Academic Education Publishing House

Application of Virtual Reality Technology to the Experiment Teaching of Junior High School Physics

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Abstract: With the advent of the information age, the traditional teaching of the physics experiment is facing severe challenges due to inherent deficiencies. The extensive application of Virtual Reality Technology (VRT) in experimental education can be used to effectively make up for the existed shortcomings of the traditional experiment teaching. Based on the basic theory and application of VRT, an innovative application mode with the usage of this information technology is constructed to explore the experiment teaching of the junior high school physics in the paper, which is taken the Ohm's Law exploration and resistance measurement experiments as examples. Combined with the flash technology, virtual experiments are designed to simulate the real physical experiment scenarios, which can effectively enhance students' understanding and cognition of the experiments. Subsequently, students, as divided into two groups including the virtual reality teaching group (VRG) and the traditional teaching group (TG), are organized to conduct physical experiment operations and questionnaire surveys are carried out to collect teaching effect data. The obtained results show that students of VRG have a more comprehensive understanding than those of TG in the experimental content and operation processes, better experimental observation and control abilities and more outstanding innovative thinking performance, which fully verifies that the auxiliary effect of VRT in experimental teaching is significantly superior to those of TG.

Keywords: Virtual Reality Technology (VRT); Experiment Teaching; Junior High School Physics; Teaching Innovation

1. Introduction

Physics is a science centered on experiments. Experiments can create scenarios consistent with students' cognitive laws for the construction of physical concepts and the exploration of laws, which enables students to obtain real materials through sensory experience. Thereby, it serves as a key way to develop core competencies in physics by fostering scientific inquiry abilities, rigorous research attitudes and sound scientific literacy. The new curriculum standard specifies the main purpose of compulsory physics courses to improve all students' scientific literacy for the basic development needs of secondary school student. Moreover, by shifting away from subject-centered ideology, the standard can effectively enhance the overall scientific literacy of citizens, which highlights the great significance of experimental teaching [1].

Under the background of the new curriculum reform, the physics experiment conditions in middle schools of remote rural areas are relatively backward and still face many challenges in most regions of China. In terms of experimental hardware facilities, the equipment is backward and incomplete. Thereupon, many experiments can only be completed through teacher demonstrations. According to the experimental instrument management, many schools lack professional laboratory technicians, leading to unprofessional instrument management. As for the environment for demonstration experiments, the clarity of some experimental effects is obviously low, which easily affects students' learning enthusiasm. Up to now, these problems will affect the teaching of physics knowledge and teaching effectiveness, which leads significantly to the cultivation of scientific literacy and other abilities. Therefore, the further exploration and application of new teaching methods and modes are of great significance for the modern physics education in the middle school.

In recent years, Virtual Reality Technology (VRT) has gradually become a research hotspot in physics experiment teaching and technological research and development, which integrates cutting-edge technologies including computer graphics, artificial intelligence, multimedia and human-machine interfaces [2]. In the early stage, the research, development and application of VRT were limited to high-end and confidential fields due to the constraints of equipment and capital. As the technological development proceeds, its application in daily life and production has only gradually emerged in recent years. Entering the new century, the comprehensive and rapid development of computer technology in China has been able to effectively support the description of realistic virtual worlds, which lays a solid foundation for the wide application of VRT in various industries [3]. In the manufacturing industry, Yu et al. [4] used VRT to accurately analyze the operational efficiency, dynamic performance changes and development trends of production equipment in the manufacturing industry. In the field of cultural heritage protection, Liu et al. [5] discussed in detail the application of VRT in visual simulation, digital collection and virtual display of cultural heritage protection, where some new approaches and methods were proposed to solve cultural heritage protection and inheritance. In the multi-medical field, this technology is currently used in simulation laboratories, simulation diagnosis and simulation surgery teaching. Zheng et al. [6] found that the application of VRT in ocular trauma teaching can effectively improve medical students' mastery of basic knowledge and practical skills to enhance their self-directed learning abilities and improve teaching satisfaction. In the field of education and teaching, Cai et al. [7] used VRT to solve the objective problems which exists in the curriculum construction of geographic information science, such as new technologies, limited resources and high requirements for teachers' professional technology updating. It is shows that this technologies effectively improved the teaching effect and efficiency of professional courses and promoted the upgrading of teaching methods. However, in rural poverty-stricken and underdeveloped areas, physics experiment teaching has long faced structural contradictions such as insufficient resources, backward methods and weak teachers, making experiment teaching a mere formality and difficult to achieve the curriculum reform goal of "from life to physics, from physics to society". In response to the above actual situation, the Ministry of Education's "Education Informatization 2.0 Action Plan" in 2025 clearly proposes to achieve full coverage of virtual experiments in rural middle schools by 2026. these facts reconstruct teaching scenarios through 5G, VR, big data and other technologies. The obtained results verify the feasibility of information technology in breaking resource barriers and reshaping teaching paradigms [7].

