Virtual Reality in Engineering Education

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Abstract. The idea of virtual reality (VR) has gained widespread acceptance in modern society. Although most people still see it as a new form of entertainment, in fact, this kind of digital technology will play an important role in the future of education, especially engineering education. It can provide students with more intuitive and visual multi-sensory stimulation. By allowing access to virtual spaces for learning activities, students can be better guided for deep learning and interest cultivation, and their cognitive and application processes can be accelerated. Therefore, it is of great significance to apply this technology to engineering education courses. This research paper reviews what virtual reality is and the application of virtual reality in engineering education, and analyzes the benefits brought by the application of virtual reality in engineering education. Virtual reality technology represents a positive vision in which it will be the most promising assistive technology for engineering education in the near future.

1 Introduction

The cultivation of engineering talents is inseparable from high quality engineering education. How to make students better understand abstract concepts and accept new knowledge with keen interest has become a challenge in engineering classroom teaching. On the one hand, the traditional electronic teaching plan model is difficult to accurately and vividly present the complex principles in engineering science. On the other hand, the iteration of new technology in engineering field is fast, and the synchronization of related teaching content is easy to be delayed. Virtual reality technology with imagination, immersion, and interactivity features is expected to make up for the lack of traditional teaching methods. With a more practical teaching system, it is especially suitable for engineering science to deepen and materialize the teaching content with the help of virtual reality technology, so as to obtain better teaching effect. This paper introduces the past and present of virtual reality, explores the application of virtual reality in modern engineering education, and analyzes the impact of virtual reality applications on students and institutions.

The research on the application of virtual reality in engineering education has both theoretical and practical significance. From the perspective of theoretical significance, this study helps to deepen the academic discussion on the application of virtual reality technology in engineering education. At present, although more and more scholars are beginning to realize the importance of this technology for education, there is still a lack of analysis on the subdivision of engineering education. This research paper discusses the application of virtual reality in engineering education, which is helpful to fill the research gap to a certain extent. From the perspective of practical significance, this study can provide a reference for how to use virtual reality technology in engineering education courses. At present, there are few schools offering courses related to virtual reality technology, and the curriculum construction is still not perfect. This research paper discusses the teaching model of VR for engineering education. In addition, this research will also help to broaden and refine the application scenarios of virtual reality technology, and promote it to gain better popularity and social reputation in the future.

2 Virtual Reality

2.1 Concept and Initial Establishment

Virtual reality technology is a computer simulation system that creates a new interactive mode by simulating the 3D world. As a new comprehensive technology, it integrates computer simulation technology, computer graphics, artificial intelligence, network parallel technology, multimedia technology, and sensing technology [1]. Users can interact with the virtual environment through data sensing devices such as sensor helmet, data pen, and data glove, operate objects in the virtual environment in real time, and feel the changes caused by its operation. It has three basic features, including imagination, immersion, and interactivity. Imagination allows users to explore virtual macro or micro environments beyond the limits of human physiology. Immersion allows the user to become visually, acoustically, and tactually immersed in a virtual environment, transforming the role from a spectator to a participant. Interactivity allows the user to manipulate objects in the virtual world through software and

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hardware interfaces, with feedback features similar to those in the real world.

From the very first day of its invention, virtual reality has meant a positive vision worth a sustained struggle. It started in 1960 with Morton Heilig's invention of a multi-sensory simulation device called Sensorama [2]. In Heilig's opinion, VR is the most intimate way for humans to engage with data. In VR, the perception of data is essential, whether it is through a VR headset, gloves, or a full-body suit.

2.2 Related Educational Practice

Many universities, research institutions, and scholars have explored the effective application of virtual reality technology in education. The Karolinska Institute was the first university to study the utilization of virtual reality techniques in the field of education, and established VR educational technology in 1992 [3]. This research led by medical school found the practicality of virtual reality experiment in medical teaching. Although the technology at that time was relatively simple, it still proved that virtual reality would have a future in the field of education. The University of Nottingham proposed the Virtual Reality Applications Research Team project, which has carried out educational and academic research and exploration on VR educational technology [4]. This project is jointly implemented by the school of machinery, materials, manufacturing engineering, and management. The VR application in various fields is the focus of this research project, and the convenience and effectiveness of virtual reality experiment in engineering experiment teaching are found.

Practice shows that virtual environment can motivate students to learn and understand better. The key reason for this is that virtual environment provides the basis for a tight coupling between instructional information and typical symbols. An early model developed by Wirth et al. shows how VR can aid concept learning [5]. The study aims to identify, use, and evaluate functional support for immersive virtual reality to facilitate the mastery of complex and abstract concepts. The possibility of adequate conceptual learning in a virtual environment is demonstrated by testing the behavior of adolescents in the virtual environment. With the passage of time, the development of this trend has added a growing body of evidence for the convenience and effectiveness of this teaching method.

