World Journal of Educational Studies
ISSN: 2959-9997
DOI: https://doi.org/10.61784/wjes3012

APPLICATION OF VIRTUAL SIMULATION TECHNOLOGY IN COMPUTER SCIENCE EXPERIMENT TEACHING

Yan Ma[1*], Hao Wang[2]
[1]*School of Computer Science, Yangtze University, Jingzhou 434023, Hubei, China.*
[2]*Internet and Information Center, Yangtze University, Jingzhou 434023, Hubei, China.*
Corresponding author: Yan Ma, Email: mayan@yangtzeu.edu.cn

Abstract: Virtual simulation technology plays an increasingly important role in the experiment teaching of professional courses in universities, demonstrating significant potential and value. This study aims to explore the current application status of virtual simulation technology in computer science experiment teaching. Through literature analysis and case studies, it analyzes the advantages and disadvantages, problems and challenges, and future development trends of virtual simulation technology in computer experiment teaching. The findings provide important references for further promoting the application of virtual simulation technology in computer science experiment teaching.
Keywords: Virtual simulation technology; Computer science; Experiment teaching

1 INTRODUCTION

Virtual simulation experimental teaching, characterized by the application of information technology, meets the demands of open education and resource sharing in higher education during the information age. It provides advanced methods, open platforms, and high-quality resources for students to engage in inquiry-based learning, autonomous experiments, and innovative practices. In the experimental teaching of computer science in higher education, traditional teaching models face challenges such as resource limitations, safety hazards, and low student participation. The application of virtual simulation technology can effectively address these shortcomings, becoming a necessary approach to enhance the quality of experimental teaching[1-2]. This paper systematically reviews the application of virtual simulation technology in computer science experimental teaching, noting its primary use in experimental courses related to computer networks, operating systems, Internet of Things technologies, computer graphics, and artificial intelligence. The advantages of applying virtual simulation technology in computer science experimental teaching include safety, cost-effectiveness, flexibility, repeatability, personalized learning, enhanced learning experiences, interdisciplinary integration, and data collection and analysis. However, challenges remain in the implementation of this technology, including high costs, insufficient teacher training, and outdated equipment.

2 APPLICATION OF VIRTUAL SIMULATION TECHNOLOGY IN COMPUTER EXPERIMENT TEACHING

2.1 Overview of Virtual Simulation Technology

Virtual simulation technology utilizes computer-generated virtual environments to simulate the behaviors of the real world or specific systems, facilitating interaction and learning. Depending on the application scenario, virtual simulation technology can be classified into types such as Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and computer simulations. This technology possesses several notable characteristics: immersion, which makes users feel present in the environment; interactivity, allowing users to operate objects in the virtual environment in real-time; real-time response, ensuring that users' actions are immediately reflected in the environment; and repeatability, enabling users to conduct experiments and practice multiple times, thus reducing practical risks[3]. Virtual simulation technology is widely applied in various fields such as education and training (providing a safe experimental environment), healthcare (surgical simulations and skills training), military (tactical training and exercises), engineering (product design and testing), and entertainment (game development).

2.2 Typical Application of Virtual Simulation Technology in Experimental Courses

2.2.1 Computer network experiments

(1) Network Topology Simulation: Using tools such as Cisco Packet Tracer, GNS3, or NS-3 for simulating network topology design and configuration. Students can build and test various network architectures in a virtual environment, validating the functionality and performance of network protocols[4-6].
(2) Network Security Simulation: Conducting network attack and defense experiments through virtual simulation platforms, such as penetration testing with Kali Linux or simulating various types of network attacks (e.g., DDoS attacks) in a virtual environment[7-8].

2.2.2 Operating system experiments

(1) Virtual Machine Management: Using virtualization software like VMware or VirtualBox for experiments on operating system installation, configuration, and management. Students can test different operating system functions in a virtual environment without altering the settings of physical computers.
(2) Operating System Function Simulation: Simulating core functions of operating systems, such as process management, memory management, and file systems in a virtual environment, helping students gain a deeper understanding of the internal mechanisms of operating systems.

2.2.3 Artificial intelligence and machine learning experiments

(1) Algorithm Testing and Tuning: Conducting training and testing of machine learning algorithms in a virtual environment, utilizing virtual resources for large-scale data processing and model training. Common tools include TensorFlow and PyTorch, which can operate in virtual machines or cloud environments.
(2) Intelligent System Simulation: Simulating the operating environment of intelligent systems through virtual simulation technology, such as robot control and autonomous driving simulations, using tools like Gazebo and V-REP for virtual robot control and scenario testing.

2.2.4 Computer graphics experiments

(1) 3D Modeling and Rendering: Conducting 3D modeling and rendering experiments using virtual simulation technology, employing tools like Blender and Unity to create and showcase graphical works in a virtual environment.
(2) Graphics Algorithm Simulation: Testing and optimizing graphics algorithms in a virtual environment, such as ray tracing and shading models, helping students understand the practical applications of graphics algorithms.

