content and evaluation.Moreover, actively promoting this project to enterprises and society can be accomplished through the university or college website, as well as various academic conferences.

4. Reformation content of mechanics experiment teaching

In response to the issues inherent in current experimental teaching, the experimental center has undertaken a reformation of teaching methods. This has been accomplished through the application of virtual simulation and multimedia teaching, in combination with traditional experimental teaching methodologies, in order to achieve a comprehensive integration of theoretical and practical approaches. This undertaking seeks to fully address a range of issues in experimental teaching, including but not limited to material deficiencies, a shortage of instructional time, and insufficient opportunities for hands-on student experimentation.

(1) Add mechanical calculation and analysis module

The virtual simulation project in question is distinguishable from conventional procedural laboratory operations. Furthermore, a mechanics calculation and analysis software has been formulated to allow for real-time computation and cloud-based diagram displays based on diverse test components and varying states of force.

(2) Self-designed bridge group

Students can independently assemble a full or half-bridge structure according to their needs, and set the corresponding coefficients and parameters to display the corresponding results. By processing the relevant data, students can obtain accurate outcomes.

(3) Develop online live Q&A system

Multiple cameras have been installed in the laboratory to enable students to observe the experimental equipment from various angles. Moreover, teachers can provide guidance and answer questions during live online broadcasts within the laboratory, allowing students to experience the experiment without leaving their homes.

(4) Record supporting experimental principles and experimental operation video explanation

During the experimental procedures, if students have any doubts regarding theory or operation, they can refer to the theory explanation and experimental operation demonstration provided at any time, which ensures a genuine understanding of the experiment and helps facilitate the completion of the virtual experimental operation process.

(5) Enrich the test methods of simulation experiments

In order to deepen the understanding of experimental knowledge, on the basis of adding conventional knowledge point tests, challenge answers are specially set up to improve and deepen students' mastery and application of knowledge.

(6) Combining traditional mechanical experiments with practical engineering applications

Based on teaching experiments and practical engineering, electrical measurement experiments have been established for reinforced concrete bridge structures and truss bridge structures with engineering background, which enriches the experimental content and enables students to link theory with practice, thus deepening their understanding of theoretical knowledge.

(7) Online and offline mixed teaching

This project integrates virtual simulation technology with mechanics teaching to achieve integration of "teaching, learning, and practicing." This approach significantly improves teaching conditions and the effectiveness of teaching while reducing equipment consumption, especially the amounts of consumables used, saving experimental funds, and overcoming time and space limitations, resulting in an increase in the rate of practical classes offered and students' operational skills.

5. Application of virtual simulation experiment

Taking the beam bending normal stress test experiment as an example, the specific implementation process is shown in Figure 1.

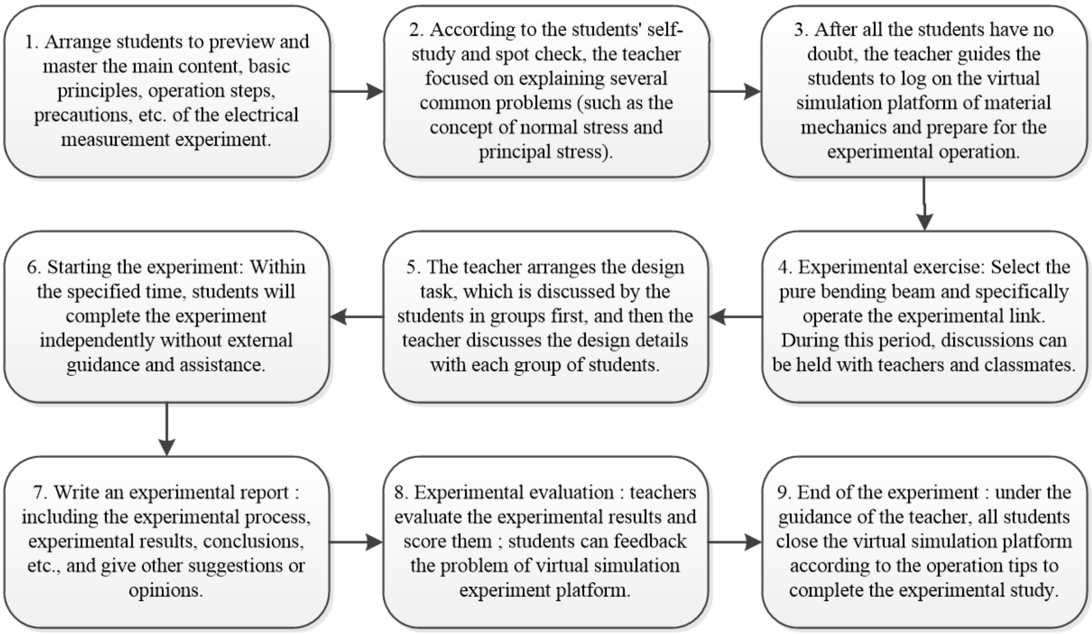


Fig 1. The implementation process of virtual simulation experiment

Combined with the beam bending normal stress test experiment, the function of the virtual simulation experiment teaching management platform is described in detail.

