



# Research on the Design and Application of Virtual Simulation Teaching for Engineering Equipment

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**Abstract.** Aiming at the problems existing in the teaching process of engineering equipment-related courses, such as abstract theoretical learning, limited quantity of equipment, and difficulty in environment construction, based on the key and difficult points of the courses, a virtual simulation teaching resource system for engineering equipment covering theoretical lecture, physical operation, and case discussion is constructed, a three-step virtual teaching process for equipment of "pre-class online autonomous learning - in-class virtual-real integrated learning - post-class virtual reinforcement learning" is designed, and applied to the teaching of the 2024 cohort students. Compared with the academic performance of the 2023 cohort students, the average score of theoretical knowledge test of the 2024 cohort students increased by 13.7%, and the average score of practical skill test increased by 200%. The results indicate that virtual simulation teaching of engineering equipment can effectively break through the limitations of traditional teaching, deepen students' understanding of knowledge and mastery of skills, and provide effective and strong support for the teaching of engineering equipment-related courses.

**Keywords:** Engineering equipment courses, Virtual simulation teaching, Construction of virtual simulation resources, Practical application

## 1 Introduction

Engineering equipment is the main equipment for carrying out engineering support tasks<sup>[1]</sup>. Deeply understanding the principles of engineering equipment, mastering operational skills, and correctly coordinating the application of engineering equipment are important methods to improve engineering support capabilities. To ensure victory in warfare and strengthen the training of professional talents who know, understand, and utilize equipment, military academies have set up a series of engineering equipment courses. At present, the teaching of engineering equipment courses generally adopts the teaching mode of "theoretical lecture + physical equipment practice". However, restricted by factors such as the quantity of equipment, teaching environment, economic

costs, and training risks, there are practical problems such as abstract theoretical learning and hands-on practice that is often “inaccessible, insufficient, or ineffective”, making it difficult to meet the needs of equipment teaching.

Virtual simulation technology<sup>[2-3]</sup>, also known as virtual reality technology, is a technique that uses computer technology to simulate real scenarios, enabling the creation of a highly realistic and interactive virtual environment. Virtual simulation teaching<sup>[4-6]</sup> is the product of the combination of virtual simulation technology and traditional course teaching. The virtual simulation teaching of engineering equipment courses can build a three-dimensional visualization equipment and virtual environment by means of computer simulation and virtual reality. It can transfer the parts that are difficult to complete in the traditional classroom to the virtual environment, and carry out the 'real equipment' teaching and training in the virtual environment, so as to realize the combined teaching of traditional classroom and virtual classroom and improve the teaching quality<sup>[7-11]</sup>.

## **2 Analysis of Issues in Engineering Equipment Courses Tables**

The teaching focus of engineering equipment courses encompasses equipment structure and principles, single-equipment operation skills, command and coordination capabilities, as well as operational application and decision-making capabilities. Such courses are characterized by an extensive teaching scope, involving a wide variety of equipment and complex operating environments. The teaching content is divided into theoretical teaching and practical training. Currently, theoretical teaching is predominantly delivered through classroom lectures by instructors, while practical training primarily relies on constructed operating environments and utilizes engineering equipment for hands-on equipment training. However, constrained by issues such as insufficient equipment quantity and difficulties in environment construction, the teaching of engineering equipment courses has exposed several prominent problems.

### **2.1 Single Teaching Method**

Traditional instruction primarily relies on theoretical lectures. However, engineering equipment courses cover diverse equipment types, and the working principles and maintenance mechanisms of different equipment are complex and abstract. Simple theoretical explanation is difficult for students to connect abstract concepts with specific equipment components and operations during class, resulting in poor visual and intuitive understanding. In addition, due to the different levels of object-oriented teaching and the different backgrounds of students' work and learning, it is easy to cause the phenomenon of "one-size-fits-all" only in classroom teaching, ignoring the differences of students and their acceptance of knowledge, thereby affecting teaching effectiveness.

