Research on Virtual Circuit Laboratory Construction Based on STEAM Concept

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Abstract. In recent years, significant changes have taken place in the teaching methods and teaching environment, especially the development of virtual reality technology, which has continuously promoted the transformation of traditional laboratories into virtual laboratories. The existing virtual laboratories generally only pay attention to the simulation of experimental process and experimental principle, but they fail to design from the cultivation of students' skills and teaching strategies ontology. Therefore, we build a new virtual circuit laboratory based on STEAM education concepts. We proposed some new design principles and strategies, and applied the interdisciplinary integration characteristics of STEAM education. The virtual reality teaching is interfaced with STEAM education and the corresponding design ideas and principles are proposed to construct the virtual circuit laboratory model. Finally, the virtual circuit laboratory is constructed according to the model under the support of software and hardware.

1. Introduction

The concept of virtual reality appeared as early as 1933, when virtual reality existed only in science fiction. In 1960, Ivan Sutherland, the father of computer graphics, proposed the concept of "The Ultimate Display". Until 1994, Burdea et al. wrote the first book on virtual reality technology, *Virtual Reality Technology*, which detailed its concept and characteristics [1]. With the development and popularization of computer technology since 1990s, virtual reality technology has taken a real start from theory to practice.

Virtual reality technology is immersive and interactive and it is considered as a branch of simulation technology. It is a cross-product of computer graphics, sensor technology, network technology, human-machine interface technology, etc. It can generate a virtual scene by computer. This virtual scene is a multi-source information fusion, interactive 3D dynamic view and system simulation of physical behavior. It is precisely because of this unique understanding of the world and the characteristics of the world that virtual reality technology is gradually affecting the development and reform of education. The construction of virtual laboratory to achieve teaching objectives is an important application of virtual reality technology.

As an effective supplement to traditional laboratories, virtual laboratories have the advantages such as no time and space constraints, low cost, safety and reliability, and high reusability. The advantages and functions in teaching have been widely recognized in related fields. At the same time, there are some problems in the construction process of the existing virtual laboratories. For example, when constructing the virtual laboratory, only the simulation of the experimental process and the experimental principle is concerned, but the design of the student skills and the teaching strategy itself are not carried out [2]. In order to solve this erroneous idea of "heavy technology and light humanity", this paper combines the STEAM education concept with the construction of virtual circuit laboratory, proposes new design principles and strategies, and applies the interdisciplinary integration characteristics of STEAM education. The aim is to develop students' ability to acquire information and to solve problems through the learning style of project-based.

2. STEAM education concept

2.1 STEAM Education Overview

Originated from the United States, STEAM education was developed by STEM (*Science, Technology, Engineering, Mathematics*). Professor Georgette Yakman proposed the concept of STEAM in 2011, where 'A' stands for Arts, including a wide range of humanities and arts subjects, such as Liberal, Musical, Language, Performing, and Fine [3]. The original intention of STEAM education was to strengthen the education of individual subjects. Later, some researchers and practitioners expanded their connotations and highlighted the characteristics of subject integration, which is, STEAM education cannot ignore the independence of each subject [4]. Value should pay more attention to the mutual influence of knowledge among different disciplines. Therefore, it is the development direction of STEAM education from the division to the gradual better integration.

2.2 Targeting of STEAM Education

STEAM education is able to rise because it has the characteristics of subject integration. STEAM education cultivates the ability of individuals to apply their knowledge in science, technology, engineering, art and mathematics and related cross-cutting fields. It is not just five simple combinations of single subjects, but reasonable and appropriate use of the theoretical knowledge and related abilities of these disciplines to explore problems, and ultimately enable students to acquire the skills needed in the new era of information acquisition, problem solving, teamwork, etc.

At present, the two most common teaching methods in STEAM teaching are project-based learning and problem-based learning [5]. The project-based integrated STEAM practice teaching is considered to be an effective teaching method. STEAM education concept of science, technology, engineering, art, mathematics, combined with the understanding of electronic components, circuit board welding, circuit working principle and other projects in virtual circuit experiment, emphasizing the multidisciplinary attributes and technical diversity of project, engineering process, artistic expression and mathematical foundation. Integrate multi-disciplinary knowledge through project-based design and teaching, realize multi-disciplinary skills, cultivate compound talents who understand technology, innovation, and exploration. Finally, the goal of comprehensive development of students is achieved.