Firstly, from the login interface, shown in Figure 2, users can enter the main page of the virtual simulation experiment teaching management system to start their study on "Architecture Component-based Electrical Measurement Virtual Simulation Experiment", shown in Figure 3. The experimental projects mainly include pure bending beam normal stress testing, principal stress testing under complex stress state, truss bridge stress testing, and reinforced concrete beam stress testing.

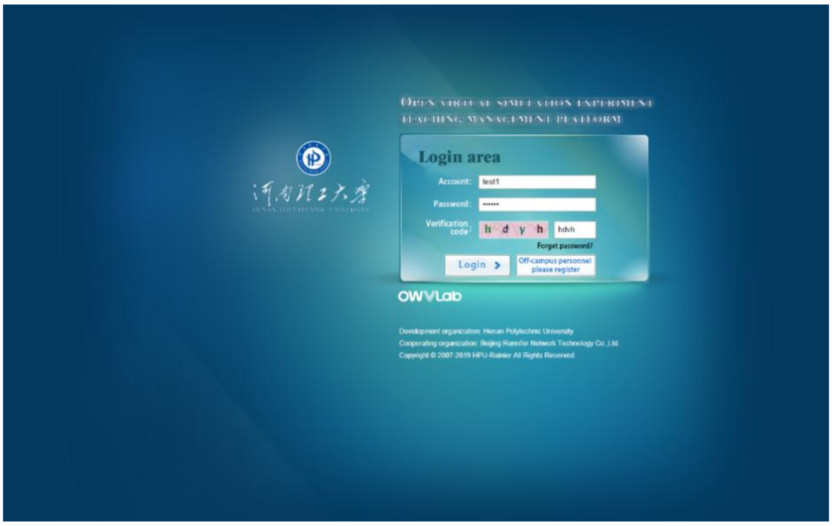


Fig 2. Virtual simulation experiment teaching management platform login interface

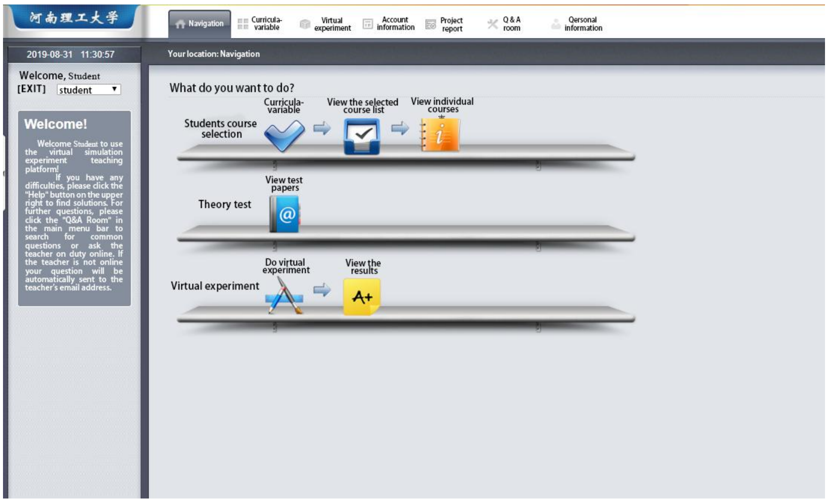
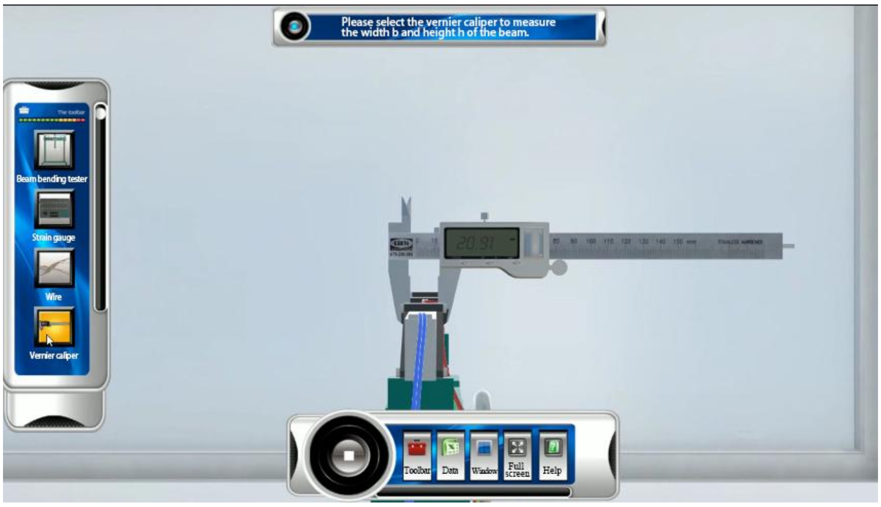


