Learning Process Through Virtual Reality: A Theory-Based Application

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Abstract. Virtual reality (VR) technology has significant application value for the teaching and learning process. Supported by the constructivism theory, VR technology can effectively promote the reform and development of education. VR technology has been applied in both disciplinary and non-disciplinary teaching settings, causing improvements in educational deployment contexts. However, the potential of VR technology has not yet been fully explored, and broader educational applications and settings can optimize the superiority of VR technology under the guidance of constructivism theory, such as virtual teaching environments, virtual labs, and virtual training environments. Students' creativity, reflective skills, and motivation are greatly enhanced when VR is applied to their learning process. Based on analyzing the concept and characteristics of VR technology, the advantages of integrating VR technology in education are the quality and effectiveness of teaching, a good teaching atmosphere creation, and students' capacities promotion. Meanwhile, the current dilemma faced by VR technology needs to be emphasized to ensure its development prospect.

Keywords: VR technology · Constructivism · Immersion · Simulation · Interaction

1 Introduction

Virtual reality (VR) technology is an emerging technology based on computer science, integrating computer three-dimensional (3D) graphics, simulation, sensing, human-machine interface, and display technology to generate a realistic 3D world [1–4]. Users can build a virtual environment based on their own views and virtual reality-related equipment, interacting with the human body to induce the same feelings as the real world in the virtual environment. The application of VR technology in education has led to a transformation, changing the traditional concept, enhancing the situational and interactive nature of teaching, focusing on student practice, and having broad educational application prospects [5–9].

2 Literature Review

The VR system is equipped with sensing and response devices for vision, hearing, and touch. It is highly integrated with various media and has various perceptual functions

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that humans have, making students easily immerse themselves in virtual scenarios. The interactivity, immersion, and multi-perception of VR technology realize the maximum combination of virtual and reality, technology and education [10–13].

In terms of interactivity, the human-computer interaction in VR systems is nearly natural [6, 12]. Users can interact not only with computer keyboards and mice, but also with sensing devices, such as special helmets and data gloves [11]. The computer can adjust the images and sounds presented by the VR system according to the user's head, hands, eyes, speech, and body movements [4]. Correspondingly, users can examine or manipulate objects in the virtual environment through natural skills such as speech, body movement, or action [4]. In terms of immersion, VR technology generates realistic 3D images by computer based on the physiological characteristics of human vision and hearing [10, 13]. After putting on helmet displays and data gloves, or other interactive equipment, users can put themselves in and become members of the virtual environment [7, 14]. The users interact with various objects in the virtual environment just as they do in the real-world settings. When users move their heads, the images in the virtual environment also follow the movements in real-time with the 3D simulation of sound [6].

Regarding multi-perception, VR technology has visual, auditory, haptic, and motion perception to create situated information representations with a high degree of interactivity, diversity, and flexibility [3, 15]. Therefore, users can obtain multiple perceptions in the virtual environment, thus can gain an immersive experience.

3 Theories Analysis

The support of theory and examples is a prerequisite for the widespread use and acceptance of VR technology. Undoubtedly, VR technology exhibits a variety of unique capabilities and demonstrates its superiority over traditional tools in educational settings, creating learning experiences and opportunities [16, 17]. As a result, the use of VR technology in education has created great excitement and anticipation. However, it is essential to note that VR technology is only a tool and does not teach per se [2, 16]. VR technology must be effectively implemented based on theoretical research to aid the learning process of students. Regarding the study of dynamic learning processes, cognitive theory, constructivism, and situated learning theory address how VR technology facilitates students' knowledge system formation through immersion, interactivity, and multi-sensory. Among these three theories, constructivism best exemplifies how VR technology, as a learning tool, plays a role in the student learning process.

3.1 Cognitive Theory

Cognitive theory views learning as a process in which students use their existing cognitive structures to assimilate and adapt to a new environment [1, 7, 15, 16]. The alternating effects of assimilation and adaptation lead to a cyclical process in which students' physiological states change from equilibrium to imbalance [7]. In other words, learning is a dynamic process where the cognitive subject interacts with the environment and actively constructs a knowledge system. In terms of dynamic processes, VR technology allows students to be intensely stimulated in their senses and convinced that their perceptions are realistic [1]. Consequently, psychological immersion comes out. Immersion is the optimal mental state for effectively extracting the human brain's awareness of reality [15]. This mental state accelerates the alternating process of assimilation and conformity between the students' existing cognitive structures and the new environment (virtual environment). Therefore, from the cognitive theory perspective, VR technology facilitates the reconstruction of students' original knowledge system and the formation of their own views and understandings.

