



# The Simulation of the Chemistry Experiment Teaching Based on Virtual Reality Technology

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**Abstract.** In comparison to the virtual experiment teaching, the traditional chemistry experiment has shortages such as inadequate experimental resources, toxic and harmful, and insufficient teaching time and space. Using the characteristics of virtual reality technology, combined with the theoretical basis of chemical experiments, a chemical laboratory system based on virtual reality technology was designed. The system provides students with a virtual teaching environment of experimental operation, video demonstration and three-dimensional scene roaming, which solves the difficulty of chemical experiment teaching to a certain extent. This proposed virtual chemical laboratory system can stimulate students' interest in learning, cultivate students' hands-on ability, and has excellent research significance and application prospects in the direction of experimental teaching.

**Keywords:** Virtual Reality Technology · Chemistry Experimental · Laboratory System

## 1 Introduction

Virtual reality (VR) technology originated in the United States. In 1987, Jaron Lanier formally proposed the concept of Virtual Reality, and defined virtual reality as: "A realistic three-dimensional virtual world is generated with computer technology as the core, through visual, auditory, tactile and other multi-sensory to realize simulated interaction in virtual environment" [9]. With the in-depth study of virtual reality technology, various countries have achieved different research results. The Ames laboratory established by NASA and the Department of Defense has established a complete virtual training system for satellite, aviation, and space station maintenance [7]. British Airways used virtual reality technology to design and develop a simulated advanced fighter cockpit [2]. The French EGA Group has developed a military vehicle simulation system suitable for actual combat simulation, collaborative training operations and troop exercises [3]. The Physical Electronics Laboratory of the TNO Institute (TNO-PEL) in the Hague, the Netherlands, has realized the technology of full user involvement in the simulation environment [6]. The Hirose Laboratory of the University of Tokyo in Japan is committed to overcoming the limitations of the current display and interaction technology and is developing a virtual holographic system for this purpose [5]. The Institute of Computing

Technology of the Chinese Academy of Sciences has achieved certain results in the field of digital human motion simulation by applying virtual human synthesis and virtual environment interaction [1]. Virtual reality technology is widely used in many fields, but so far, the research on virtual reality technology in chemical experiment teaching is insufficient.

In traditional chemical experiments, there are problems such as limited resources, insufficient experimental space and potential safety hazards [8]. This paper combines virtual reality technology with chemical experimental teaching. Using 3DsMax software to build a model, Unity3D platform to build a virtual scene, and design a chemical laboratory system with the preparation and properties of sulfur dioxide experiment as the design object.

The remainder of the paper is organized as follows: Section 2 describes the analysis of teaching requirements of the virtual chemistry experiment. Sect. 3 describes the design and application of the virtual chemical laboratory system. Conclusion is provided at the end.

## 2 Requirements Analysis

### 2.1 The Selection of Experimental Subject

TO verify the advantages of virtual chemical laboratory compared with traditional chemical laboratory, an appropriate experimental subject needs to be selected. The experimental subject should be a chemical experiment with certain danger, commonness and difficulty in operation. Therefore, the experiment of preparation and properties of sulfur dioxide is selected as the experimental subject in this simulation.

### 2.2 Requirements for System Functions

To meet the need of experimental teaching in a virtual environment and achieve the expected goals of experimental teaching, the following three requirements should be satisfied:

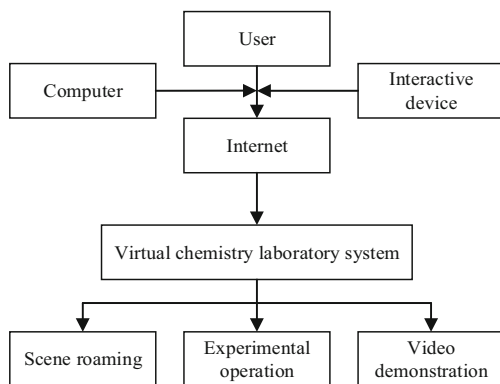
(1) Authenticity of the scene. The designed virtual scene should be consistent with the real scene. If the gap with the real environment is too large, it will have a great impact on students' interest and efficiency in learning.

(2) Virtual environment roaming. This function makes students can fully experience the world in the virtual environment from the first-person perspective, and observe the model equipment in the virtual laboratory to deeply experience the immersion and interactivity of the system [4].

(3) Experimental interaction effect. The user can operate the experiment through the interactive device, and the operation process is smooth and in line with the real experimental process.

