Influence of Learning Engagement on Learning Effect under a Virtual Reality (VR) Environment

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Abstract—In this study, the differences generated by the scenario resources under a virtual reality (VR) environment to the learning effect and learning engagement were explored. Next, the influences of learning engagement (including emotional engagement and cognitive engagement) on the immediate test performance and the one-week-later test performance were tested. Finally, the mediating role played by the VR technology in the facilitating effect of learning engagement on the learning effect was analyzed. Results reveal that the emotional engagement (3.366) and cognitive engagement (3.854) in the experimental group under the VR environment are higher than those (3.325 and 3.618, respectively) in the control group. The difference between the control group and experimental group in the aspect of immediate test performance is significant at the 0.01 level (t=−3.388, p=0.002), and the same significance level is manifested in the aspect of one-week-later test performance (t=-3.126, p=0.003). Whether VR-based teaching was adopted plays a complete mediating role in the influences of cognitive engagement on the immediate test performance and the one-week-later test performance, but it does not play any mediating role in the influences of emotional engagement on the immediate test performance and the one-week-later test performance. The conclusions have important reference values for giving full play to VR-based teaching design, encouraging front-line teachers to participate in customizing VR-based immersive teaching resources, optimizing the VR learning contents highlighting emotional elements, and designing multichannel perceived knowledge contexts.

Keywords—virtual reality (VR), learning engagement, learning effect, mediating effect

1 Introduction

Virtual reality (VR) technology, a new information technology (IT), has been widely applied. In particular, educational methods have undergone enormous changes in the 21st century with the application of VR technology in education, resulting in obvious IT use requirements for teachers and learners. In comparison with traditional offline learning, the VR-based teaching method has favorable interaction and simulation authenticity, with better space for educational implementation. Under the VR-based teaching environment, a series of artificial environments applicable to virtual education has been generated via VR technology. Such environments are capable of true reproduction of environments in the real world, and they have lowered the teaching cost. VR technology has created a dynamic self-learning environment and transformed the traditional teacher-centered teaching environment into a student–teacher interaction-based teaching method. Through such interaction, students can acquire more real knowledge and enhance their skill levels. The VR immersive environment has broken the boundaries of learning scenarios and enabled learners to be personally on the scene. VR technology users view 3D images of nearly real scenarios and are immersed in them. The users conduct visual, auditory, and tactile multi-channel information perception and processing through helmets, headsets, and hand shanks. They also interact with the information. VR immersive resources have been increasingly widely applied in the educational field by virtue of their characteristics. Especially in the educational field, compared with video learning, the VR immersive environment enhances students' degree of participation, and in turn, the interaction between students and learning resources stimulates their potential learning motivation and interests.

A more real virtual teaching center can be established using VR technology, thereby realizing individualized reproduction of real scenarios by the combination of VR devices. VR devices in particular have good interactive functions, enabling users to realize the information exchange and operation feedback of real environments under the VR environment. Thus, the teaching contents that are not easily seen in everyday time are reproduced in teaching environments. The VR-based teaching method has been favored by more teachers and students especially in courses with practical operations such as geotechnical experiments and mechanical tests. Thanks to the immersion and friendly interaction of VR, students can play concrete roles in virtual environments to participate in the teaching process, thereby enhancing their learning engagement, improving their learning efficiency, and exercising and cultivating their skills. Different from traditional textbook teaching, VR technology brings more vivid teaching environments, and learners can master and truly experience skills and knowledge by manipulating relevant VR devices. Therefore, how to design better teaching models to enhance students' learning engagement under the VR environment and further improve the learning effect becomes very important.