3.2 Situated Learning

Situated learning theory advocates using scenarios of specific activities or learning resources to create situations where students can acquire many vivid and imaginative concrete representations [5, 6, 11, 14]. Notably, students become interested in active learning when they are exposed to a specific situated atmosphere and are able to increase their learning efficiency [14]. Based on this point, VR technology simulates all the characteristics of an actual situation, including the senses of sight, sound, and touch [14]. In the visualized world of VR simulation, students feel novel and interested in learning, thus thoroughly motivating them to learn [6, 11]. Therefore, the application of VR technology helps students break through the limitations of traditional thinking (focusing on book knowledge) and facilitates the formation of higher-order thinking (independent learning ability). In summary, from the situated learning theory perspective, VR technology can provide students with a vivid and realistic learning environment because students can become a participant or play a role in a virtual scenario. The immersion of VR technology can play a positive role in motivating students to learn, breaking through the key points and difficulties of teaching, and developing students' skills [6].

3.3 Main Theory: Constructivism

Since VR technology, when used in education, creates problematic situations for students, stimulates curiosity, and fosters interest and motivation, constructivism is best suited to study VR technology as a learning tool. Constructivism believes that the teaching and learning process should enable the educated to use the tools and resources given by the teaching environment to build their awareness and understanding [7, 10, 17]. Based on this view, a virtual teaching environment is a system of scenarios rich in resources to be shared by students and strong enough to elicit sensory stimulation. In addition, VR technology can explore and build worlds in which problematic situations can be realistically presented and await users to solve them [14, 16]. VR technology can also map users into any role of their choice, dramatically enhancing the learner's initiative and applying the constructivist view of the dynamic process of individual knowledge construction [17]. Besides, VR provides a shared virtual world that can serve situated and constructivist learning well [14]. Through the interactive environment of VR, learners' motivation and interest in learning will naturally be enhanced with reproduction ability and one-on-one practice.

Constructivism as a learning theory emphasizes the development of new meaning and understanding through active, authentic, collaborative, and reflective learning activities that combine sensory input, existing knowledge, and new information [7, 16, 17]. VR provides a controlled environment in which learners can navigate and manipulate virtual objects, and more importantly, the effects of this interaction can be observed in real-time. Therefore, VR technology is well suited to provide an exploratory learning environment that enables learners to learn by internalizing and reflecting on knowledge.

In conclusion, the characteristics of VR technology are fully compatible with the axioms of constructivism learning theory, and constructivism theory provides a valid and reliable foundation for VR technology in turn.

4 Educational Deployment Context

The application of VR technology in disciplinary teaching settings is constantly innovating, prompting apparent changes in the teaching model at this stage, building a well-established teaching platform and tool, and improving teaching quality. VR application in the discipline is mainly reflected in the following three aspects.

Firstly, VR application in the display of 3D objects. In teaching medical, biological, physical, chemical, and mathematical subjects, teachers usually need to build relevant physical models for students according to the actual knowledge content, helping students understand the more abstract concepts and reducing the learning difficulties [6, 11, 13, 19]. VR-assisted teaching model has more advantages over traditional models, and the overall interactivity is more substantial, which can prompt students to participate in learning practices [9, 14, 15]. For example, the medical training application of Z-Space enables medical students to use human anatomy atlas to explore human body structure, helping students deepen their understanding of human body structure and lay a good foundation for subsequent learning [4, 12, 13].

Secondly, VR application is the embodiment of skills. In carrying out the teaching process, teachers innovate the teaching model for the actual situation of students and guide them to practice skills [1, 5, 19]. Through VR technology in this process, students may internalize the current stage of knowledge, deepen their understanding of knowledge, improve their practical ability in the virtual world, and master skills training that is difficult to carry out in the real world. For example, for medical surgery and physical chemistry experiments, VR technology can effectively reduce the costs and the interference generated by external factors to improve the quality of teaching [4, 12, 13]. The improvement is because of the intense immersion of VR technology. In this case, students would be more focused on the learning process and maintain learning motivation without distribution.

Thirdly, VR application in the virtual scenes. Teachers can flexibly use the advantages of VR technology to build scenes, such as historical and story scenes [7, 9, 10]. In these virtual scenes, students can immerse themselves in past events to stimulate their learning motivation.

5 Implication: Deployment and Constructivism

Constructivism has provided a theoretical basis and has greatly facilitated the application of VR in education. For example, the Virtual Academy developed by Central Florida University and the Science Space developed by George Mason University in collaboration with Virtual Environment Technology Laboratory are successful examples. Thus, constructivism is highly aligned with and provides strong theoretical evidence in educational deployments.

