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Influence of Virtual Reality (VR) Technology on the Teaching Effect of Engineering Practical Training

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Abstract

Emerging technologies represented by artificial intelligence, blockchain, and big data have comprehensively promoted the improvement of education quality and the reform of teaching models. The comprehensive and efficient integration of advanced technology and teaching courses is conducive to the implementation of different teaching modes and breaks through the constraints of traditional teaching modes. Using Virtual Reality (VR) technology to teach practical training courses can significantly enhance students' interest in participating in practical training, improve teaching effectiveness and quality, reduce the risk of misoperation in practical training, avoid teaching risks, improve teaching quality, and has high promotion value in the existing engineering training courses. This study designed a questionnaire on the impact of VR technology on the teaching effect of engineering training, and analyzed the impact of five aspects of VR technology (teaching objectives, teaching design, teaching resources, teaching process, and assessment methods) on the teaching effect of engineering training. The variance analysis method was used to measure the different effects of VR teaching frequency on the effect of engineering training. Results show that the overall reliability coefficient value is 0.834 and the convergent validity and discriminant validity are very good. Specifically, teaching objectives, teaching design, teaching resources, teaching process, and assessment methods in VR teaching have a significant promoting effect on the teaching effect of engineering training. The frequency of VR teaching has a 0.05 significance level for the effect of engineering practical training (F=2.340, p=0.042). In addition, the relationship between the frequency of VR teaching and the effect of engineering practical training showed an inverted U-shaped curve. Conclusions provide a valuable reference for using VR technology to support engineering training teaching and the improvement of engineering training teaching methods.

Keywords: VR technology, engineering training, teaching effect, variance test, questionnaire technology

1. Introduction

Modern educational information technology that is based on the Internet and information exchange medium is presented in the form of "Internet plus Education."

With the continuous development of various new technologies in society, how to improve the quality of engineering talent training has become the focus of higher education in many countries under the background of economic globalization. To respond comprehensively to the wider and deeper scientific and technological progress and industrial transformation on a global scale, China has actively promoted the construction of new engineering disciplines and achieved the quality of engineering talent training by improving the quality of engineering specialty and building industrial college platform. Countries around the world are attaching great importance to the practical training of engineering majors. Engineering training courses is a key link in cultivating engineering undergraduate to improve their innovative consciousness and engineering practice ability. A good effect of the engineering training course will help students gain a good understanding of the engineering industry, and to have a systematic knowledge construction in engineering construction. At present, many universities in China have established engineering training centers. By incorporating the government and enterprises into the construction of engineering training centers, the real production scenarios of enterprises have been moved to the university campus. As one of the teaching methods, engineering training mainly aims to improve engineering students' ability to solve practical engineering problems and improve their ability to engineering practice. The training is the core means to cultivate high-quality engineering and technical talents with innovative consciousness and innovation ability. Engineering training teaching can activate college students' interest in the practical teaching of engineering majors, and combine the development of professional characteristics to build a distinctive personalized learning plan. The teaching of engineering training projects is intended to cultivate the innovative ability of learners and encourages students to explore the mechanism of unknown things profoundly. In particular, many engineering training programs require teamwork, which can allow students from different majors to participate in teams, support one another, and improve their abilities. Given that engineering training requires learners to operate various equipments, training is difficult, and some training projects are even dangerous. Therefore, using VR technology to implement engineering training teaching to improve learners' engineering training motivation and teaching effect is a direction for the reform and update of engineering training teaching methods.

As a new type of technology, virtual reality (VR), has entered the field of educational technology in an all-around

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manner, and it has led the direction of educational informatization reform. Virtual reality technology integrates 3D modeling technology, simulation technology, network technology, and other computer technologies to build a 3D virtual environment that features realistic visual, auditory, tactile, and multi-sensory elements. The virtual environment is similar to the real environment. Users utilize IoT devices, sensor devices, and other peripherals to interact and experience the virtual environment and objects naturally and harmoniously. The interactive, immersive, and conceptual characteristics of virtual reality technology itself make the immersive teaching system have 3D visual effects and sound characteristics. Natural and harmonious human-computer interaction is a new and important technical means of visual teaching. Engineering training is an essential innovative comprehensive practice course for college students. However, in traditional work training teaching, due to the lack of practical training conditions and other reasons, many universities have difficulties in the practical teaching link. Thus, using virtual reality technology and applying it to educational reform is one of the important measures. It visualizes knowledge, provides virtual interaction and a new type of teaching experience, enhances students' interest in learning, and has a significant impact on existing education and teaching models.