## 2.2 Insufficient Quantity of Equipment for Physical Teaching

Engineering equipment courses cover a wide range of types and have a large number of trainees. Moreover, the instructional content often involves equipment module learning and operational exercises that necessitate the use of actual equipment.

Currently, equipment utilization in classroom instruction primarily follows a model where equipment is requested prior to class and training is conducted in groups during class sessions. However, due to the limited quantity of existing engineering equipment for teaching in military academies, there is a mismatch between the number of equipment and the number of students. This leads to problems such as tight equipment coordination and a severe shortage of equipment available for teaching demonstrations in class. It is not uncommon for a group of more than ten students to gather around a single piece of equipment waiting for training, which consequently results in issues like long waiting times for students' training, limited training sessions, and delayed training, ultimately affecting the effectiveness of teaching.

## 2.3 Single Teaching Method

Engineering equipment teaching involves many types of engineering equipment and complex operating environments. Equipment teaching often requires constructing an appropriate teaching background. For example, equipment maintenance needs to be carried out on the basis of equipment failures, and the operational application of equipment needs to create a special combat environment. For daily teaching, there are mainly two problems in setting up these teaching environments. Firstly, it is difficult to construct scenarios, and it may even cause damage to equipment. For instance, in equipment maintenance teaching, it is hard to reproduce some failure phenomena, and it is not feasible to randomly damage teaching equipment; During case studies and scenario-based exercises, it is challenging to realistically demonstrate battlefield confrontation settings, resulting in poor teaching immersion. Second, the teaching environment has poor repeatability. Student training may be destructive to the teaching environment, and environmental recovery takes time. Therefore, the teaching environment is difficult to support students' repeated training.

In response to the above problems, this paper reforms traditional engineering equipment courses and conducts research on virtual simulation teaching of engineering equipment courses. By leveraging virtual simulation technology, highly realistic virtual equipment objects and environments are constructed to visualize complex theoretical knowledge and virtualize both equipment and teaching environments. This enables students to break free from various limitations of real classrooms and engage in personalized learning and training within virtual classrooms. so that students can get rid of the limitations of real classrooms and carry out personalized learning and training in virtual classrooms.

### 3 Construction of Virtual Simulation Teaching Resources for Engineering Equipment Courses

According to the different levels of students facing engineering equipment courses, the teaching focus is divided into three categories: single equipment theory and professional skills, systematic technical application of engineering equipment, and tactical application of equipment. Addressing key teaching challenges, the construction of virtual simulation teaching resources mainly focuses on three parts: "theoretical lecture, physical equipment operation, case discussion and scenario-based assignment".

In order to improve the teaching quality, a principle of "point-to-point" development between teaching focuses and virtual simulation resources is proposed. This principle aims to establish a full-process modular virtual simulation teaching resource system for engineering equipment teaching, covering "theoretical foundation - practical equipment operation - case studies". The virtual simulation teaching resources are illustrated in Figure 1.

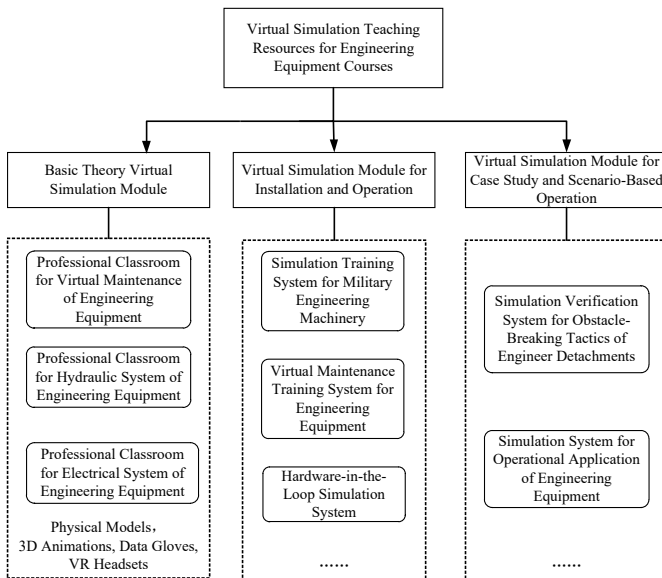


Fig. 1. Virtual Simulation Teaching Resources for Engineering Equipment Courses.