3. Construction of virtual circuit laboratory model based on STEAM concept

3.1 The combination of virtual reality teaching and STEAM education concept

STEAM education concept can fully reflect the practicality and relevance of knowledge in virtual reality teaching. It is the same as the immersive and interactive learning method in virtual reality teaching, it emphasizing the subjective position of students and attaching importance to the active participation of students in knowledge construction and enthusiasm in experimental operations. At the same time, STEAM education pays more attention to the integration and application of the knowledge learned in solving practical problems. It is a project-based or problem-oriented teaching method, and the learning scenarios supported by virtual reality can exceed human visual observation points and the description of knowledge ontology. It also can observe the experimental phenomena that cannot be presented in the virtual experiment process. Therefore, designing the virtual reality teaching project under the guidance of the STEAM educational concept to train students' multidisciplinary and comprehensive development is a feasible solution.

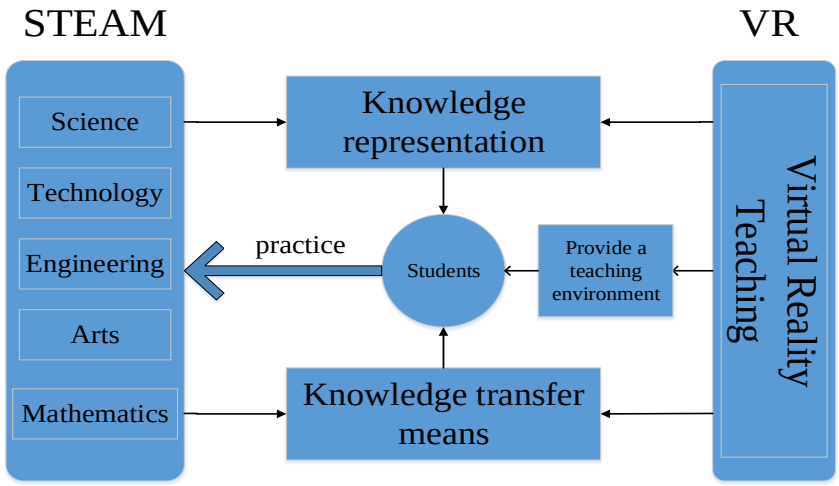

Fig. 1. STEAM education combined with VR

As shown in Fig. 1, the virtual reality teaching provides a virtual simulation learning environment with the student as the main body, and the learning content is obtained by the learner interacting with the learning object in the virtual environment. This paper introducing the STEAM education concept in knowledge representation and knowledge transfer means, and integrating the multi-disciplinary theoretical background to provide students with a complete and comprehensive knowledge network, which ultimately enables students to practice what they have learned in science, technology, engineering, art, mathematics, etc. In the form of knowledge representation, instructional design can be organized according to the inherent structural relationship of knowledge, and strengthen the systematic and systematic interdisciplinary knowledge content construction. The learners will be more organized in the process of receiving, and the learning process will also be more clearer; in the means of knowledge transfer, the instructional design is aimed at the teaching content and teaching purposes. Under the STEAM education concept, the teaching content is actively transmitted to the learner through the construction of a virtualized learning scenario. The means of transmission use intuitive methods such as video, pictures, and text information, the use of procedural and evolutionary methods in the transmission of information content, so that learners in the learning scene feel immersive to obtain a steady stream of knowledge content.

3.2 Virtual circuit laboratory model construction ideas and principles

3.2.1 Virtual circuit laboratory model construction ideas

The construction of the virtual circuit laboratory is based on electronic science, integrating computer science, engineering, information technology, physics, art and other disciplines. Each independent circuit experiment is used as a learning project to realize STEAM educational philosophy—*teaching science, learning technology, doing engineering, seeking art and studying mathematics*. By incorporating multidisciplinary knowledge into the experimental process, students extract key information from text, audio, video and other forms of knowledge transfer in virtual experiment scenarios to build STEAM subject knowledge.

The experimental design process should focus on the coherence of knowledge and skills and the multiple possibilities of experimental results. Different modes of operation of students during the experiment may produce different experimental results, which can enable students to improve design thinking and problem solving ability in the inquiry experience. The experimental design should stimulate students' interest in the virtualized learning environment, ensure the clarity and smoothness of the experimental images and the visualization and fidelity of the 3D model of the experimental equipment. Through virtual experiment scenes to simulate real-world situations, students not only can obtain knowledge directly from virtual scenes (*such as circuit schematics, electronic component characteristics, etc.*), but also use virtual reality technology to reproduce virtual experiments that cannot be performed under various natural states. Eventually they can combine mathematical problems (*such as resistance calculation, binary conversion, etc.*),

engineering problems (*such as board soldering, microcontroller programming, etc.*), scientific experiments (*such as circuit logic, observation of experimental phenomena, etc.*), to promote the integration of STEAM and virtual experiments.