2. Theoretical Analysis and Hypothesis Development

2.1 Theoretical Analysis

Brown et al. [1] believed that Situated Cognition is a theoretical concept gradually formed after the development of behaviorist learning theory and cognitive psychological learning theory. This theory attempts to correct the behaviorist theory that specific stimuli can elicit specific responses. Situational cognition theory believes that knowledge learning should be combined with a specific situation, and knowledge does not exist independently of the situation but is attached to the situation. Situational cognition has four characteristics: situational, interactive, dynamic, and immediacy. Learning based on virtual reality situations seeks to provide learners with rich, realistic situations for learning. With the cooperation of multiple virtual senses and through interaction with virtual situations, users can have an immersive experience from a first-person perspective, changing the way students acquire knowledge and cultivating their divergent thinking. Therefore, this theory is one of the theoretical foundations of this study.

Experiential learning theory explains that the learning process should be learner-centered, emphasizing the learner's real experience or contextual simulation of an event or process, and reflecting on it to acquire knowledge, develop abilities, and generate emotions [2]. Experiential learning consists of four stages: concrete experience, observation and reflection, abstract conceptualization, and active testing. These stages spiral through a person's entire learning process. In the process of experiential learning, teachers can help learners test their theoretical assumptions in new situations by constructing real situations or simulated situations to gain direct experience. Experiential learning focuses on the direct experience of learners throughout the inquiry process, after which learners gain understanding and cognition in three dimensions: cognition, skills, emotions, and attitudes. Experiential teaching not only focuses on knowledge and skills but also emphasizes changes in perceptions and attitudes during the learning process. In addition to past knowledge and experience, the learning content focuses on learners' immediate feelings and acquisitions, and the experience of content and process. The construction of an experiential learning environment based on VR technology will receive important technical guarantees and support, and the most important feature of this learning environment is that the objects used to build the learning environment are digital and virtual. The strong interaction, high immersion, contextuality, and other technical features of virtual technology have positive effects on enhancing students' learning motivation, experimental experience effect, and learning effect. Therefore, this theory is one of the theoretical foundations of this study.