2. Virtual Reality Technology

VRT is a computer technology to create and experience virtual worlds. By constructing a digital three-dimensional simulation environment, it supports real-time interaction between users and virtual scenes, which displays a virtual experience highly similar to the real world [8]. Its core characteristics include the following sections. Immersion, in the section users can obtain sensory experiences, which is tantamount to the real world in virtual scenes. Thereby these sensory experimences are deeply engaged in the context. Imagination, in virtual scenes, people can perceive things or scenes that exist or have existed in reality and can conceive things that do not exist in reality through the brain. This can make the perceive things or scenes to actually present in the virtual environment. Interactivity, which is human-computer interaction. Operators can use various sensors to send interactive information to the information environment, manipulate keyboards, mice and single-layer digital information to interact. And the interaction can directly control, transform and modify virtual scenes [9-11].

At present, there are many development software for virtual reality technology [12], mainly including Java, C language, Flash software, VRML 3D world modeling and other programming languages [13]. In this paper the Flash software is used to implement VRT. Animations created by Flash can construct Flash APPs with rich content and high-quality dynamic animation effects on the basis of various effects such as images, audio and video. In image processing, the flash image tools can be applied or external network materials can be directly imported into Flash documents, which has a straightforward and convenient ability to expand material resources, making it an interactive animation design tool [14,15].

3. Teaching Effect and Analysis of VRT in

Physics Experiments

To demonstrate the superiority of the Virtual Reality teaching, the group teaching is adopted to analyze the innovative effect of VRT which is applied in the specific experimental teaching process in physics experiment teaching [16].

Virtual reality teaching group (VRG): Before the experiment, the teacher analyzed and explained the key and difficult points through demonstration experiments. Then students are guided to carry out virtual experiments using VRT to help them proficiently master the experimental principles, operation steps and expected results. After the students had no doubts, they conducted operation verification with physical experimental instruments.

Traditional teaching group (TG): The teacher adopts the traditional lecture method. First the teacher demonstrates the experiment for students and analyzes the key and difficult points. After these students of the TG had no doubts, they directly started the operation of physical experimental instruments.

The teaching objects are students from two ninth-grade classes with equivalent academic foundations, with 42 students in each group. After the teaching process is finished, a questionnaire survey is conducted to evaluate the teaching effect of the two classes [17].