5.1 Cognitive Theory

A virtual teaching environment is realized through VR technology, similar to the authentic teaching environment (virtual and real objects). Meanwhile, the virtual teaching environment can realize information resources, knowledge backgrounds, intrinsic mechanisms, and laws of entities that cannot be perceived in a real teaching environment [1, 16]. Theoretically, the traditional teaching model is based on behaviorism theory, while the modern teaching model using VR technology is based on constructivism [17]. Specifically, Central Florida University has developed Explore, a two-dimensional web-based virtual environment for public education, as a successful example. Explore is based on role-playing in a web-based MUD environment, which means each participant has an avatar on the screen, and all participants can see the result when an avatar acts. The instructor guides students to select the desired content [9]. After that, students are allowed to build a virtual world based on their own understanding of knowledge and deliver that content to other students [9]. The MUD's text-based virtual worlds provide a context in which learners can explore and investigate, while also giving students a broad scope for imagination [9]. Students can take on different roles in different humanistic environments and communicate or interact with characters in virtual reality, providing equal opportunities for students in different cultural contexts, in line with the constructivism emphasis on collaborative and interactive learning environments.

5.2 Virtual Experimental Environment/Virtual Labs

Virtual experimental environments (or virtual labs) are among the most promising application areas for VR technology [8, 12]. Since the advent of VR technology, many previously untouched problems are becoming the subject of research. These problems are either limited by understanding and observation conditions or time and space constraints, forcing people to use model experiments to simulate real objects [2, 12, 19]. However, VR technology breaks the limitations of the traditional simulation methods due to technical reasons in scientific experiments. By virtualizing experiments with no simple and effective instruments to demonstrate them, VR technology highly enables the virtual and the real combination [8]. In the contemporary world, virtual prototypes to study physical and chemical mechanisms laws have become a common approach in scientific experiments [2].

One successful example is Science space, developed in collaboration with George Mason University and VETL with support from the National Science Foundation to verify that students can better understand scientific concepts through direct interactive experiences. Science space provides three virtual experimental contexts: a Newtonian world where students can experience Newton's three laws; a Maxwell world where students can test the natural properties of electromagnetic fields directly to verify Gauss' law; and a Pauling world where students can focus on molecules [12]. Besides, science space also improves prediction skills through game-like questioning activities in which students observe one or more phenomena, then are asked to describe what they observed and compare their previous predictions [12]. Furthermore, science space embodies the dynamic process of learning from the constructivism theory. Notably, the activities in science space reflect that students change from passive recipients of external stimuli to active constructors of knowledge meaning, eventually internalizing knowledge and giving self-assessment of what they have learned.

6 Implication: Deployment & Constructivism

VR technology is gradually entering the classroom, making teaching more exciting and innovative because of its immersive, interactive, and conceptual characteristics [1, 3]. Specifically, VR technology can enhance teaching and learning, help students understand the operation process, save money and space, and keep teachers and students safe [1, 2, 11]. However, the current development of VR technology is in a difficult situation, including the lack of quality educational resources, insufficient teacher training, and poor user experience [1, 19].

6.1 Immersion Enhances Teaching and Learning

The traditional teaching approach is conducted in the teaching assessment format, theoretical tests, and experimental operations, which usually presents a "teacher indoctrination while students' passive acceptance" phenomenon and dramatically reduces the teaching effect [17]. With the embedding of VR technology, immersive teaching can make the learning atmosphere vivid and lively [1, 11]. Students can put on VR equipment in class, enter a realistic simulated environment, and interact with the characters up close, making teaching colorful while significantly enhancing the learning effectiveness [1]. For example, in a tourism class, students can experience the simulated panoramic view through VR devices, as if they were in the environment of different scenic spots, helping to enhance students' interest and outcomes in the learning process.

6.2 The 3D Display Helps Students Understand the Operation Process

In the traditional teaching process, teachers need to demonstrate abstract concepts employing physical displays to help students understand those concepts [17]. This one-to-many (one teacher to many students) format does not allow every student to experience and touch, producing unsatisfactory results [17]. With VR technology support, the 3D display can build the same physical model as the actual objects, avoiding the time-consuming and inefficient problems caused by multiple students using the same physical object and enhancing the interactivity between each student and the physical model [6]. For example, VR technology can assemble or restore geometric figures at will when learning mathematical geometry, intensely exercising students' hands-on skills. When learning biology, VR modeling allows students to understand and accurately identify the location of the various animal models' structures. Students can even see cell division and DNA replication in a 3D display, which greatly facilitates their understanding and knowledge mastery [12, 18].