2.2 Hypothesis Development

Western developed countries such as Germany, the United States, and Japan proposed to apply VR technology to the education field. Now, VR is applied to practice in remote practical training teaching. Owing to the good visual experience offered by VR technology, many universities have realized the comprehensive integration of VR technology and engineering practical training teaching content through the construction of virtual scenes. The resources are inclined to be small and exquisite, and the construction of normative training in which the content focuses on the process of the training. By developing VR practical training sessions consistent with actual teaching and constructing a variety of differentiated VR teaching scenes, the teaching methods are optimized so that students' personalized development, emotional value shaping, innovative and entrepreneurial consciousness construction are organically integrated with engineering practical training teaching, thus improving the quality of talent training. Regarding the research on the relationship between VR technology and variables such as teaching effectiveness and learners' performance levels, Bricken [3] introduced the unique characteristics of VR technology and the potential of virtual worlds as learning environments, and discussed the relationship between VR and educational theory and teaching practice. Shin [4] examined the effect of VR technology on learners' learning process, and the results confirmed that VR technology can enhance learners' specific cognitive processes through presence and immersion. Vergara et al. [5] argued that the application of VR has been widely used in engineering education, and the results showed that VR technology combined with engineering education can enhance learners' learning performance levels. Chen [6] argued that VR presents many alternative learning opportunities. The results showed that by adopting VR technology for use in students' language learning practical training, students improved their phonological, morphological, grammatical, and syntactic knowledge. Moreover, virtual world learning helps develop complex and higher-level thinking, thereby creating a positive impact on students' language cognition. O'Connor et al. [7] argued that by using off-the-shelf virtual environments and retooling their use, teachers can create engagement, community building, and immersive learning opportunities for students. Moreover, how teachers can develop useful learning interactions, guide their learning environment, assess learners, and evaluate the environment was explained. Pan et al. [8] analyzed the impact of VR and augmented-reality-based VR technologies on education and showed that virtual learning can enhance, motivate, and stimulate learners' understanding of certain events, especially those where traditional concepts of instructional learning have proven inappropriate or difficult. Singh et al. [9] developed a virtual reality-based learning environment (VLE) designed to provide engineering students with pre-training on electronic laboratory hardware. Experimental results showed that virtual reality had a significant positive impact on students' knowledge, motivation, and cognition, and that students were able to demonstrate a better understanding of the lab hardware by interacting with a 3D virtual model of the lab apparatus. Vergara et al. [10] suggested that student motivation can be enhanced through the use of VR technology. Di Lanzo et al. [11] showed that the use of virtual classroom environments as a supplement to traditional teaching environments is escalating with the substantial and beneficial use of virtual reality environments in engineering education. Soliman et al. [12] concluded that virtual reality is an excellent tool in engineering education with positive cognitive and pedagogical benefits, ultimately improving student understanding, performance and achievement in the subject and educational experience. Kumar et al. [13] discussed the opportunities and challenges of incorporating VR into chemical and biochemical engineering education. The results showed that the use of augmented virtual reality interfaces can enhance advanced immersion for learners. Halabi [14] thought that in the context of engineering education, VR technology enhances student motivation and creativity, improves problem-solving skills, and improves learning outcomes. Akbulut et al. [15] investigated the impact of VR on the performance of Bachelor of Science (BS) in Computer Engineering students within a data structure course. The experiment showed that VR-ENITE based on VR technology is effective in teaching software engineering courses and is complementary to traditional teaching methods. Syed et al. [16] introduced VR technology into teaching, and it can improve the effectiveness of undergraduate mechanical engineering courses by supplementing traditional learning experiences with out-of-classroom materials, thereby increasing students' confidence in using engineering tools. Zhou et al. [17] showed that immersive scene models of workspaces can be reconstructed through the use of VR technology to improve learners' 3D scene reconstruction in robotic teleportation efficiency and situational awareness of human operators. Shi et al. [18] showed that the 3D and VR groups outperformed the 2D simple and 2D complex groups in terms of operation time and maintenance accuracy. Udeozor et al. [19] concluded that VR games in chemical engineering and industry can help learners gain a better learning experience, and the study found that both students and professionals found that VR games facilitate learning. Marks et al. [20] thought that virtual and augmented (VAR) technology has improved reported learning outcomes for engineering learners. Chen et al. [21] found that VR enables learners to interact with multiple forms of information, and results show that students in the experimental group significantly outperformed those in the control group in terms of vocabulary acquisition and were more willing to learn English related to their future careers. Kumar et al. [22] showed that VR technology can enable learners to demonstrate better levels of learning performance when taking the Crystallography course and that the VR experience is interactive and motivating. Criollo-C et al. [23] found that augmented reality (AR) can increase learner engagement and interactivity and have a positive impact on learning. The literature shows that VR technology has been more widely used in engineering education research, VR technology enhances students' self-exploration and self-problem-solving abilities in engineering learning, and students' verbal expression and creative thinking skills are well exercised. Using VR technology for learning can meet the needs of students to acquire knowledge in specialized fields and extends practical training teaching. It also allows students to complete the learning of practical training skills in the course without teacher guidance, creating conditions for differentiated practical training teaching. Students can proficiently operate VR tools and complete virtual practical training tasks that are the same as real teaching. Every step of students' operations (including misoperations and the number of prompts) will form data and be automatically recorded by the system. This process can effectively guarantee that students gain more opportunities for practical training and thus improve their operational skills. Therefore, this study puts forward the following five hypotheses.

H1: The teaching objectives in VR teaching have a significant contribution to the teaching effect of engineering practical training.

H2: The instructional design in VR teaching has a significant contribution to the teaching effect of engineering practical training.

H3: Teaching resources in VR teaching have a significant contribution to the teaching effect of engineering practical training.

H4: The teaching process in VR teaching significantly contributes to the teaching effect of engineering practical training.

H5: The assessment method in VR teaching has a significant role in promoting the teaching effect of engineering practical training.