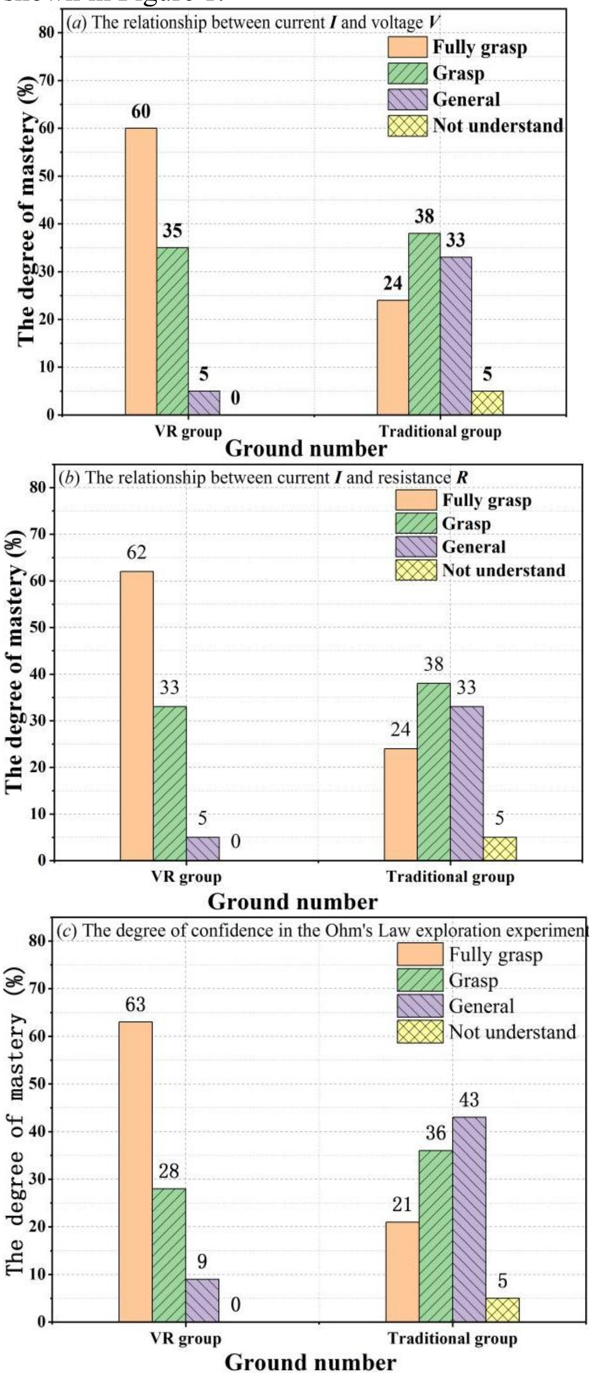
3.1 The Ohm's Law

The Ohm's Law is very important in the electricity of the junior high school physics [18], which clarifies the quantitative relationship among three physical quantities including current *I*, voltage *U* and resistance *R* in a circuit under normal temperature conditions. It measures relevant data through experiments and fits the quantitative relationship between the current I and the voltage (or resistance).

Relationship between current and voltage: When the resistance is constant, the greater the voltage across the conductor, the greater the current. During the experiment, the resistance is kept constant, the voltage and current across the resistance are measured, and the voltage across the resistance can be changed to measure multiple sets of data to ensure universality. Students are guided to analyze the data using the graphical method to draw conclusions.

Relationship between current and resistance: When the voltage across the conductor is constant, the greater the resistance of the conductor, the smaller the current. The control variable method is used to keep the voltage across the conductor constant. With the change of the conductor resistance, the current is measured through the conductor. For each physical quantity, Multiple sets of data are measured to ensure universality. The experimental data are visually analyzed using the graphical method to draw conclusions.

After the two groups of students completed the experimental teaching, the experimental teaching effects of the two classes are counted to demonstrate the advantages of VRT, as shown in Figure 1.