2 Literature review

Many studies show that the VR environment is significantly correlated with learning motivation. The VR-based teaching model can effectively promote the learning effect. To verify the advantages of VR-based teaching, Rega, P. P. et al. [1] created an immersive one-semester simulation exercise. Most students believed that the desktop exercise based on this VR training mode was innovative, recreational, and educational. Wood, N. T. et al. [2] deemed that the VR-based teaching method facilitated advertising students to more deeply understand the knowledge about advertisement science. Witmer, B. G. et al. [3] developed an immersion tendency questionnaire and demonstrated teaching effectiveness under a virtual environment. Baños, R. M. et al. [4] compared three immersion systems (PC display, post-projection video wall, and head-mounted display (HMD)) and two virtual environments, and then tested the interaction between the two media features (form and content). The results revealed that immersion and emotional contents would influence the sense of presence, and immersion was more associated with the emotional environment than the unemotional environment. Gorini, A. et al. [5] tested whether immersion technology would affect users' sense of presence, and then provided a more convincing experience than non-immersive and non-contextualized virtual spaces. A total of 84 students were randomly divided into four groups, and the influences of the four circumstances on users' sense of presence were measured through two presence questionnaires and changes in heart rate. The results showed that immersion and narrative were very important in creating effective VR experiences because they contributed differently to the enhancement of the sense of presence. Wang, Y. F. et al. [6] developed an immersive English learning environment in a three-dimensional virtual world. The experimental results indicated learners' immersion and presence via a chatbot and time machine. Cadet, L. B. et al.[7] thought that VR had been increasingly used as a tool to evaluate or train memory. A total of 108 young people were divided into four experimental groups in the experiment. The results indicated that the memory was not directly affected by immersion. The sense of presence was stronger under HMD conditions, but it was weakly associated with memory representation. Faas, D. et al. [8] deemed that in the VR field, sense of presence and immersion were the criteria measuring individual participation in activities. The results indicated that immersion, sense of presence, sense of frustration, and calmness of designers were wider when designing activities. As regards the relationship between learning engagement and learning effect, Bakker, A. B. et al. [9] explored the dynamic relationship between job engagement and job performance and included personal effort and goal orientation as mediating variables in the analysis. They pointed out that for the employees with strong responsibility, job engagement presented close positive correlations with task completion, contextual performance, and learning initiative. Wu, H. et al. [10] stated that compared with students not in key universities, those in key universities showed higher internal motivation, better learning performance, and lower external motivation. Internal and external motivation could generate significant indirect effects on academic achievement via learning engagement. Blasco-Arcas, L. et al. [11] explored the influence of an auto clicker (i.e., an audience reaction system) on students' learning performance. High-level interaction with peers and teachers promoted by auto clickers would facilitate positive collaborative learning and participation, thereby improving students' learning performance. Summerlee, A. et al. [12] indicated that enquiry-based learning (EBL) facilitated students to change their way of acquiring information, carrying out research using more complicated resources, and more actively participating in communities. Students' degree of participation was thought to be able to improve academic achievement. Bergdahl, N. et al. [13] discussed the relationship between participation (separation) and academic achievement in technology-enhanced learning (TEL). The results showed that high-performance students could concentrate more when studying technologies than ordinary students and low-performance students. High-performance students had already formulated the strategies of using digital technologies in supportive and productive ways. Chen, M. R. A. et al. [14] facilitated 19 students (7 males and 12 females) to learn through reflective thinking in the experimental group. They found that a flipped classroom not only significantly improved students' learning design project results and reflective thinking but also elevated their degree of participation in flipped learning in the pre-class phase. Rashid, T. et al. [15] showed that the use of VR technology had direct positive correlations with students' degrees of participation and autonomous learning. The technology use of students showed complex interactions with their degree of participation, autonomous learning, and academic achievement. The literature indicates that regardless of the teaching environment, learning engagement continues to present a close positive correlation with learning results as a whole. Especially with the application of artificial intelligence (AI) and 5G IT to the educational field, students' sense of presence has been enhanced, and the learning effect can be strengthened by other variables (e.g., self-efficacy, emotional response). Therefore, the differences in students' learning engagement (cognitive engagement and emotional engagement), immediate performance, and one-week-later performance were compared by designing environmental control variables (VR-based teaching group and traditional teaching group). Then, their relationships with the learning results were explained in this study, thus exploring multiple factors influencing the deep engagement and their relationships.

3 Research design

3.1 Research objects

All the experimental objects in this paper were sophomore and junior students of different majors in the School of Architectural Engineering in an ordinary provincial university in Henan province. This university, which undertakes concrete projects of the Henan provincial "Intelligent University Pilot Program," has further expanded and enhanced its digital campus. It has established an information-based supporting platform with big data as the core, intelligent applications as the support, and self-adaptation and individualized user interaction as the goal. The university has created an intelligent and open educational and teaching environment and a convenient and comfortable living environment, thereby realizing the people-oriented individualized innovative management and services. The School of Architectural Engineering in this university has implemented overall practical teaching reform as a concrete unit undertaking the provincial-level virtual simulation experiment teaching project. It has invested approximately CNY 3.6 million in constructing its VR virtual simulation training room. A total of 82 subjects (mean age: 21 years old) participated in this experiment. To meet the data acquisition needs, the 82 subjects were randomly allocated into experimental and control groups (41 persons in each group) according to different learning materials presented and different learning environmental conditions.