3. Methodology

3.1 Questionnaire Design

This study designs a questionnaire on the effect of VR technology on the teaching effect of engineering practical training, which includes three aspects. The first aspect is the measurement of the specific information of the respondents, including four aspects such as gender, major, grade, and frequency of VR teaching. The second aspect is the measurement of five aspects of VR engineering practical training teaching, which specifically includes five aspects of teaching objectives, teaching design, teaching resources, teaching process and assessment methods, corresponding to 3, 3, 3, 4, and 4 measurement questions. The third aspect, which is the teaching effectiveness of engineering practical training, is measured in this study by drawing on five questions from the literature of Kember et al. [24]. All questions were measured using a 7-point Likert scale.

3.2 Data Sources

This study conducted a questionnaire survey for undergraduate students in seven universities in Wuhan, China. The teaching system of engineering practical training in these seven undergraduate universities has been reformed several times, and teaching forms such as video and computer virtual simulation have been added. The teaching of engineering practical training encourages independent and critical thinking and cognitive development of college students, which is conducive to the personalized development and innovative and entrepreneurial thinking of college students. Especially in the engineering practical training teaching of mechanical majors, the teaching mostly adopts virtual simulation animation, model, and video to introduce the development of new technology and the working principle of new equipment. Students intuitively understand its internal structure and operation mechanism, which leads to a clearer grasp of knowledge. In response to the above problems, the teaching team analyzes and studies the construction of serial VR courses through literature and research, and introduces them to the teaching of engineering practical training. This study mainly investigates the role of VR technology in practical training courses, and students' interest points in VR technology, and uses SPSS 26.0 for questionnaire data statistics. The group issued questionnaires through the spring semester of 2021-2022 into the school, and a total of 365 questionnaires were issued, after eliminating invalid questionnaires, 274 valid questionnaires were obtained. The effective recovery rate was 75.07%.

Table 1. Descriptive statistics of research subjects

Name	Options	Frequency	Percentage
Gender	Female	100	36.5
	Male	174	63.5
Specialties	Mechanical Engineering	32	11.68
	Mechanical design and manufacturing and its automation	58	21.17
	Material Forming and Control Engineering	96	35.04
	Mechanical and Electronic Engineering	47	17.15
	Industrial Design	29	10.58
	Process Equipment and Control Engineering	12	4.38
Year	Freshman	62	22.63
	Sophomore	70	25.55
	Junior	59	21.53
	Senior	83	30.29
Frequency of VR teaching	1 time/week	3	1.09
	2 times/week	8	2.92
	3 times/week	65	23.72
	4 times/week	67	24.45
	5 times/week	118	43.07
	>5 times/week	13	4.74

4. Results Analysis

4.1 Reliability and Validity Analysis

As shown in Table 2, the overall reliability coefficient (Cronbach's alpha coefficient) value of the questionnaire is 0.834, which is greater than 0.8, thus indicating the high quality of reliability of the study data. The Cronbach's alpha coefficient for each specific variable is also higher than 0.8.

Table 3 shows that all six factors correspond to AVE values greater than 0.5, and all CR values are higher than 0.7, implying good convergent validity of the data for this analysis.

Table 4 shows that the AVE square root values of all six factors are greater than the maximum of the absolute values of the correlation coefficients between the factors, implying that they have good discriminant validity.

Table 2. Reliability results

Type of variables	Name of variables	Questions	Cronbach's α	Cronbach's α
Independent variable	Teaching Objectives	3	0.887	0.834
	Teaching Design	3	0.890	
	Teaching Resources	3	0.896	
	Teaching Process	4	0.889	
	Assessment method	4	0.957	
Dependent variable	Teaching effect of engineering practical training	5	0.943	

Table 3. Results of model AVE and CR indicators

Variables	Average variance extracted AVE value	CR value of combined reliability
Teaching Objectives	0.725	0.887
Teaching Design	0.730	0.890
Teaching Resources	0.744	0.897
Teaching Process	0.679	0.894
Assessment Method	0.850	0.958
Teaching effect of engineering practical training	0.769	0.943