## 3 Design and Application of the Virtual Chemical Laboratory System

The virtual chemical laboratory system is mainly composed of hardware and software. The hardware part utilizes the traditional desktop interaction method, which reduces



**Fig. 1.** Overall system framework.

the user's learning cost and simplifies the operation process. The software part utilizes Unity3D as the development platform, and 3DsMax is used to build the model. The experimental scene is built in Unity3D, and the script control model is written through the visual studio editor to realize the logical function of the virtual chemical laboratory.

### 3.1 System Frame Design

Figure 1 shows the overall framework of the experimental system. The user logs into the system on the Internet and operates the hardware interaction device to experience the functions of the system. Combined with common high school chemistry experiment courses, it simulates the experimental environment, equipment and experimental operation procedures in a real environment. The whole system includes three main functions of scene roaming, experimental operation and video demonstration.

### 3.2 System Flow Design

The system design flow chart is shown in Fig. 2. There are mainly the following steps:

(1) Collect materials. The first step is the collection of materials such as models and textures according to experimental contents.

(2) Design of 3D model. In the second step, 3DsMax is used to model the laboratory scene and experimental equipment, and the texture and rendering of the model are completed according to the collected information.

(3) Building virtual scene. In the third step, a new project in the Unity3D engine is created, and the imported model is used to build the main structure of the laboratory scene, and the scene layout of the virtual laboratory is completed.

(4) Function realization. The fourth step is to add corresponding components to the 3D model in the scene, use C# to write corresponding scripts or use corresponding plug-ins to realize the courseware function.

(5) Release project. Finally, the virtual chemical laboratory is packaged and released to the client.

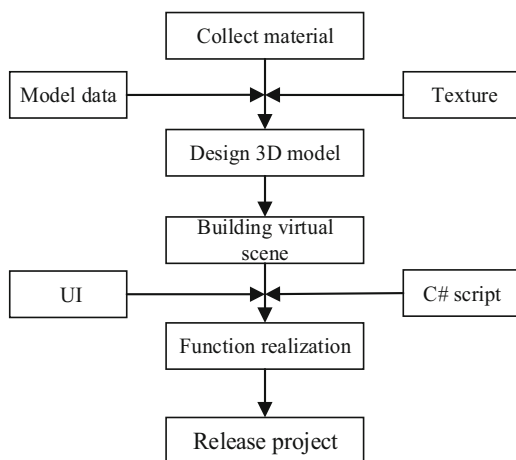


Fig. 2. System design flow chart.

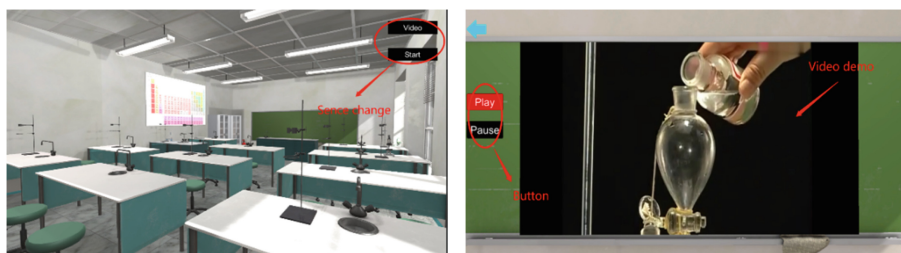
### 3.3 Main Functions

The functional scene interface is shown in Fig. 3. The displacement and rotation of the user's perspective in the virtual scene is realized through interactive devices, see Fig. 3(a). The user can jump to the experimental operation module and the video playback module, see Fig. 3(b), through the buttons on the interface. Figure 3(c) is the experimental operation interface. The backpack system is added in the experimental operation process, and the instruments, reagents and medicines required in the experimental process are carefully classified and managed, which is convenient for students to choose. It can not only restore the process of selecting chemical supplies in the real experiment, but also reflect the interactive advantages of virtual chemical experiments.

Figure 4 shows the experimental setup process. In the preparation and properties of sulfur dioxide experiment, an iron stand and a test tube must be instantiated through the backpack system, then placed in the fixed position, and sodium sulfate solution is added to the test tube. The effect of rising sodium sulfate solution in the test tube is achieved by the script function achieve. Then combine the separatory funnel with the test tube, add the sulfuric acid solution according to the prompts, and then place the litmus solution, the magenta solution, the hydrogen sulfide solution, the chlorine water, and the beaker in the fixed position, and finally add the caustic soda to the beaker and connect the catheter. At this time, a prompt pops up indicating that the experiment is completed.