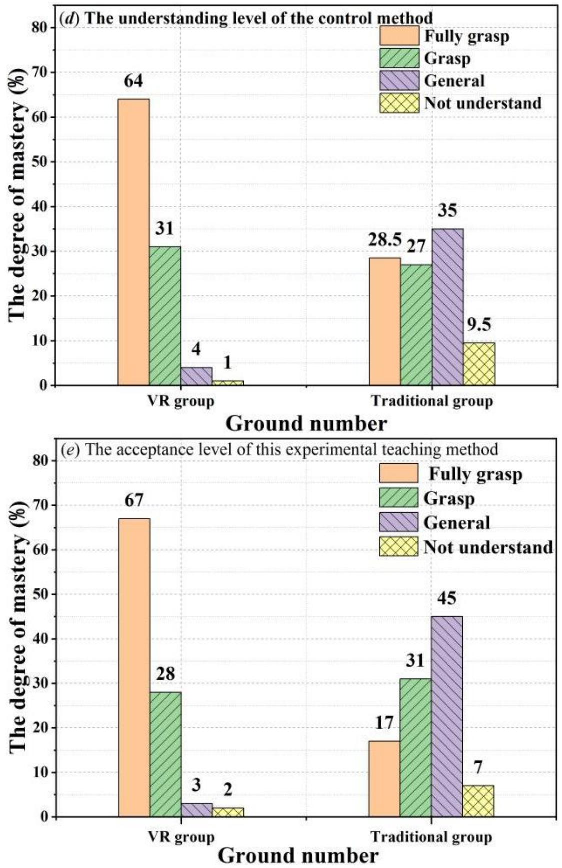


Figure 1. Analysis of Experimental Teaching Effects of the Ohm's Law under Normal Temperature Conditions. (a) Degree of mastery for the relationship between current I and voltage U; (b) Degree of mastery for the relationship between current I and resistance R; (c) Degree of mastery for the Ohm's Law exploration experiment; (d) Degree of mastery for the control variable method (an experimental method); (e) Degree of acceptance for the teaching method of the experimental teaching

It can be seen from Figure 1 that in terms of students' mastery of the relationship between current I and voltage U, the relationship between current I and resistance R, the Ohm's Law exploration experiment, and the control variable method in the experiment. The proportion of students in the VRG who achieves full mastery exceeded 60%, while that in TG is only about 20%. The proportion of students in the VRG with a general level of mastery is close to those of TG. The sum of the above two proportions is about 95% in VR, far higher than about 60% in TG.

In addition, about 40% of the students in TG dose not understand or master the teaching content, while most students in VRG can well grasp the experimental content and process. This further indicates that VRT effectively improves students' mastery of experimental objectives, content and steps, has obvious advantages in practical teaching. In experiential teaching process VRT offers a solid foundation for the practical group experiments to enhance students' interest in experimental teaching courses.