Table 4. Discriminant validity: Pearson correlation and AVE square root values

	Teaching Objectives	Teaching Design	Teaching Resources	Teaching Process	Assessment Method	Teaching effect of engineering practical training
Teaching Objectives	0.851	-	-	-	-	-
Teaching Design	0.233	0.854	-	-	-	-
Teaching Resources	0.203	0.166	0.862	-	-	-
Teaching Process	-0.05	0.038	0.101	0.824	-	-
Assessment Method	-0.075	0.01	0.155	0.284	0.922	-
Teaching effect of engineering practical training	0.188	0.237	0.239	0.117	-0.053	0.877

Note: The diagonal numbers are the AVE square root values

4.2 Linear Regression Results

As can be seen from Table 5, the model passed the F-test when the model was subjected to F-test ($F=8.252$, $p<0.05$).

Hypothesis H1 holds. Teaching objectives in VR teaching have a significant contribution to the teaching effect of engineering practical training. The main reason is that the teaching objectives in VR teaching can cultivate students' innovative consciousness and design thinking, exercise students' ability to judge and solve practical engineering problems and deepen students' cognition of engineering principles. The teaching contents of practical training courses various engineering practical training contents such as operation principles, assembly process methods and assessment schemes are made into teaching resources of VR virtual scenes. Students need to operate the VR virtual machine for various engineering practical training operations in the VR practical training process. Before the start of the class, the lecturer can make the course description containing clear teaching objectives into a video uploaded to the learning end in advance. This measure is convenient for learners to have an overall advanced judgment of the key points and difficulties in the lecture and to master the teaching objectives of engineering practical training systematically.

Table 5. Linear regression results

Variables	Standardization factor	T	P	VIF	F
Constants	-	3.009	0.003***	-	F(5,268) =8.252, *p*=0.000
Teaching Objectives	0.133	2.240	0.026*	1.093	
Teaching Design	0.194	3.264	0.001***	1.093	
Teaching Resources	0.176	2.980	0.003***	1.076	
Teaching Process	0.106	1.781	0.076*	1.102	
Assessment Method	0.132	2.213	0.028**	1.108	

Note: D-W Value: 1.486; * p<0.10; ** p<0.05; *** p<0.01

Hypothesis H2 holds. The teaching design in VR teaching has a significant contribution to the teaching effect of engineering practical training. According to the active, critical, and inquiring characteristics shown by college students' cognitive higher-order thinking, and considering the diversity of college students learning methods and approaches, the practical training course sets most of the contents that need to be explained by teachers in VR virtual scenes, mainly by students' independent learning methods. Training teachers will provide auxiliary guidance and assessment registration for the operation of the training equipment. A good teaching design includes theory and thinking teaching, VR virtual practical training and assessment, physical engineering equipment operation training, innovation and entrepreneurship training. More practical training content embedded in VR teaching design can cultivate students' comprehensive use of basic and professional theoretical knowledge and cultivate engineering practical ability to solve complex engineering problems with positive effects.

Hypothesis H3 holds. Teaching resources in VR teaching have a significant contribution to the teaching effect of engineering practical training. As education new technology and education new media emerge, mobile terminals represented by smartphones are almost in hand. Hence, fragmented "anytime and anywhere" self-learning has become one of the ways for people to acquire knowledge and improve their skill level. When students are studying in specific VR engineering training, the school should provide students with high-quality VR practical training teaching resources suitable for "mobile" learning. For example, universities can build personalized platforms such as catechism and micro-course by constructing engineering training resource centers. Students can reasonably arrange their study schedule in an open, self-learning mode, and use the information platform of the practical training center to learn in a fragmented form. The VR engineering practical training resources are acquired fully and independently to meet the personalized needs of learning. VR teaching resources in line with the independent completion of practical training teaching basics and general safety knowledge can further develop students' independent learning ability and improve their learning performance level.