2.2.5 Internet of things technology experiments

(1) IoT System Design: Using simulation tools like Cisco Packet Tracer and NS-3 for the design and testing of IoT networks[9-12].
(2) Sensor Networks: Simulating the deployment and data transmission of sensor nodes using virtual simulation platforms, such as Contiki OS for simulation[13-14].
(3) Embedded System Development: Developing and debugging embedded systems in a virtual environment, commonly using tools like QEMU and Proteus[15].
The application of these virtual simulation technologies not only enhances the teaching effectiveness of experimental courses but also helps students gain practical experience in simulated environments, reducing the need for physical experimental facilities and making the experimental process more flexible and safe.

3 COMPARISON OF TRADITIONAL EXPERIMENTAL TEACHING AND VIRTUAL SIMULATION TECHNOLOGY IN COMPUTER EXPERIMENT EDUCATION

Both traditional experimental teaching and virtual simulation experimental teaching have their advantages. Traditional experimental teaching emphasizes practical experience, allowing students to directly operate real equipment, thereby developing their problem-solving skills. This method is suitable for experiments that require an in-depth understanding of hardware and real environments. However, it comes with high costs, complex environment setup, and greater risks.
On the other hand, virtual simulation experimental teaching offers high flexibility and safety, capable of simulating various experimental environments and conditions, making it suitable for conducting multiple experiments and adjustments. Yet, it lacks practical operating experience with real devices, and the simulation results may not fully reflect real-world situations. When making a specific choice, it is important to consider the teaching objectives and experimental needs to achieve the best educational outcomes.
The following table compares and explains the advantages and disadvantages of traditional experimental teaching and virtual simulation experimental teaching, using examples from computer network experiments, operating system experiments, Internet of Things (IoT) technology experiments, and artificial intelligence and machine learning experiments.

Table 1 Comparison of Advantages and Disadvantages of Traditional Experimental Teaching and Virtual Simulation Experimental Teaching

Experiment Course	Teaching Method	Advantages	Disadvantages
Computer Network	Traditional	1.Provides real network devices for student to operation 2.Enhances practical operation and trouble shooting skills	1.High costs and complicated device maintenance 2.Network configuration can be complex and difficult to manage
	Virtual Simulation	1.Can simulate various network environments with high flexibility 2.Allows for quick resetting of the experimental environment	1.Lacks operational experience with real devices 2.Simulation of system response speed may not be realistic

Experiment Course	Teaching Method	Advantages	Disadvantages
Operating System	Traditional	1.Real operating system operation for deep understanding of system functions 2.Better understanding of hardware and software interaction	1.Dependency on specific hardware support 2.Security risks (e.g., system crashes)
	Virtual Simulation	1.Allows for safe experimentation, avoiding system crashes 2.Supports experiments on multiple operating systems	1.Lacks operational experience with real hardware 2.Performance simulation may be limited
IoT Technology	Traditional	1.Real hardware operation for a profound understanding of sensors and controllers 2.Learning in real application scenarios	1.High investment and maintenance costs for equipment 2.Complex and time-consuming environment setup
	Virtual Simulation	1.Flexibly build various IoT scenarios 2.Easy to test different configurations and conditions	1.Lacks direct operational experience with physical devices 2.May not fully simulate real-time data transmission
Artificial Intelligence and Machine Learning	Traditional	1.Real data processing and model training for a deep understanding of algorithms 2.Helps solve real-world problems	1.Long data processing and training time with high resource consumption 2.Actual projects limited by computing power
	Virtual Simulation	1.Can use large datasets and models to improve experimental efficiency 2.Easy to visualize experimental results	1.Lacks experience in solving real-world problems 2. Overly optimistic about model performance in virtual environments

4 ISSUES AND CHALLENGES OF VIRTUAL SIMULATION TECHNOLOGY IN EXPERIMENTAL TEACHING

Virtual simulation technology plays an important role in experimental teaching for computer science majors, but it also faces various problems and challenges.

High Technical Costs: One major barrier is the cost. High-quality virtual simulation software and hardware are often expensive, making it difficult for many institutions to afford, which affects the accessibility and quality of teaching.

Insufficient Teacher Training: Teachers often lack systematic training in the application of virtual simulation technology, leading to an inability to fully leverage the advantages of the technology during the teaching process. This can result in teachers being unable to provide effective guidance when students encounter problems in experiments.

Rapid Technological Updates: The fast pace of technological advancements makes it challenging for textbooks and course content to keep up. The rapid changes in the computer field require continuous updates to educational content; however, existing virtual simulation teaching platforms and course structures often lag behind technological developments, making it difficult to meet students' actual needs.

Impact on Student Motivation: Students' motivation to learn may also be affected. Some students may find the virtual environment lacking in realism, which can diminish their interest and engagement in learning.

Therefore, it is essential to strengthen investments in technology, teacher training, and content updates to address these issues effectively.