a) Construction of basic theoretical virtual simulation teaching resources. At present, theoretical teaching mostly uses video and graphic methods for explanation, lacking visualized knowledge decomposition and display. This paper leverages the digital and intelligent features of virtual simulation technology to establish virtual simulation professional classrooms, design various physical equipment models and 3D animations, and develop auxiliary devices such as data gloves and VR headsets. These enable students to interact with virtual equipment through multi-sensory channels including hearing, vision, and touch. Learning resources are made available online via internet platforms, supporting students in customizing personalized learning plans based on their individual

progress and self-regulating their study pace. By constructing vivid and realistic learning environments with richer, more dynamic 3D models and interactive dynamic resources that integrate both visual and auditory elements, students can truly understand knowledge through "observing, practicing, and thinking" rather than rote memorization. For example, in the teaching of engineering equipment structure content, students can conduct virtual disassembly and assembly at the same time, independently explore the equipment structure, transforming the traditional one-way knowledge teaching by teachers into a process of students' independent exploration of knowledge, deepening students' understanding of equipment structure.

*b)* Construction of physical equipment operation virtual simulation teaching resources. In response to problems such as insufficient quantity of engineering equipment and difficulty in environment construction, virtual training systems such as military engineering machinery simulation training system and engineering equipment virtual maintenance training system are developed. For teaching involving engineering equipment operation training, virtual equipment models are established through systems like military engineering machinery simulation training systems and hardware-in-the-loop simulation systems. A level-based progressive training mode and an incorrect operation warning model are also integrated to enhance the engagement of training. This enables students to operate equipment directly in classrooms, breaking free from the constraints of limited physical equipment. Students can conduct repeated training according to their individual needs, gradually mastering the correct equipment operation procedures and solidifying their operational skills.

At the same time, for fault diagnosis and maintenance courses, if fault diagnosis and maintenance training is carried out, it is often necessary to artificially set equipment faults, which may affect the equipment status and make it difficult to repeat the organization in high frequency. The engineering equipment virtual maintenance training system can virtually set fault phenomena, or create typical task scenarios and dynamically display the fault elimination process. Students can use this system to independently set fault scenarios, and explore and practice fault diagnosis methods combined with learned knowledge.

*c)* Development of Virtual Simulation Teaching Resources for Case Studies and Scenario-Based Assignments. At present, case studies and scenario-based tasks mostly remain at the level of plan design and discussion. It is difficult to verify the effectiveness of the tasks, and thus challenging to accurately evaluate the application effect of the plans. Therefore, a simulation verification system for obstacle-breaking operation tactics of engineer units and a simulation system for the combat application of engineering equipment have been developed. In engineering equipment combat operations instruction, the combat operations simulation system can create virtual battlefield environments. It assigns roles such as commanders, squad leaders, and operators, enabling tactical simulation exercises based on operational plans to project tactical outcomes. The simulation verification system for obstacle-breaking operation tactics of engineer units can support back-to-back confrontation training, simultaneously organize and implement obstacle placement and obstacle-breaking operation plans, and conduct simulation deduction. Through the analysis of deduction results, a complete link of "practical oper-

ation - phenomenon observation - data reading - analysis and induction" is formed. Students can check for gaps and make repeated iterations based on the deduction results, deepening their understanding of existing knowledge and scenarios.

## **4 Application Strategies of Virtual Simulation Teaching in Engineering Equipment Courses**

### **4.1 Principles of Virtual Simulation Teaching for Engineering Equipment**

The virtual simulation teaching of engineering equipment courses follows the principles of "integration of virtual and real, systematic design, and effect first".