Hypothesis H4 holds. The teaching process in VR teaching has a significant contribution to the teaching effect of engineering practical training. In VR teaching, the teacher's explanation of skill operation can only be point to point because of the limitation of time and space. Moreover, hand-holding teaching is not good for refining students' will, and the time-consuming and laborious operation prevents the teacher from letting students understand each action and each operation skill in place. For example, in VR teaching, in the pre-course pre-study session, teachers can teach students theoretical knowledge of extension training, to enter the practical learning of extension training courses to lay a solid theoretical foundation. In the class lecture session, instructors explain the operation process of various equipments for engineering practical training, demonstrate the use of simulation software, and students operate engineering equipment through the actual hands-on operation. By combining online and offline, students learn theory online, watch relevant videos, complete online tests, and then teach in a practical way in the training room, the teacher can have more time to solve problems encountered by students in practice and give insights. The teacher can record students' answers through the VR software to understand the student's mastery of the relevant content prep. For students' common problems, they can explain them in detail again in class. At the same time, they can find deficiencies in the online video content and further adjust it. The results of the online learning software can also be used as a file record of the students' usual grades, and those who fail the grade will have the chance to learn it again.

Hypothesis H5 holds. The assessment method in VR teaching has a significant contribution to the teaching effect of engineering practical training. Scientific and objective assessment results of VR practical training teaching guarantee of the quality of engineering practical teaching. Given that the engineering practical training course is mainly based on practical operation, it cannot simply take the traditional single final paper assessment result as the final result. Therefore, teachers can organize students to conduct skill competitions after students complete individual work training, and the result obtained is the students' operation skill score. A scientific and reasonable assessment method in VR teaching can be initiated when students are first exposed to the engineering practical training course. Each practical training project has target requirements, assessment criteria, and learning records. For example, the online pre-study, offline operation and after-class consolidation can be given relative scoring weights, and the grades given can all reflect students' mastery of various aspects and items of this course. The structure of the grades is pre-set, and human intervention is removed by setting a scientific and reasonable way of VR teaching assessment to improve the effect of engineering practical training teaching.

4.3 Variance Test

Table 6 shows that the frequency of VR teaching showed a 0.05 level of significance (F=2.340, p=0.042) for the effect of engineering practical training. The relationship between the frequency of VR teaching and the effect of engineering practical training showed an inverted U-shaped curve, with the best effect of engineering practical training when the frequency of VR teaching was 4 times per week. The main reason is that if the number of VR training is low (less than 4 times per week), students can make full use of their leisure time after class to train repeatedly and improve their skills. Only through constant practice can students master the operation essentials in depth and improve their operation skills. Practice helps exercise students' engineering consciousness and is a key part of the practical training course to realize students' inquisitive thinking training and innovative ability cultivation. However, if the number of practical training is too high, students are prone to VR virtual teaching fatigue. When students are familiar with the differences of the VR teaching environment and simulation software, students may treat VR learning as a game. If the frequency of VR teaching increases to more than 5 times/week, it will reduce learners' learning efficacy across the board, and the effect of engineering practical training will be greatly reduced. This conclusion inspires our college managers that in VR teaching because college students as a whole have very good self-learning abilities, teachers should put more energy into VR teaching design and not simply repeat a specific VR teaching process.

Table 6. Differential effects of the frequency of VR teaching on the effectiveness of engineering practical training

Analysis Items	Item	Mean value	Standard Deviation	F	P
Effectiveness of engineering practical training	1 time/week	3.13	1.62	2.34	0.042*
	2 times/week	5.10	1.01		
	3 times/week	5.00	1.46		
	4 times/week	5.17	1.31		
	5 times/week	4.99	1.29		
	More than 5 times/week	4.06	1.85		

Note: * $p<0.10$

5. Conclusion

In this study, we designed a questionnaire on the effect of VR technology on the teaching effect of engineering practical training and measured it by using reliability and validity analysis, regression analysis, and variance test. The main conclusions of the study are as follows:

(1) The reliability coefficient, convergent validity, and discriminant validity of the questionnaire designed in this study are very good.

(2) Five aspects of VR teaching, such as teaching objectives, teaching design, teaching resources, teaching process, and assessment methods, have significant promotion effects on the teaching effect of engineering practical training at the significance level of 10%, 1%, 1%, 10%, and 5%, respectively.

(3) VR teaching frequency showed 0.05 level significance (F=2.340, p=0.042) for the effect of engineering practical training.

However, as engineering practical training teaching still needs further penetration research in terms of teaching mode, how to combine with VR technology application efficiently, and how to improve engineering practical training course performance comprehensively through VR technology should be explored.

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