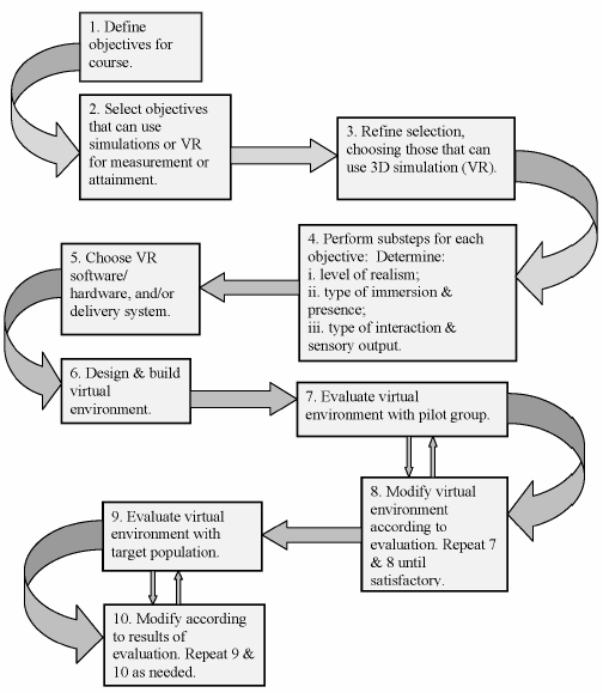

Fig. 1. A schematic view of a VR Education system [5].

Figure 1 shows the steps of using virtual reality in education. The constructivism theory also provides theoretical support for the application of VR in education. The constructivism learning theory refers to students' constantly engagement in learning by allowing them to "build" new knowledge on a basis of existing knowledge [6]. Context is a basic condition of meaning construction, and the cooperative dialogue between teachers and students is an auxiliary way in the process of meaning construction. VR technology can be used to construct a simulated learning situation or integrate teaching content into virtual courseware for teaching. Vivid three-dimensional images will replace the abstract text theory. In such a learning environment, students are more likely to unconsciously form self-constructed knowledge frameworks. This facilitates the internalization and transfer of knowledge. Detailed feedback can enrich the monitoring of the research process and results [7]. Through many steps and processes, the results of the study can meet the appropriate mission criteria and requirements.

3 Virtual Reality in Engineering Education

3.1 Auxiliary Theoretical Teaching

Using virtual reality technology can make the abstract theory teaching become more intuitive and perceptual. Engineering theory courses are usually more abstract. For example, drawing is a compulsory basic course for mechanical majors, which requires students to have certain spatial thinking ability. It is difficult to accurately express this spatial thinking ability merely by language, especially for students with a poor spatial sense. They

find it difficult to imagine planar plans into three-dimensional ones [8]. The traditional project which helps students accomplish their learning goals has its own drawbacks. For example, projects are often overly ambitious, which prevents students from testing or implementing their hypotheses [9]. By taking advantage of visual features, virtual reality technology can help solve this problem. For example, when a teacher is explaining a planar graph to students, he or she can scan the planar graph with the camera of a mobile phone or tablet. Then the virtual reality software will be able to match the corresponding 3D model by recognizing the plane graph, and present the model. Students can rotate, scale, and manipulate the model. Other engineering majors could use a similar approach to support classroom instruction.

3.2 Overcoming Experimental Limitations

The virtual simulation laboratory established through virtual reality technology is not limited by the number of sites, equipment, and instruments. Engineering students are affected by the safety factors, a lack of proper infrastructure and equipment, as well as time and space limitations in their study [10]. Specifically, because some engineering courses involve disassembly practice, such as automobile courses with engine disassembly experiments, the experimental equipment is prone to show a sign of wear and tear. With the development of science and technology, experimental equipment needs to be updated constantly. However, some universities update the laboratory equipment slowly due to funding and space constraints. Virtual reality technology can solve these problems in experimental teaching. In addition to learning the knowledge of simple devices and systems, engineering education also involves the learning of how complex systems and large-scale devices operate and are regulated. However, universities cannot purchase the above equipment to provide practical conditions for students in terms of financial resources and venues, and it is difficult for relevant enterprises to frequently provide students with practical learning opportunities. In that case, VR technology can be used for simulation and interactive design of, for example, a 1000MW coal-fired power station. In this virtual environment, students can experience the overall display and a panoramic tour of the power station, ans carry out load regulation and fault handling process simulation of the power station [11]. Makarova et al. also proved that virtual reality can help overcome experimental limitations pragmatically by demonstrating the role of virtual reality in automotive industrial engineering education [12].