The principle of "integration of virtual and real" means that the teaching content of virtual simulation training and physical equipment teaching should be reasonably designed to achieve complementary advantages. The ultimate goal of equipment teaching is to enable students to master the operation, maintenance, and application of equipment, which cannot be separated from the verification of practical training with physical equipment. Therefore, the virtual simulation teaching of engineering equipment-related courses must not be divorced from physical equipment; instead, it should be carried out based on the "integration of virtual and physical elements". It is necessary to make good use of both the intuitiveness and three-dimensional interactivity of virtual simulation teaching and the characteristics of physical equipment operation in traditional classrooms.

The principle of "systematic design" entails that virtual simulation teaching runs through the entire teaching process, providing virtual teaching resources in the whole process of pre-class, in-class, and after-class. Students can independently decide the learning time and place and customize personalized learning plans.

The principle of "effect first" means that when carrying out virtual simulation teaching, the teaching effect is taken as the primary indicator for teaching design, and virtual simulation teaching resources are reasonably designed according to students' actual learning state.

### **4.2 Optimization of Teaching Content**

In designing the virtual simulation teaching content of engineering equipment courses, it is necessary to identify the key and difficult points in different course contents and pinpoint the integration points of virtual simulation teaching for engineering equipment. By rationally designing the correlation between course key-difficult points and virtual simulation resources, a three-element mapping table integrating course content modules, teaching key-difficult points, and virtual simulation teaching resources should be constructed, so as to provide a reference for the subsequent implementation of course teaching.

Taking the teaching of bridge equipment combat application in the course Combat Application of Typical Army Engineering Equipment as an example, a teaching content mapping table is constructed, as shown in Table 1.

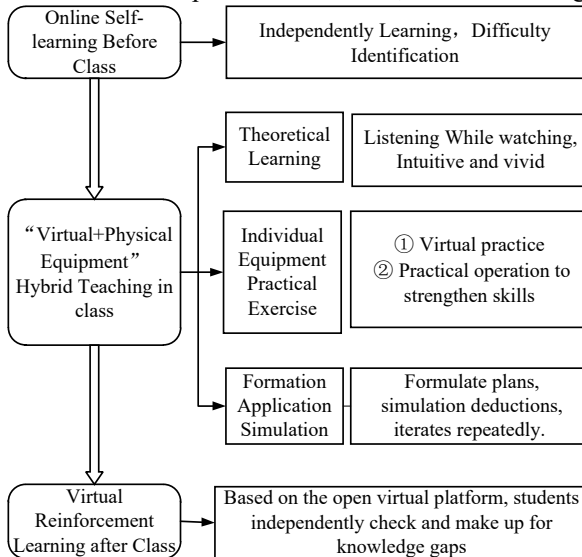
**Table 1.** Virtual Simulation Teaching Content Mapping

Course Module	Key and Difficult Teaching Points	Virtual Simulation Teaching Resources
Combat Application of Bridge Equipment	Structural Principles	3D animations, solid models, etc.
	Operation and Application Methods	Equipment Simulation Training System, Semi-physical Simulation System
	Formation Application Methods	Combat Application Simulation System

Based on virtual simulation resources, the teaching content is optimized: virtual simulation resources such as physical equipment models and data gloves are embedded into the teaching of abstract structural principle knowledge; the equipment simulation operation training system is embedded into physical equipment operation practice; and the combat application simulation verification system is embedded into combat scheme verification.

### 4.3 Improvement of Teaching Process Implementation

The teaching process primarily comprises three phases: pre-class, in-class, and post-class. Building on the traditional teaching model, and in conjunction with the virtual simulation teaching mapping table, virtual teaching resources are developed to implement a multi-stage teaching model. This model encompasses online autonomous learning before class, 'virtual + real' blended learning in class, and reinforcement learning based on open virtual simulation platform after class, as shown in Figure 2.



