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PAPER

Effects of Immersive Virtual Reality Technology on Online Learning Outcomes

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ABSTRACT

In the digital information era, such information technologies (ITs) as the Internet, big data, artificial intelligence (AI), and virtual reality (VR) are changing people's production and lifestyle. Moreover, ITs have exerted significant influences on the thinking modes and learning styles of people. On the bases of such characteristics as sensory immersion, roaming, and manipulation, immersive VR (IVR) can support learners to pursue contextualized learning, promote their embodied cognition, improve their emotional experience, and solve problems of traditional classrooms, such as poor interaction, poor contextualization, and unreal immersion. This study used existing associated research as basis in analyzing the influences of IVR factors on degree of concentration, sense of traversing, emotional engagement, and sense of enjoyment on online learning outcome. Moreover, differences in learning outcomes under different contact periods IVR technology were analyzed. Research results are as follows. The overall Cronbach's α, KMO value, and P value of the questionnaire are 0.905, 0.870, and 0.01, respectively. Degree of concentration, emotional engagement, and sense of enjoyment of IVR technology can promote online learning outcome significantly. Contact period with IVR technology has significant influences on learning outcome at the 0.01 level ($F=3.895$, $p=0.009$). Lastly, research conclusions provide important references in exploring the complicated relationship between sense of immersion and learning outcome in IVR environment, and in improving emotional experience and knowledge transfer based on IVR technology.

KEYWORDS

immersive virtual reality, online learning, learning outcome, questionnaire technology, analysis of variance

1 INTRODUCTION

With the continuous development of education informationalization, people have launched significant reforms in online teaching modes. Moreover, the extremely rapid pace of knowledge updating has overcome spatial and temporal limitations.

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Learners can learn new knowledge and skills online at any time and any place according to their own needs, thereby enabling them to address shortcomings in knowledge in a timely manner. This situation is an essential trend of education development in the future. With policy support from China's government for education, the digitalization and virtualization of education resources are among the important means of displaying education resources in the future. The development of virtual reality (VR) technology has resulted in immersive communication becoming a new research. Immersive communication is the set of audience-centered communication methods and dynamic communication processes based on the environment and spaces. Moreover, VR technology is the coexistence and integration of materials and spirit, virtuality, and reality. Multimedia technology is often used in teaching to create a learning environment. For example, teaching resources, such as videos and pictures, are played and displayed, respectively, using computers, projectors, and interactive all-in-one machines. However, high-quality interaction is lacking between learners and resources in the teaching process. Learners have low participation in online learning and they often accept knowledge passively, resulting in difficulty acquiring good learning outcomes. Moreover, a vivid learning situation that can enhance learning experiences for some subjects in a traditional classroom environment is impossible to build owing to spatial and temporal limitations. Learners have no access to the practical process of knowledge generation, thereby significantly decreasing learning outcomes.

Focus has been directed to the idea that immersive VR (IVR) technology improves experiences by introducing it in various fields, such as design and teaching. For classroom teaching in the new environment, students can access sensory cognition, which is impossible to accomplish in a traditional classroom, by combining the immersion and extension characteristics of VR. Thus, better learning experiences and effects are achieved and learning outcomes of students are improved. IVR technology enters into simulation scenes through equipment to produce vivid scenes. This technology also provides users with multisensory simulation of vision and touch based on 3D display and perception technology to realize the effect of immersion. Users perceive and operate the environment to obtain multisensory feedback and interact with any objects in the simulation environment in the most natural way through sensing equipment. Users can image the future according to their interactions with objects in the virtual environment through thinking processes, such as association and logical inference. The online 3D environment built by IVR technology can attract students, stimulate their interest in learning, and improve their understanding of concepts. Moreover, it can decrease cognitive loads and release short-term memory to lead students to concentrate. Lastly, IVR technology helps students become real knowledge explorers and build their own knowledge system while learning, thereby improving online learning outcomes.