5 FUTURE DEVELOPMENT TRENDS OF VIRTUAL SIMULATION TECHNOLOGY IN EXPERIMENTAL TEACHING

The future development trends of virtual simulation technology in computer science experimental teaching are primarily reflected in the following aspects:

Increased Realism and Immersion: With continuous technological advancements, virtual simulations will become more realistic and immersive, enhancing student engagement and learning outcomes. The integration of artificial intelligence with virtual simulation allows for personalized adjustments to teaching content based on students' learning pace and abilities, improving the targeted nature of learning.
Support from Cloud Computing and Big Data: The application of cloud computing and big data provides robust support for experimental teaching, enabling students to conduct experiments anytime and anywhere while receiving real-time feedback, which promotes increased learning efficiency.
Innovation in Teaching Models: Innovative teaching models, particularly blended learning, will gradually become more widespread. This approach combines the advantages of online and offline teaching, fostering a blend of independent and collaborative learning, which cultivates students' comprehensive abilities.
Support and Investment from Education Policies: Emphasis on virtual simulation technology in educational policies will drive its widespread application. Additionally, teacher training and professional development are crucial for enhancing educators' proficiency in new technologies, ensuring effective implementation of virtual simulation in teaching.

6 CONCLUSION

Virtual simulation technology offers a safe and repeatable experimental environment in computer science education, enhancing students' practical skills and innovative thinking. While this technology is currently applied to varying degrees in many universities' computer science experimental teaching, challenges such as high costs, insufficient teacher training, and outdated resources remain. As technology continues to advance, virtual simulations will enable more personalized and diverse learning experiences, further promoting student autonomy and collaborative learning. Therefore, it is essential to encourage broader application and research, strengthen educational policy support, and promote the deep integration of virtual simulation technology with experimental teaching to enhance the quality of computer science education and improve students' employability.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Liang Q, Wu H, Yuan Y. Exploring the improvement path of virtual simulation experiments: based on the influencing factors and mediating effects of learning satisfaction. BMC Medical Education, 2024, 24(1): 1081. DOI: https://doi.org/10.1186/s12909-024-06082-x.
[2] Wang Weiguo, Hu Jinhong, Liu Hong. The Current Status and Development of Virtual Simulation Experiment Teaching in Foreign Universities. Research and Exploration in Laboratory, 2015, (5): 214-219.
[3] Soliman M, Pesyridis A, Dalaymani-Zad D, et al. The application of virtual reality in engineering education. Applied Sciences, 2021, 11(6): 2879.
[4] Wang Ke, Liu Wenyang, Wang Yu, et al. Research on the Application of Cisco Packet Tracer-Based Virtual Simulation Software in "Computer Network Technology" Experiment Teaching. China Information Technology Education, 2023, (20): 86-90.
[5] Jiao Min, Liu Yonggang, Zhou Xiaoming, et al. Demonstration and Virtual Simulation Teaching Training Platform for Computer Network Principles under the New Engineering Background. China Modern Education Equipment, 2023, (07): 5-8.
[6] Wang Yanjun. The Application of Virtual Simulation Technology in Computer Network Experiment Teaching. China Journal of Multimedia & Network Teaching, 2022, (08): 22-25.
[7] Cao Tengfei, Wang Jian, Wang Xiaoying. Teaching Practice of Computer Network Experimental Courses Integrating Virtual Simulation in Western Universities . Computer Education, 2023, (10): 40-43.
[8] Kang Haiyan, Yan Han, Jiang Hongling. Design of Penetration Attack Virtual Simulation Experiment Methods in Cybersecurity Environments . China Modern Education Equipment, 2022, (05): 38-41.
[9] Xing Yilan, Li Ying. Research on Virtual Simulation Teaching for Internet of Things Professional Courses. Journal of North China Institute of Aerospace Engineering, 2024, 34 (01): 39-41.
[10] Zhu Yi, Cao Qinghua, Liu Huixia. Design of Internet of Things Virtual Simulation for Comprehensive Development Training Focused on "End-Cloud Use" . China Modern Education Equipment, 2024, (19): 38-40+44.
[11] Wang Liang, Han Yujun. Research on the Construction of Virtual Simulation Training Platform for Internet of Things Application Technology Major. Internet of Things Technologies, 2024, 14 (08): 159-162.
[12] Li Tao, Xun Zhan, Gao Yun. Design of a Multidimensional Virtual-Physical Combined Experimental Platform for Internet of Things Mobile Applications. Internet of Things Technologies, 2024, 14 (06): 159-162.
[13] Zheng P, Yang J, Lou J, et al. Design and application of virtual simulation teaching platform for intelligent manufacturing. Scientific Reports, 2024, 14(1): 12895. DOI: https://doi.org/10.1038/s41598-024-62072-5.
[14] Li Y, Li C, Wang Y, et al. Design and development of immersive 3D virtual simulation experiment teaching platform for internet of things. Multimedia Tools and Applications, 2024. DOI: https://doi.org/10.1007/s11042-024-20209-8.

[15] Li Wei, Yuan Haidi. Exploration and Practice of Teaching Microcontroller Courses Based on Virtual Simulation Platforms. Computer & Telecommunication, 2024, (04): 63-67.