**Fig. 2.** Teaching Mode

Before-class online learning. According to students' cognitive laws and the principle of student-centered learning, 3D three-dimensional models of equipment are pushed to

students through the online virtual learning platform before class. Students can independently rotate and disassemble the models to understand the equipment structure in advance, complete simple knowledge learning before class, and learn key and difficult problems with questions in class.

In-class "virtual + physical equipment" Hybrid learning. According to the law of students' ability development, the teaching process is structured in the sequence of "theoretical learning-individual equipment operation practice - formation application simulation". For theoretical learning, virtual simulation resources including 3D solid models, data gloves, and VR technologies are deployed to enable students to observe the internal structure of the equipment synchronously while receiving theoretical instruction; Regarding individual equipment operation practice, a "virtual practice + physical equipment reinforcement" approach is adopted. Students first complete simulated individual operation training via the equipment simulation training system to establish preliminary operational competence, followed by hands-on practice with physical equipment to further enhance their practical operational skills; For formation application simulation, an engineering equipment combat simulation system is utilized to construct virtual battlefield environments and red-blue confrontation scenarios. This system serves to verify the equipment formation application schemes formulated by students, thereby cultivating their combat planning capabilities and practical combat thinking.

After-class Virtual Reinforcement Learning. According to their own weak points in learning, students use the open virtual simulation operation platform after class to conduct targeted individual equipment operation practice and equipment formation application simulation, so as to further improve their equipment operation skills and command decision-making capabilities.

## 5 Empirical Analysis

The teaching design was applied to the teaching of the Engineering Equipment course in 2024 to further verify its effectiveness, with a comparative analysis of the academic performance of students from the 2023 and 2024 cohorts. The evaluation focused on two core dimensions: theoretical knowledge mastery and practical skill proficiency. Theoretical knowledge mastery was assessed through a closed-book examination covering core content such as equipment structure principles and operational application rules, with a full score of 100. Practical skill proficiency was evaluated by an assessment team consisting of 3 senior instructors based on unified scoring criteria, with a full score of 100.

The academic performance of the two cohorts is presented in the table 2 below:

**Table 2.** The academic performance of the two cohorts

Evaluation Indicators	Experimental Group (20 students, 2024 cohort)	Control Group (20 students, 2023 cohort)
Average score of theoretical knowledge test	85.6±4.1	75.3±4.8
Average score of practical skill test	88.3±3.5	73.6±5.2

The average score of theoretical knowledge test for the experimental group ( $85.6\pm 4.1$ ) increased by 13.7% compared with the control group ( $75.3\pm 4.8$ ). The average score of practical skill test for the experimental group ( $88.3\pm 3.5$ ) increased by 20.0% compared with the control group ( $73.6\pm 5.2$ ).

Statistical analysis (t-test) indicated a highly significant difference between the two groups ( $P < 0.01$ ), demonstrating that the virtual simulation teaching design can effectively enhance students' understanding of theoretical knowledge and mastery of practical skills.

## 6 Conclusion

Based on the current status of engineering equipment-related courses, this paper deeply analyzes three major contradictory problems in engineering equipment teaching, and clarifies the necessity and urgency of virtual simulation teaching for such courses. Developed on the Unity Simulation Platform, the Virtual Simulation Experiment Platform for Engineering Equipment optimizes the multi-stage teaching implementation process, solving issues such as insufficient equipment quantity and difficulty in environment construction. It transforms the traditional knowledge transmission process into an intuitive and engaging independent exploration process, implements the student-centered teaching philosophy, and enables students to understand the knowledge thoroughly, practice skills conveniently, and master them proficiently. Next steps will focus on the demand for virtual simulation teaching resources, continuously enrich and improve the virtual simulation teaching resource library for engineering equipment-related courses, so as to provide strong support for virtual simulation teaching of engineering equipment.