3.2 Measurement method

The learning task design in a VR environment should be differentiated from the traditional learning design. The independent assessment in the original cognitive domain, motor skills, or emotional domain should be integrated into the overall task evaluation to facilitate students to solve the problems in practical life by coordinatively using all types of complicated cognitive skills. Therefore, the problem designed in this research based on the connotation and design principle of complex tasks covered two or more variables or knowledge points. A scenario of learning skin tissue knowledge was provided via the VR environment. In this paper, multi-dimensional data characterization analysis was adopted, where learning engagement was investigated using the questionnaire designed by Henrie C R, comprising nine items (four items of emotional engagement and five items of cognitive engagement) [16]. The learning effect was expressed by the immediate performance and the one-week-later performance. The test performance of the experimental (VR-based teaching model) and control groups (traditional teaching model) was reflected by the examination questions regarding the teaching contents in Chapter 6 of *Engineering Structure*, i.e., test preparation, loading, and data acquisition of steel beam integral instability. The immediate performance was expressed by the class test results on "Intelligent Vocational Education," and the one-week-later performance was reflected by the unit performance test result via test papers. The results of all students were transformed into grades of 1–5. In the experimental group, the VR experiential teaching of *Engineering Structure* was mainly adopted in a VR virtual simulation training room. The HTC Vive integration system was used as the experimental equipment in the VR group, in which the participators interacted with 3D scenarios through headsets, realizing the simulation learning of test preparation and loading. Before the experiment was formally started, the necessary VR operation training was done among the students in the laboratory, helping them become familiar with VR immersive environment, including play, pause, fast-forward, rewinding, playback, handle operation, and interaction. In the control group, the traditional offline face-to-face PowerPoint teaching model was adopted.

4 Result analysis

4.1 Reliability and validity test of learning engagement

To verify the questionnaire reliability, Cronbach's α coefficient was calculated via SPSS 22.0. The overall Cronbach's α coefficient of the learning engagement questionnaire was calculated as 0.914, indicating its good reliability. The questionnaire validity was verified through the principal component analysis) method, KMO=0.871. Statistically significant differences were manifested among the samples in Bartlett's test of sphericity ($p<0.001$), manifesting the favorable validity of the learning engagement questionnaire.

4.2 Differences in learning engagement and learning effect

Table 1 shows that in the experimental group, the learning engagement of students could be obviously enhanced by VR-based teaching. The main reason for this finding is that the steel beam integral instability in the curriculum—*Engineering Structure*—

was a critical link, involving the knowledge related to the sticking of a strain gauge, the connection of sensors, the positioning of specimens, and the setting of step loading. Such work is highly professional. VR-based teaching could return to the basic laws of learning and cognition under the orientation of the working process and systematically and organically integrate knowledge and skills into the practical project tasks, thus gradually upgrading skill requirements in the practical experience of a real operating environment.

Table 1. Differences in learning engagement

Title	Experimental group	Control group
Emotional engagement	3.366	3.325
Cognitive engagement	3.854	3.618

As seen in Table 2, in the test immediately conducted after the experiment, the two groups show evident differences in learning performance, and the learning performance in the experimental group is higher than that in the control group. In the second test implemented one week later, the learning performance in the experimental group is also markedly higher than that in the control group. VR environment provides an opportunity for more deeply understanding abstract scientific concepts, enhances the interaction between students and media resources, and even increases the collaboration opportunities and strengthened the sense of reality, which, is undoubtedly an effective means of changing the learning style and information processing method. Given the combination of information processing and learning engagement, the mental representation could be strengthened into long-term memory, and the VR-based teaching could facilitate students to form real experiences about steel beam integral instability in their brain and establish long-term memory. According to the experimental results, learning in the VR environment could keep and even increase the knowledge retention rate of students, and this phenomenon could further facilitate students to migrate knowledge to new contexts or new problems, thereby strengthening their information memorizing and retrieving abilities. Using VR immersion technology to simulate the complex realistic problems possibly faced in real environments could help students to understand and internalize the knowledge. The data analysis results indicate that the VR-supported knowledge learning no longer aimed to memorize contents within a short time, but instead, it broke through the barrier of traditional short-term memory. Therefore, compared with the non-VR learning method, especially in the learning process of contents similar to *Engineering Structure* that need practical operations, VR-based teaching could contribute to better learning effects.