Next, click on the highlighted piston on the separatory funnel to trigger the experimental reaction. As shown in Fig. 5, the same experimental phenomenon as the real environment appeared after a period of experimental reaction: the litmus solution turned red, the magenta solution faded, and the hydrogen sulfide solution became cloudy. The UI interface shows the equation and experimental principle of the chemical reaction, which proves that the aqueous solution of sulfur dioxide is acidic, and that sulfur dioxide has oxidizing, bleaching, and reducing properties.

The virtual chemical experiment system not only simulates the real experimental operation steps and phenomena, but also prompts the UI interface during the operation

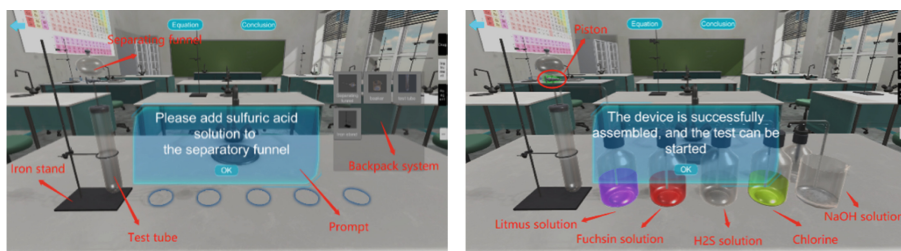


(a) Roaming interface

(b) Video playback interface

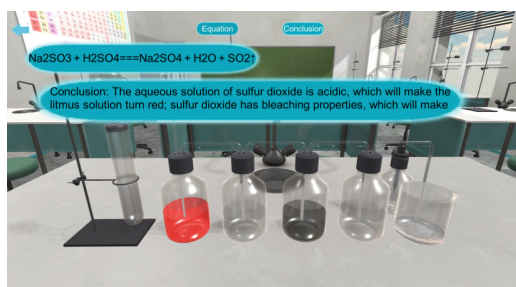


(c) Experimental operation interface

**Fig. 3.** Functional scene interface.

(a) Under construction

(b) Completed

**Fig. 4.** Experimental setup process.**Fig. 5.** Experimental response.

to guide the user to the next step. If the operation is wrong, an error will be reported and the operation needs to be repeated until the operation is completed correctly. This system avoids the danger of experiments, saves experimental resources, breaks through the limitations of time and place, and can also mobilize students' interest in learning.

## 4 Conclusion

This paper designs a virtual chemical laboratory system based on virtual reality technology. The system has three functions: scene roaming, experimental operation, and video demonstration. It can simulate the same experimental process and phenomenon of the preparation and properties of sulfur dioxide experiment in the real environment. The test shows that the system has good stability and repeatability. The system effectively avoids the danger of experiments, saves experimental resources, breaks through the limitation of time and place, and has good practicability. This study provides a technical reference for building a richer virtual chemical experiment platform.

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## References

1. Ding Y., Li Y.H., Cheng L. (2020) Application of Internet of things and virtual reality technology in college physical education. *IEEE Access*. 8.
2. Huang H.M., Rauch U., Liaw S.S. (2010) Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. *Computers & Education*., 55(3):1171-1182.
3. Jiang Y., Wei J. (2007) Virtual reality technology and its application in the field of military. *Foreign Electronic Measurement Technology*, 26(01):43-45+52.
4. Lamb R., Lin J., Firestone J.B. (2020) Virtual reality laboratories: a way forward for schools. *Eurasia Journal of Mathematics Science and Technology Education*, 16(6), em1856.
5. Lei C. (2017) Status and trends of virtual reality in foreign countries. *Competitive Intelligence*. 13(02): 51-58.
6. Li Q., Ye Z.Z., Liu G.H. (2021) Design of virtual laboratory simulation platform for communication principle. *Experimental Technology and Management*, 38(10):261-264.
7. Yang Q., Zhong S.H. (2021) A review of foreign research on "development and evolution of virtual reality technology". *Journal of Dialectics of Nature*. 43(03): 97-106.
8. Zhang C.H. (2018) Investigation and suggestions of chemical experiment in junior and senior high schools. *Chemistry Teaching and Learning*. 5: 76-78.
9. ZHAO Q.P. (2009) A survey on virtual reality. *Science in China (Series F: Information Sciences)*. 52(03):348-400.

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