3.3 Integration of Complex Systems

Virtual reality technology can help students better understand the complexity of engineering systems. The lack of integration of the current education system has led to the fact that new engineers or operators often do not have enough equipment to deal with the complexity of modern technology. Generally speaking, the modular courses of undergraduate colleges and training institutions are designed in the current educational environment. Each course involves a specific focus. For example, subjects or courses of industrial and systems engineering majors are devoted to product innovation and design, facility planning and design, manufacturing engineering, ergonomics, logistics and operation management, planning, scheduling, optimization, information systems and statistics [13]. Ildiko Horvath demonstrated in his research that how VR, through the application of innovative educational methods, enables people and information and communications technology to integrate in the collaborative virtual reality scene in the working process, and teaches future engineers the ability to use complex systems [14]. VR can help to better combine the characteristics of each course and design courses that integrate these modules.

3.4 Supplement to Teacher Resources

By combining big data and intelligent voice technology, VR can generate "virtual tutors" for teaching and tutoring. Cobb et al. [15] pointed out that the increasing number of students in the UK limits the opportunities for educators to provide positive learning experiences for all, which makes it imperative for educational institutions to adopt innovative new teaching methods in order to provide more satisfying learning experiences despite limited resources. Before and after formal school courses, students can use "virtual tutors" to solve basic engineering problems and help with related experiments. In addition to the teaching knowledge and models that have already been input, the capabilities of the "virtual tutor" are constantly upgraded based on feedback from interactions with students. This will supplement the resources of teachers majoring in engineering, and the virtual reality teaching can also be better carried out according to the engineering foundation and the learning ability and personality characteristics of students.

4 Benefits of Virtual Reality

4.1 Benefits for Students

VR can help improve students' understanding of subjects, grades, and educational experiences. Since engineers are natural problem solvers who need to instill creative and critical thinking, meaningful participation in the innovation process is essential [9]. Virtual reality can transform traditional classroom teaching methods and create imaginative situations that help them understand difficult topics in interesting ways. Students can observe the performance and manufacture of different machines from many angles, without the limitation of classroom space. This combination of visualization and interactivity helps students actively learn through the experience. At the same time, the technology allows students to study in an undisturbed environment, further improving their concentration levels and helping them to better remember the content. By comparing the results of 48 engineering college students after each test, Alhalabi proved the

positive effect of virtual reality system on teaching [16]. In addition, based on digital storage and manipulation technology, the intellectual output of each learner will be more effectively shared by the entire research team. This will promote their cooperation and effective communication. Compared with the traditional education model, this is the communication advantage of VR. If distance learners have the ability to purchase their own VR headsets, they can experience the same level of education on campus as full-time students. According to Dunnagan et al. [17], a virtual laboratory of organic chemistry was created and the short-term and long-term memory of students was compared with that of a conventional laboratory. The results showed that students' short-term and long-term memory had better performance in the virtual experimental environment.

4.2 Benefits for Institutions

By using VR instead of physical laboratories, universities/institutions can benefit from the reduced liabilities and costs. In the field of engineering education, experimental teaching has a series of safety requirements. Compared to real LABS, virtual reality experimental environments and operations tend to be safer, and many risks can be avoided at source. At the same time, the use of 3DMAX for modeling and the development and production of Unity3D virtual reality engine can promote the deep integration of virtual reality technology and teaching [18]. The realization process of courseware based on this engine has strong operability and testability. The design, development, and implementation of this method are simple, which can help reduce the cost of teaching and the waste of resources.

5 Conclusion

As a revolution of human-computer interaction, virtual reality can become an important auxiliary technology in engineering education. This study analyzes the concept, characteristics, and research on the teaching of virtual reality technology through literature review. With the development of virtual reality technology, the way people think, remember, and educate their children is changing. This represents the researchers' positive vision for education to be moved away from traditional models. This digital technology will stimulate students' creativity and help them achieve meaning construction more consciously. In engineering education, virtual reality technology can transform boring theoretical knowledge into perceptual cognition, with the help of visual and interactive characteristics. At the same time, due to the limitations on the site, equipment, funds, and safety, some engineering experiments and operations are difficult to be demonstrated and operated. Virtual reality technology can reduce the cost of these experiments. VR is not only in line with the future development direction of engineering education, but also can meet many needs of teachers and students. However, this study still has some limitations. Because the actual simulation analysis has not been carried out, the application and effect analysis of the teaching model still needs to be further verified.

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