2 THEORETICAL BASES AND HYPOTHESES DEVELOPMENT

2.1 Theoretical bases

Csikszentmihalyi and Wolfe [1] believed that people are unaware of any other psychological interference factors when they play games or complete tasks, and that they can even concentrate unconsciously and devote themselves completely to the entire context without other unnecessary interference factors. As information technologies (ITs) are gradually integrated to teaching, scholars around the world gradually introduce flow theory to teaching as well. Therefore, designing teaching content has to consider whether learners may feel that the designed knowledge points during learning are considerably simple or difficult. If knowledge points are markedly simple, then learners will be bored and lose interests. If knowledge points are markedly difficult, then learners may become anxious while learning, thereby losing motivation to learn. Accordingly, virtual experiments have to design contents and scenes based on flow theory. Virtual scenes created on scene design must conform to objective facts and avoid unnecessary interferences to influence the attention of learners. In designing virtual experimental teaching contents, the difficulty is suggested to be increased appropriately under the premise of meeting teaching standards to stimulate learners' thirst for knowledge. Accordingly, they can focus on learning and produce a strong sense of immersion, eventually increasing the learning efficiency of the virtual experiment.

Bodner [2] believed that constructivism advocates for learner-centered learning, and that learners realize sense-making in scenes under the instruction of teachers. First, IVR teaching resources have to find the framework conforming to learners' cognition, review the knowledge system, organize materials according to the principal line of knowledge, and present teaching contents in modular form to help learners acquire the principal instruction from resources. Second, focus should be given to designing a learning environment. This endeavor will maximize the IVR characteristics to create highly immersive and multisensory problem scenarios to help students construct knowledge positively.

2.2 Hypotheses development

The development of VR technology provides technological support to immersive learning. All sensory organs of learning are stimulated by creating vivid environments and man–machine interaction based on equipment. Accordingly, they can completely focus on the simulated virtual environment, thereby realizing the immersive experiences. Various universities globally promote IVR technology vigorously to enhance the learning interest of students, change learning experiences, improve students' abilities of operation and knowledge use, offset the shortcomings of exam-oriented education, and train the creative thinking and knowledge transfer abilities of students during teaching. With respect to influences of IVR technology on online learning outcomes, Jennett et al. [3] believed that immersion is a type of psychological experience, which is only next to flow, and can be described and measured from six dimensions: degree of concentration, temporary dissociation, sense of traversing, challenge, emotional engagement, and sense of enjoyment. This study combines the practical situation of the research objects and plans to analyze how IVR technology influences online learning outcomes from the perspectives of degree of concentration, sense of traversing, emotional engagement, and sense of enjoyment.

Altobello [4] argued that students have good concentration and reflection skills, which significantly influence basic academic abilities. Krithika and GG [5] reflected on learners' degree of concentration by recognizing and monitoring their emotions in an e-learning environment. Changes in learners' degree of concentration can remind teachers to further improve teaching modes to enhance the former's experiences. Daniel and Kamioka [6] proposed a high-efficiency remote learning system that can accurately detect the attention of learners in class and proved the close relationship between learners' degree of concentration and learning outcomes. Yang and Chang [7] investigated the influences of digital game creation on students' attention and academic performances. Experimental results demonstrated that digital game creation could improve critical thinking skills and academic performances. Moreover, students with better concentration achieved better academic performances. Li and Yang [8] believed that learners' concentration on mobile learning is worthy of extensive study. The interactive effects of learning style and interest on the learning concentration and academic performances of students who learn conceptual knowledge on mobile phone were investigated. Results indicated that weak interest constantly leads to poor learning concentration. The recommendation is to develop and use appropriate mobile learning materials to educate students according to their degree of concentration, interest, and learning styles. Hence, the first research hypothesis of this study is proposed as follows:

H1: Degree of concentration of IVR technology can significantly improve online learning outcomes.

Radianti et al. [9] demonstrated that assessment of VR applications focus on usability rather than learning outcome. Lee et al. [10] believed that VR is a highly efficient technology that can provide people with pleasant and immersion information on collections in museums, generating evident sense of traversing. Araiza-Alba et al. [11] believed that IVR technology provides relevant positive education achievements. Research results indicated that participants using IVR have remarkable scores in interest and enjoyment. IVR is a technology that can attract the interest of and stimulate users and also has the potential to assist in cognitive treatment and knowledge transfer. Hence, the second research hypothesis is formulated as follows:

H2: Sense of traversing of IVR technology can significantly improve online learning outcomes.

Ninaus et al. [12] concluded that in games-based learning, positive and negative emotions are relatively increased and emotional engagement helps learners to strengthen initiatives of learning and learning outcomes. Schöbel et al. [13] reported that game-based teaching mode improves students' problem-solving abilities through the mediating effect of emotional engagement, and that satisfaction degree in game-based learning is positively related with emotional engagement. Xin [14] analyzed the influences of emotional engagement on instant test performances and test performances one week thereafter, indicating no mediating effect of emotional engagement. Pham Kim et al. [15] discussed how students use mediating tools to experience online learning and found that emotional engagement positively supports the improvement of online learning outcome. Hence, the third research hypothesis is proposed as follows:

H3: Emotional engagement of IVR technology can significantly improve online learning outcomes.