## References

1. Xu Gang, Lian Changchun, Xiong Zhijun. Thoughts on the Development of Engineers and Engineering Equipment[J]. *Engineering Corps Equipment Research*, 2020, 39(4): 6-9. URL: <https://d.wanfangdata.com.cn/periodical/CiBQZXJpb2RpY2FsQ0hJU29scjkyMDI1MTIyNDE1NDU1NRIPZ2J6YnlqMjAyMDA0MDAyGgg1OWN1cHBrYw==>
2. Yaling Yin, Ruohui Zhan, Xiangge Kong. Visual Analysis of Virtual Simulation Technology Applied to Physics Teaching[J]. *Laboratory Research and Exploration*, 2025, 44(4):76-80,85. DOI: 10.19927/j.cnki.syyt.2025.04.017.
3. Guo Yanqiu, Zhu Yuanzheng, Cheng Ping, et al. Application Progress of Virtual Simulation Technology[J]. *Technology Innovation and Application*, 2020(1): 149-151. URL: <https://d.wanfangdata.com.cn/periodical/CiBQZXJpb2RpY2FsQ0hJU29scjkyMDI1MTIyNDE1NDU1NRINcWdzajIwMjAwMTA2MRoIcXpoNHk1MWI=>
4. Zhang Xiaoxue, Li Lei, Su Hexin. Research on the Application of Virtual Simulation Teaching in the Course of Mechanical Engineering Control Foundation[J]. *Equipment Manufacturing Technology*, 2021(9): 151-154. DOI:10.3969/j.issn.1672-545X.2021.09.042.

5. Zhang Jichuan, Wu Xiaohui, Zhang Tongfei, et al. Virtual Simulation Teaching is Imperative for Advanced Experimental Courses in Rubber Engineering[J]. *Polymer Materials Science and Engineering*, 2023, 39(6): 154-159. DOI:10.16865/j.cnki.1000-7555.2023.0121.
6. Li Wenhua, Wang Jingqin, Zhao Jingying. Exploration and Research on Virtual Simulation Teaching under Interactive Mode—Taking the Course "Electrical Reliability Technology" as an Example[J]. *Education and Teaching Forum*, 2022(11). URL: <https://d.wanfangdata.com.cn/periodical/CiBQZXJpb2RpY2FsQ0hJU29scjkyMDI1MTIyNDE1NDU1NRIPanlqeGx0MjAyMjExMDMwGghxaTlmMmoydA==>
7. Zhang Min, Wen Fu'an, Liu Junbo. Discussion on the Construction Logic of Virtual Simulation Teaching Environment in Colleges and Universities[J]. *Experimental Technology and Management*, 2023, 40(3): 1-6. DOI:10.16791/j.cnki.sjg.2023.03.001.
8. Yang Chen, Chen Zhong, Jin Guangzhe, et al. Application of Virtual Simulation in Online and Offline Teaching of Sensors[J]. *System Simulation Technology*, 2022, 18(2): 136-140. DOI:10.16812/j.cnki.cn31-1945.2022.02.006.
9. An Tao, Zhang Teng, He Yuting. Exploration and Practice of Virtual Simulation Experimental Teaching on Aircraft Structure Strength in Military Academies[J]. *Technology Wind*, 2025(26):22-24. DOI:10.19392/j.cnki.1671-7341.202526008.
10. Jiao Chuanhai, Sun Xiaojing, Xu Jing, et al. 'Wisdom + Simulation' Teaching Method for 'Basic Electronic Technology' Course in Military Academies[J]. *Journal of Electrical and Electronic Teaching*, 2025, 47(1):133-136. DOI:10.3969/j.issn.1008-0686.2025.01.033.
11. Miao Yusong, Zhang Xingang, Zhang Ying, et al. Initial Exploration on the Reform of Basic Mechanics Experiment Teaching Empowered by Artificial Intelligence and Virtual Simulation[J]. *Laboratory Research and Exploration*, 2025, 44(8): 155-160. DOI: 10.19927/j.cnki.syyt.2025.08.027.

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