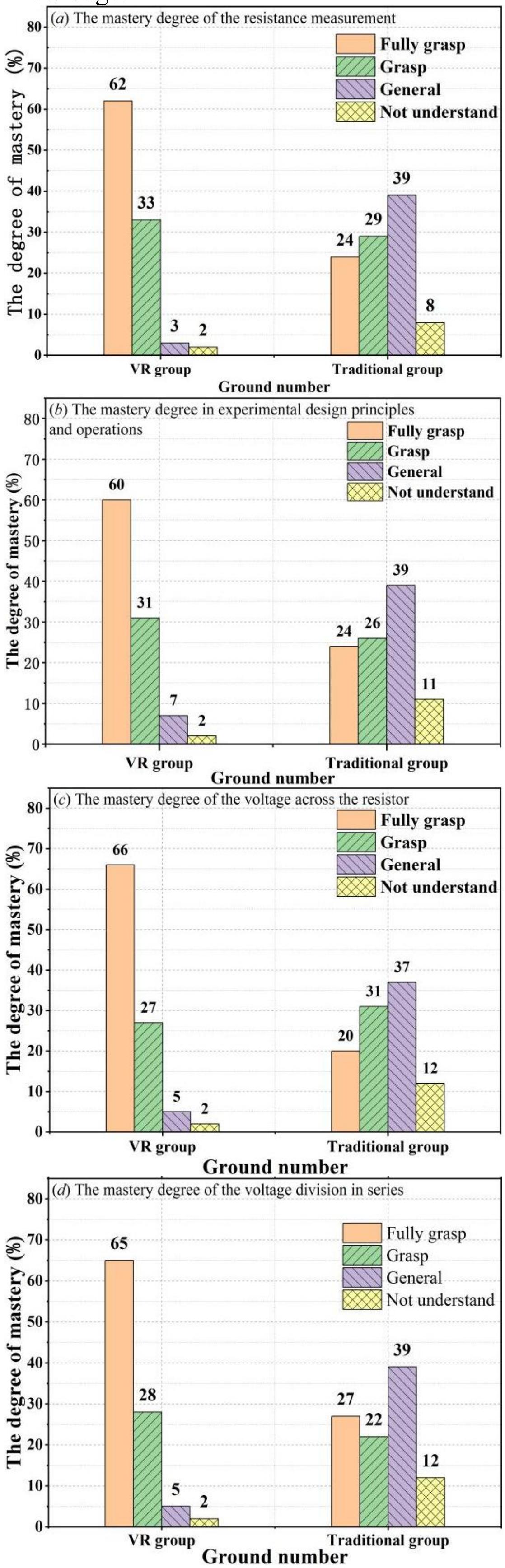
3.2 Resistance Measurement

Resistance measurement is an important application of Ohm's Law [18], which provides students with a method for measuring resistance. It is a case of applying Ohm's Law to solve practical problems and effectively enable student to understand the principle of measuring resistance using Ohm's Law. Meantime, it help them to learn the skill of measuring conductor resistance with the usage of the voltmeter-ammeter method. It realizes the systematization and coherence of knowledge through experiments based on previously learned knowledge.

Based on the Ohm's Law, the voltage across the conductor and the current through it are measured, the resistance is calculated using the voltmeter-ammeter method, and the experimental equipment and circuit diagram are determined. The voltage U and current I of the unknown resistance (R_x) need to be measured, and the sliding rheostat is used to change the voltage across (R_x). Multiple sets of data are recorded and depicted in Figure 2. Finally, students are guided to process and analyze the data, calculate the conductor resistance (R_x), and complete the experimental report. The experimental teaching effects of the two groups of students are analyzed, as shown in Figure 2.

It can be seen from the Figure 2 that there are significant differences between the two groups in students' mastery of resistance measurement principles, experimental design principles and operations, series voltage division principles, and the understanding of changing the voltage across the unknown resistance.

The proportion of students in VRG who achieves mastery or above in all designed questions exceeded 90%, while that in TG is only about 50%, indicating that the innovative application of VRT in physics experiment teaching improves the quality of experimental teaching. The usage of VRT can obtain better teaching effects and enhances various abilities of students from the learning interest, the understanding and mastery of teaching knowledge.



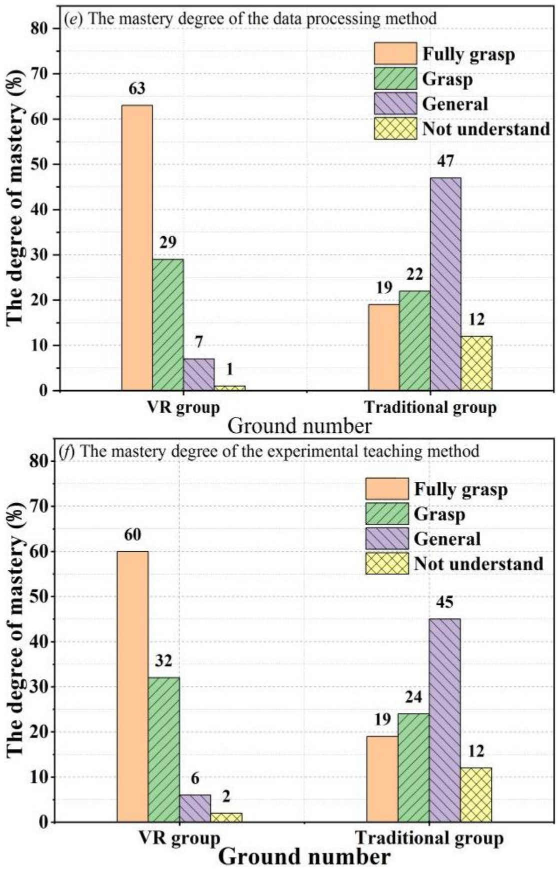


Figure 2. Analysis of Experimental Teaching Effects of Resistance Measurement. (a) Degree of mastery for the principle of resistance measurement; (b) Degree of mastery for the principle of experimental design and operation; (c) Degree of mastery for changing the voltage across the unknown resistance; (d) Degree of mastery for the principle of series voltage division; (e) Degree of mastery for data processing and calculation; (f) Degree of acceptance for the teaching method of the experiment.