3.2.2 Virtual circuit laboratory model construction principle

The construction of the virtual circuit laboratory should follow the principle of student-oriented to meet the various needs of students in the learning process. In STEAM education process, teachers and all educational tools can only serve as a guide, facilitators, regulators and interactors for students. Students are the explorers and practitioners of learning and they needs to explore, judge, organize, and creatively use the acquired knowledge when operating in an interactive virtual scene, which can ultimately be achieved in practical life. Everyone have a unique way of thinking and solving problems, you have to use your knowledge and skills in you own way to solve a variety of problems.

The construction of the virtual circuit laboratory must follow the principle of conformity with the facts. In the actual experimental process, the teacher will formulate the teaching objectives, teaching procedures, experimental equipment, and evaluation methods for each experiment. In the construction of the virtual circuit laboratory, this process should also be strictly followed. For example, the audio playback method can be used to tell the students the operation steps and precautions of the experiment. After the experiment is completed, the learning effect can be detected by answering the questions in the virtual scene. Let students complete all their learning tasks in a virtual environment.

4. Virtual circuit lab implementation

The implementation of virtual circuit laboratory includes hardware part and software part. 3dsMax software is used for modeling, and Unity3D engine is used for setting up the scene of virtual laboratory and circuit experiment. Combined with the HTC VIVE head-mounted display, operating handle and positioning device in the hardware part, the actual experimental scenes will be brought into the virtual world, giving the operator a real and strong sense of immersion. Real-time interaction with the scene through the operation handle, learning the circuit principle, welding the circuit board, testing the circuit and implementing the corresponding logic function in the virtual environment. The functions that can be realized in the virtual circuit laboratory designed and implemented under the STEAM education concept are: roaming of laboratory virtual scenes, learning circuit principle and component characteristics, circuit board welding and microcontroller programming.

Fig.2. Laboratory virtual roaming

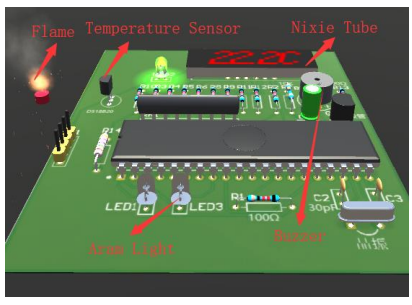

Fig.3. Circuit experiment scene

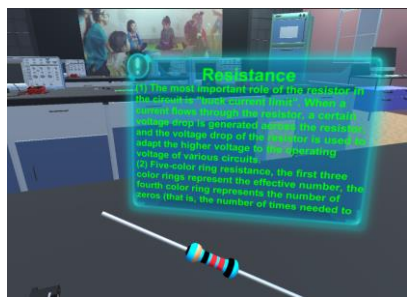

Fig.4. Component characteristics

Fig. 2. shows the virtual tour scene of the laboratry, which is completely built according to the actual laboratory. After the virtual reality device is worn, the students can walk around the virtual laboratry to observe the lab environment. They can also obtain experimental knowledge by watching the video. Fig. 3. shows the scene of electronic components. When the student is close to the test bench, the component can be grasped by the handle for 360-degree observation, and the UI interface will display the working principle and characteristics of the component. Fig. 4. shows circuit experiment scene (*acousto-optic digital alarm thermometer, for example*). The operations that can be implemented in this scenario are: soldering of the circuit board, writing of the microcontroller program, implementation of the logic function of the circuit. When the circuit

board is welded correctly, the circuit starts working after writing the correct microcontroller program. The temperature sensor displays the temperature of the fire source in real time on the digital tube. When the temperature is higher than 30 degrees Celsius or lower than 10 degrees Celsius, the buzzer will alarm and the whole circuit works.

5. Summary

The purpose of building virtual circuit laboratory is to create a virtual circuit experiment environment for students to promote them to learn and master experimental knowledge and skills, and develop a good scientific literacy. The purpose of constructing virtual laboratory model is to make the content organization more scientific and reasonable, and thus to promote the students multidisciplinary and comprehensive development. This paper expounds the virtual laboratory construction ideas and principles in combination with the STEAM education concept, combining the essence of STEAM education with virtual reality teaching to form a targeted teaching support strategy for virtual laboratory knowledge of different types of disciplines. In practical applications, the virtual laboratory constructed with STEAM education concept as the main line is an effective virtual teaching method. It integrates multi-disciplinary knowledge background through project-based design to cultivate students' literacy improvement in all aspects.

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