6.3 Virtual Training Fields Save Money and Space and Guarantee Safety

The virtual training fields are VR simulations to create training and experimentation places where students can start different training experiences by wearing gloves with built-in vibrators and simulated reality equipment [6, 7]. In such virtual fields, students are fully immersed in their training without being disturbed [7]. More significantly, even if operational errors or vulnerabilities exist, they do not cause property damage or threaten personal safety in a virtual environment [8]. For example, because of the high requirements for venues and equipment, sports disciplines' training is affected by cost, weather, space, and other uncontrollable factors, resulting in students losing professional and systematic training opportunities. However, the virtual training field can save a lot of money and space compared to traditional venues and be open to students at any time, greatly improving the efficiency of use [8].

7 Conclusion

As the development achievement of the new era, virtual reality technology can make teachers and students have a new teaching and learning experience. Ideally, VR technology can build an experiential learning situation, open up students' horizons, and cultivate their innovation. It should be noted that while paying attention to and boldly applying VR technology in the learning process, the effectiveness of VR technology should be studied based on constructivism. Changing the traditional education concept is the key when using VR technology in teaching. Only a VR teaching system based on constructivism can fully play the personal initiative and creativity of both teaching and learning subjects, and ultimately interpret the true meaning of the modern teaching and learning approach. As an emerging technology, VR technology needs to be explored and practiced in-depth for improvement and development in educational settings.

References

1. Christou C. Virtual reality in education[M]//Affective, interactive and cognitive methods for e-learning design: creating an optimal education experience. IGI Global, 2010: 228–243.
2. Kavanagh S, Luxton-Reilly A, Wuensche B, et al. A systematic review of virtual reality in education[J]. Themes in Science and Technology Education, 2017, 10(2): 85–119.
3. Liu D, Bhagat K K, Gao Y, et al. The potentials and trends of virtual reality in education[M]//Virtual, augmented, and mixed realities in education. Springer, Singapore, 2017: 105–130.
4. Stepan K, Zeiger J, Hanchuk S, et al. Immersive virtual reality as a teaching tool for neuroanatomy[C]//International forum of allergy & rhinology. 2017, 7(10): 1006–1013.
5. Anderson A. Virtual reality, augmented reality and artificial intelligence in special education: a practical guide to supporting students with learning differences[M]. Routledge, 2019.
6. Braun S, Slater C. Populating a 3D virtual learning environment for interpreting students with bilingual dialogues to support situated learning in an institutional context[J]. The Interpreter and Translator Trainer, 2014, 8(3): 469–485.
7. Parong J, Mayer R E. Cognitive and affective processes for learning science in immersive virtual reality[J]. Journal of Computer Assisted Learning, 2021, 37(1): 226–241.

8. Ray S, Koshy N R, Reddy P J, et al. Virtual Labs in proteomics: New E-learning tools[J]. Journal of proteomics, 2012, 75(9): 2515–2525.
9. Silva G, Magome J, Ishidaira H. Online learning process management and learners' Motivation: a case study of University of Yamanashi Virtual Academy Programme[J]. 2012.
10. Chau M, Wong A, Wang M, et al. Using 3D virtual environments to facilitate students in constructivist learning[J]. Decision support systems, 2013, 56: 115–121.
11. Farra S L, Smith S J, Ulrich D L. The student experience with varying immersion levels of virtual reality simulation[J]. Nursing education perspectives, 2018, 39(2): 99–101.
12. Kilmon C A, Brown L, Ghosh S, et al. Immersive virtual reality simulations in nursing education[J]. Nursing education perspectives, 2010, 31(5): 314–317.
13. Kyaw B M, Saxena N, Posadzki P, et al. Virtual reality for health professions education: systematic review and meta-analysis by the digital health education collaboration[J]. Journal of medical Internet research, 2019, 21(1): e12959.
14. Dawley L, Dede C. Situated learning in virtual worlds and immersive simulations[M]//Handbook of research on educational communications and technology. Springer, New York, NY, 2014: 723–734.
15. Garcia-Betances R I, Jiménez-Mixco V, Arredondo M T, et al. Using virtual reality for cognitive training of the elderly[J]. American Journal of Alzheimer's Disease & Other Dementias®, 2015, 30(1): 49–54.
16. Chen C J. Theoretical bases for using virtual reality in education[J]. Themes in Science and Technology Education, 2010, 2(1–2): 71–90.
17. Onyesolu M O, Nwasor V C, Ositanwosu O E, et al. Pedagogy: Instructivism to socio-constructivism through virtual reality[J]. International Journal of Advanced Computer Science and Applications, 2013, 4(9).
18. Wu S, Duan N, Wisdom J P, et al. Integrating science and engineering to implement evidence-based practices in health care settings[J]. Administration and Policy in Mental Health and Mental Health Services Research, 2015, 42(5): 588–592.