As shown in Figure 2(e) and (f), the proportion of students in VRG who masters data processing and calculation also exceeds 90%, far higher than 40% in TG.

In addition, the proportion of students in VRG who barely understand the experimental results is basically about 10%, far lower than about 50% in TG, indicating that students in VRG are comprehensively superior to those in TG in terms of data processing and analysis abilities and the quality of experimental teaching is better. Therefore, the teaching effect is more significant and students' interest is greatly enhanced in the VRT teaching mode, reflecting the advantages of VRT in physics experiment teaching.

4. The Role of VRT in Experiment Teaching

The above two practical teaching cases highlight the advantages of VRT in physics experiment teaching: it enhances students' learning interest, effectively improves the effect of experimental teaching and the efficiency of teaching time utilization, and students' mastery of knowledge points, principles, content and steps of experimental teaching is significantly better than that of traditional experiments. The application of VRT breaks the basic mode of teacher-centered teaching methods in traditional experiment teaching and establishes a new experimental teaching mode that gives full play to students' independent innovation [19,20], which is mainly reflected in the following aspects:

Firstly, traditional demonstration experiment teaching is easily restricted by equipment requirements, external environment and human factors, which affects the accuracy of the experiment itself and teaching effect. In contrast, VRT experiment teaching can effectively reduce the loss and demand of experimental facilities. The correctness of VRT results can be further verified using experimental equipment, and it is not restricted by time and space, with simple operation and high accuracy, which is consistent with the results of literature [21].

Secondly, for teachers, using this innovative and highly compatible VRT teaching mode, relying on VRT with rich simulation teaching resources, combining students' own characteristics and subject literacy, and using the characteristics of materials to carry out virtual experiment teaching from multiple perspectives to meet the teaching needs of students in different environments, can broaden the diversification of teachers' teaching methods and realize the significant improvement of teachers' professional development and teaching abilities.

Thirdly, for students, VRT has rich simulation teaching experiment material resources, diverse learning scenarios and interaction methods, which can directly show experimental effects. Students can repeatedly simulate and operate the experimental process to verify their own guesses until they fully grasp the learned knowledge, providing a platform for students' autonomous learning. Therefore, it achieves good teaching effects and further improves students' learning interest.

5. Conclusions

Taking the Ohm's Law and its application as the practical teaching objects, this paper studies the innovative impact of VRT on the physics experiment teaching in the junior high school, and analyzes in detail that VRT effectively improves the effect of physics experiment teaching. Some main conclusions are as follows:

(1) The application of VRT in experiment teaching significantly improves students' understanding and mastery of experimental teaching content, with an acceptance rate of over 90%, which is far higher than the teaching effect of the traditional group.

(2) VRT serves as a bridge between physical knowledge and experiments, deepens students' understanding of experiments, enhances their interest in learning physical experiments, improves the practical efficiency of experimental teaching, and is conducive to students' all-round development.

Acknowledgments

This work was supported by the Project of Guangdong Education Evaluation Association (VDPG25002), the University-Industry Collaborative Education Program of the Education Ministry(251102279104936), the 2022 School-level Educational Teaching Reform Project of Lingnan Normal University (Science and Engineering Category 17), the 2021 "Curriculum Ideology and Politics" Demonstration Course Construction Project of the School of Physics Science and Technology, and the Humanities and Social Sciences Project of Guangdong Provincial Colleges and Universities (YXY1806).

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