Yang et al. [16] developed a virtual education robot system by using the augmented reality (AR) technology and found that students using a virtual education robot system have stronger interests in learning but failed to achieve better academic performances. Aubusson et al. [17] found that teachers' use of teaching methodology could significantly promote learners' sense of enjoyment, thereby improving their learning outcomes. Wang et al. [18] deemed that new technologies represented by AI provide new means of improving teaching effects and enriching learning experiences. An empirical analysis indicated that perceptual enjoyment indirectly influences intelligence teaching participation and learning outcomes through the mediating variable. Jin and Zhang [19] invited 320 Chinese high school students who are native English speakers to complete a revised scale of foreign language enjoyment. Pathway analysis indicated that sense of enjoyment can influence the mid-term exam scores of students learning a foreign language. Hsu et al. [20] demonstrated that expert decision-making-based chatbot (EDM-chatbot) can significantly improve the fun of learning, decrease learning anxiety, and enhance students' academic performance. Hence, the fourth hypothesis is proposed as follows:

H4: Sense of enjoyment of IVR technology can significantly improve online learning outcomes.

3 METHODOLOGY

3.1 Questionnaire design

With the development of computer technology, flow theory has been extended to the field of man-machine interaction. In particular, the development of VR technology provides technological support to immersive learning. All sensory organs of learning are motivated by creating a vivid environment and man–machine interaction based on equipment. Consequently, they can devote completely to a simulated virtual environment, thereby realizing immersive experiences. With the continuous development of VR technology, many studies have combined this technology and flow theory. In the current study, a questionnaire on the Effects of IVR Technology on Online Learning Outcome was developed based on existing literature. The questionnaire comprises three parts. Part I is general information of the respondents, including gender, major, grade, and contact period with IVR technology. Part II investigates the use of IVR technology from degree of concentration, sense of traversing, emotional engagement, and sense of enjoyment according to Georgiou and Kyza [21]. The four aspects have five, four, four, and four questions. Part III measures learning outcome using five problems according to Chen et al. [22].

3.2 Respondents

Jiangxi Province is located in Central China. Given the effects of the COVID-19 pandemic, universities in Jiangxi Province maximize the advantages of online courses, and teachers provide interactive live broadcasting or remote teaching of synchronous classes at home or inside the classroom by using an intelligent teaching system and live interactive technology. In particular, some majors in universities have comprehensively applied IVR technology to guide learning of online practice courses. In this study, a questionnaire survey was conducted involving computer-related majors in eight universities in Nanchang, Jiangxi Province. The questionnaire was formulated by the common Wenjuanxing Survey Platform in China. A QR code was generated and sent through a network for one week in the fall semester of academic year 2022–2023. A total of 419 questionnaires were collected and 308 were considered valid (effective recovery rate: 73.51%). The detailed descriptive statistical results are shown in Table 1.

Table 1. Descriptive analysis results

Name	Option	Frequency	Percentage (%)
Gender	Males	252	81.82
	Females	56	18.18
Majors	Software Engineering	38	12.34
	Internet of Things Engineering	78	25.32
	Computer Science and Technology	98	31.82
	Electronic Engineering and Computer Engineering	52	16.88
	Intelligent Science and Technology	42	13.64
Grade	Freshman	52	16.88
	Sophomore	87	28.25
	Junior	128	41.56
	Senior	41	13.31
Contact period with IVR technology	<0.5 years	18	5.84
	0.5–1 years	109	35.39
	1–3 years	82	26.62
	>3 years	99	32.14

4 RESULTS ANALYSIS

4.1 Reliability and validity

The first step of the questionnaire analysis is to test reliability and validity. Reliability refers to the consistency, stability, and dependability of test results; and it is generally expressed by internal consistency. A higher reliability coefficient indicates a test's higher consistency, stability, and dependability. Validity refers to the degree of tools or means to accurately measure objects. It reflects the degree of the investigating contents. If the measuring results agree more with the investigating contents, then the validity is higher; otherwise, the validity is lower. In this study, SPSS22.0 was used for the reliability and validity tests of the questionnaire survey data.