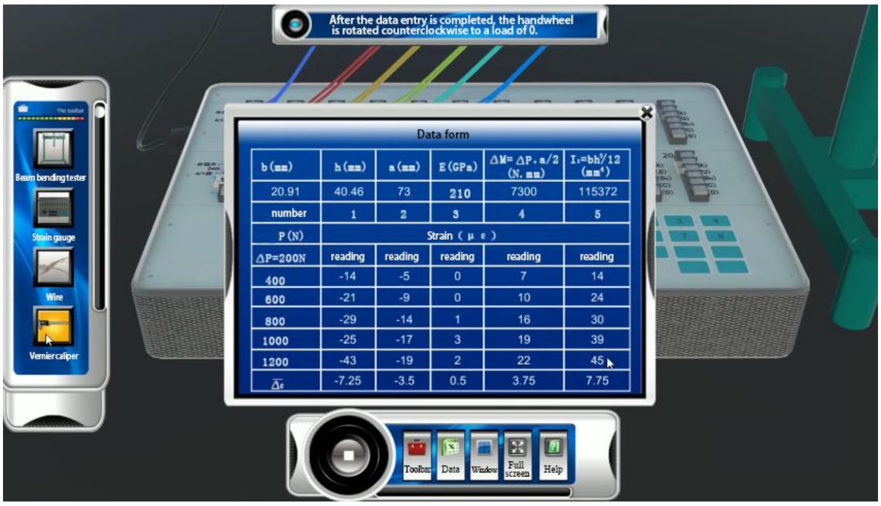
Fig 3. Virtual simulation experiment teaching management system homepage

Figure 4 illustrates the operational process of the beam bending normal stress testing experiment on the virtual simulation experiment teaching management platform. The process mainly includes connecting the experimental equipment (shown in Figure 4a), measuring experimental data (shown in Figure 4b), conducting the experiment process (shown in Figure 4c), outputting experimental data (shown in Figure 4c), and generating student experimental reports (shown in Figure 4d).

(a) Connection of strain tester and bending tester



(b) Size measurement of beam



(c) Experimental process and data

(d) Complete the experimental report

Fig 4. The operation process of teaching process

(1) Experimental instrument connection

Select "Beam Bending Normal Stress Experiment", and enter the laboratory interface. Choose the beam bending test equipment from the left-hand working column and install it onto the operating platform. From the tool column, select the strain testing apparatus and place it on the left-hand side of the bending test equipment. Connect the strain testing apparatus and the bending test equipment by using a wire.

(2) Experimental process and data

Use the tool bar to call the vernier caliper to measure the width and height of the beam. Use a ruler to measure the distance between the load point and beam support. Turn on the power switch of the strain gauge and use the 1/4 bridge circuit wiring method to measure. Rotate the hand-wheel clockwise and increase the load to 400N. Record the value in the experimental table. Increase the load to 600N, select the strain channel, and enter the experimental values. Increase the load to 800N, select the strain channel, and enter the experimental values. Increase the load to 1000N, select the strain channel, and enter the experimental values. Increase the load to 1200N, select the strain channel, and enter the experimental values. After entering the data, rotate the hand-wheel counterclockwise to unload the load to 0, turn off the power switch of the strain gauge, remove the strain gauge wiring, generate the experimental report, submit it, and complete the experiment.

After the above virtual simulation process is completed, students gain a clear understanding of the entire process of the beam bending normal stress test experiment, including the instrument connection, data measurement, loading and unloading, experimental results, and data export.

6. Conclusion

Through virtual simulation technology, the mechanical theory teaching and experimental teaching are organically integrated. The fundamental theories of mechanics, equipment principles, experimental operations, and scientific exploration are integrated into the virtual simulation interactive system. This achieves a harmonious integration of theory, practice, and innovation. Abstract and formulaic theoretical knowledge is attached to experimental equipment, operations, and phenomena, achieving a complementary combination of theoretical learning, knowledge exploration, and entertainment. This is beneficial for cultivating students' abilities to apply knowledge, analyze and solve problems, and stimulate their initiative and creativity in learning.

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