Table 2. Reliability test results

Variable Type	Variable Name	Number of Questions	Cronbach α	Cronbach α
Independent variable	Learning outcome (Y)	5	0.922	0.905
Independent variable	Degree of concentration (X1)	5	0.923	
	Sense of traversing (X2)	4	0.880	
	Emotional engagement (X3)	4	0.884	
	Sense of enjoyment (X4)	4	0.959	

Table 2 shows that the overall Cronbach's α of the questionnaire is 0.905 (>0.9). Moreover, Cronbach's α of all variables is above 0.8, indicating a high reliability of the research data.

Table 3. Validity analysis results

Variables	AVE	CR
X1	0.712	0.925
X2	0.672	0.887
X3	0.669	0.889
X4	0.855	0.959
Y	0.708	0.923

Table 3 shows that AVE of all five variables is above 0.5 and CR is over 0.7, indicating that the analysis data have good convergent validity.

As shown in Table 4, the AVE square root of the five variables is higher than the maximum of the absolute correlation coefficient among the factors. This result indicates good discrimination validity.

Table 4. Pearson correlation and square roots of AVE

	X1	X2	X3	X4	Y
X1	0.844	–	–	–	–
X2	0.334	0.82	–	–	–
X3	0.28	0.311	0.818	–	–
X4	0.459	0.258	0.284	0.925	–
Y	0.296	0.362	0.151	0.131	0.841

Table 5. KMO and bartlett test

KMO		0.870
Bartlett's test of sphericity	Approximate Chi-square	5817.224
	Df	231
	P-value	0.000

Table 5 shows shat validity is verified by KMO and Bartlett's test of sphericity. The KMO value is 0.870 (>0.8), and the research data are applicable to extracting information.

4.2 Linear regression

Table 6. Linear regression results

Variable No.	Standardization Coefficient	T	P	VIF
Constant	–	1.236	0.217	–
X1	0.036	2.844	0.005**	1.153
X2	0.037	1.255	0.211	1.212
X3	0.066	2.177	0.030*	1.280
X4	0.845	29.344	0.000**	1.155
Adjusted R^2	0.783			
F	F (4,303) = 272.970, p = 0.000			
D-W	2.16			

Notes: *p < 0.05, **p < 0.01.

In Table 6, R2 of the model is 0.783, indicating that four independent variables can explain 78.3% changes of y. It found in F-test that the model passed through F test (F = 272.970, p = 0.000 < 0.05). That is, at least one of the four independent variables can influence the dependent variable. Moreover, a multicollinearity test of the model indicated that the VIF values in the model are all below 5, signifying the absence of collinearity problem. Moreover, the D-W value is near 2. This result implies no autocorrelation in the model and no correlation among the sample data. Hence, the model is relatively good.

(1) H1 is true. Degree of concentration of IVR technology can significantly improve online learning outcomes. The main reason is that learners' degree of concentration in an IVR environment is an important potential factor influencing learning outcomes. Given that learning outcomes are highly correlated with students' memory ability, the relationship between degree of concentration and memory ability has been proven. The attractive details (e.g., vivid scenes and exquisite animation), which were added in the IVR environment to enhance immersion, can help learners maintain high attention, so they can achieve good learning outcomes. Meanwhile, a stable IVR learning environment can relatively influence learners' degree of concentration. That is, it attempts to avoid interruption events in the IVR learning environment to cause low learning efficiency. Teachers shall tell learners to be more self-disciplined while learning based on mobile terminals, standardized learning behaviors, and decrease events influencing the degree of concentration to significantly improve learning outcomes.

(2) H2 is false. Sense of traversing of IVR technology cannot significantly improve online learning outcomes. The possible reason is that sense of traversing mainly represents the extent to which individuals believe they are in a virtual environment rather than the real world. Given that there are only a few courses in online learning that use IVR technology, learners are still in the traditional teaching mode for considerable time, thereby resulting in poor sense of traversing. This result also enlightens universities to provide IVR teaching activities to assist teaching for a semester or for several weeks to improve learners' sense of traversing.

(3) H3 is true. Emotional engagement of IVR technology can significantly improve online learning outcomes. The main reason is that emotional engagement means the degree of emotional dependence of learners on tasks, including curiosity in tasks, empathy, and other emotional experiences. In an IVR learning environment, learners can generate strong motivations to learn, thereby producing strong willpower and strengthening confidence in the online learning of professional knowledge. It makes students overcome difficulties in a positive manner during the online learning of professional knowledge. In addition, it is conducive for them to focus on online learning with a full spirit and develop a positive learning attitude, thereby improving online learning behaviors. They will take actions to provide time and exert effort to learn online positively and keep up with teaching objectives of the course. With improvement in online learning attitudes and behaviors toward professional knowledge, the learning objectives are consistent with those of teachers. Hence, teachers and students will have homodromous impetus to teaching. Under the superposition of homodromous impetus, online learning outcomes are increased significantly, thereby resulting in the easy realization of teaching objectives.

(4) H4 is true. Sense of enjoyment of IVR technology can significantly improve online learning outcomes. The main reason is that sense of enjoyment refers to the degree of pleasure of individuals in completing tasks. Numerous online teaching activities have focused on the teaching of teachers for a long time, while students lack opportunities for operational exploration. IVR-based scientific exploration can generally solve the preceding problems. This method is different from the traditional "cramming system" but provides students with a safe virtual context, in which they have the opportunity to explore positively and think independently. Consequently, it strengthens learning enthusiasm and improves learning outcomes. It also relatively meets the curiosity of learners, and agrees with the basic philosophy of university course standards. In an IVR learning environment, students play some roles and they can observe with their eyes, listen with their ears, and experience independently. Evidently, stimulating the enthusiasm and learning interest of students is easy by standing in a virtual scenario. Lastly, learning tasks are completed by learners' knowledge construction. After learners complete their online learning, they can perceive the novelty of IVR technology and further expect the next learning of knowledge contents. Learning outcomes also gradually enter into a sustainable improvement.

4.3 Analysis of variance

Table 7. Intermediate process value of analysis of variance

Variables	Difference	Square Sum	Degree of Freedom	Mean Square	F	P
Learning outcome	Intergroup	22.098	3	7.366	3.895	0.009
	Intragroup	574.902	304	1.891	–	–
	Total	597	307	–	–	–

Table 8. Analysis of variance results

Contact Period with IVR Technology (Mean ± Standard Deviation)	Learning Outcomes
<0.5 years (n = 18)	4.94 ± 1.35
0.5–1 years (n = 109)	4.70 ± 1.32
1–3 years (n = 82)	4.09 ± 1.42
>3 years (n = 99)	4.55 ± 1.41
F	3.895
P	0.009**

Note: **$p < 0.01$.

Tables 7 and 8 show that the contact period with IVR technology has significant influences on learning outcomes at the 0.01 level ($F = 3.895$, $p = 0.009$). Moreover, there are clear differences in the comparison of mean scores among different groups. Evidently, learners who have contacted with IVR technology for under 0.5 years and 0.5–1 years show the best learning outcomes. The main reason is that IVR technology can build virtual learning context through a 3D diagram and close organs of learners through VR hardware. Learners can likewise interact with the virtual learning context through hardware equipment, such as VR handle, data glove, and action sensing. They learn knowledge and skills in virtual scenes. They will produce stronger interests in learning from the first contact to learning of IVR technology. If they are more interested in interactive and immersive teaching media, then they easily improve the immersion and interaction of learning resources more positively and find the learning method conforming to themselves, improving learning outcomes. Meanwhile, learning outcomes of students who have contacted with IVR period for 1–3 years are the poorest. The explanations of the reasons are as follows. When learners contact with IVR technology for a certain period, the learning challenge is considerably low with improvements of learning abilities, and users will be bored and lose interest, thereby gradually decreasing learning outcomes. This situation also reminds university managers to focus on learners' comprehension of ITs when maximizing IVR-assisted teaching to formulate more personalized learning schemes and meet different online learning needs of learners, thereby relatively keeping their learning immersion.

5 CONCLUSION

Given IVR technology's characteristics of sensory immersion, natural interaction, and idea creation, it can support contextualized learning, help learners transfer knowledge learned in a virtual environment to real life, promote them to analyze, and understand higher-level cognitive activities, thereby causing significant influences on learning outcomes. This study analyzes the influences of degree of concentration, sense of traversing, emotional engagement, and sense of enjoyment of IVR technology on online learning outcomes. Moreover, differences in learning outcomes under different contact periods with IVR technology are investigated. According to research results, degree of concentration, emotional engagement, and sense of enjoyment of IVR technology can significantly promote online learning outcomes. However, sense of traversing does not improve online learning outcomes. Contact period with IVR technology shows significant influences on learning outcomes at the 1% level. This result indicates that it has to consider learners' familiarity with IVR technology to improve learning outcomes in an IVR environment. This research recommends to further study individual differences in immersive experiences and cognitive loads in IVR online teaching, relationship between learning cognition and emotional engagement in an IVR environment, and influences of gender on learning outcomes.

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