Table 2. Differences in learning effect

Title	Experimental group	Control group
Immediate performance	4.707	4.317
One-week-later performance	4.731	4.414

4.3 Paired-samples t test

The paired-samples t test was performed for the immediate test score after the experiment and the compressive score in the one-week-later test in the experimental and control groups. The data analysis reflected that the participators in the experimental group were significantly different in the total score of immediate test and one-week-later test.

Table 3 shows that the differences in experimental data were studied via a paired-samples t test. A total of one group of paired data was studied, and differences were manifested ($p<0.05$). The immediate performance in the control group was significantly different from that in the experimental group at the 0.01 level (t=−3.388, p=0.002). The concrete comparative differences show that the mean value (4.32) of immediate performance Y1 in the control group is evidently lower than that (4.71) in the experimental group. This finding fully verifies that the overall learning effect—immediate performance—in the experimental group under the VR-based teaching model is better than that in the control group under the traditional offline teaching model. The main reason for this result is that the VR-based teaching model enabled students to more truly experience the practical operations of steel beam integral instability. This result also encourages teachers to design open roles when formulating the teaching contents under the VR environment. Front-line teachers are also encouraged to explore immersion learning courses, hand the classroom over to students, and design and optimize the VR learning resources that highlight emotional elements.

Table 3. Paired-samples *t* test of immediate performance

Name	**Pair (mean ± standard deviation)**		**Difference value (pair 1-pair 2)**	***t***	***p***
	Control group	***Experimental group***			
Immediate performance	4.32±0.57	4.71±0.46	−0.39	−3.388	0.002**

* $p<0.05$ ** $p<0.01$

Table 4 shows that one group of paired data was studied, and differences were embodied ($p<0.05$). The one-week-later performance in the control group is significantly different from that in the experimental group at the level of 0.01 (t=−3.126, p=0.003). The concrete comparative differences indicate that the one-week-later performance Y2 (4.41) in the control group is evidently lower than that (4.73) in the experimental group. Differences are manifested in all of the paired data. Therefore, the VR-based teaching model could deepen students' sense of presence in the learning process of *Engineering Structure* and facilitate them to establish the specific operating scenarios in their brain, thus keeping their learning outcomes for a longer time. This result also encourages teachers to attach importance to emotional interaction while motivating the further self-exploration process of students. The emotional interaction between students and that between students and resources are conducive to a longer duration of the VR-based teaching effect.

Table 4. Paired-samples t test of one-week-later test performance

Name	**Pair (mean ± standard deviation)**		**Difference value (pair 1-pair 2)**	**t**	**p**
	Control group	***Experimental group***			
One-week-later performance	4.41±0.50	4.73±0.45	−0.32	−3.126	0.003**

* p<0.*05* ** p<0.01

4.4 Correlation analysis

Table 5 shows that whether VR technology was used is closely positively correlated with immediate performance and one-week-later performance. This finding indicates that the VR-based teaching could obviously positively promote the learning effect. Learning engagement is also closely associated with immediate performance, one-week-later performance, and use of VR technology. The primary reason for this result is that the deeper the learning engagement, the stronger the students' perception of VR technology. The correlation coefficient between the use of VR technology and one-week-later performance is smaller than that between the use of VR technology and immediate performance. Notably, the immediate perception of VR technology could obviously improve students' performance, but with time, students' learning effect could be easily degraded. Therefore, sufficient credit hours should be given to VR-based teaching, and VR-based experiential teaching should be avoided. Owing to the restriction of resources, only a few credit hours are given to VR-based teaching in many schools, discouraging students from consolidating and mastering complex operative techniques and technical skills and knowledge.

Table 5. Correlation coefficients

	Immediate performance	**One-week-later performance**	**Whether VR technology is used**
Immediate performance	1	-	-
One-week-later performance	0.448**	1	-
Whether VR technology is used	0.357**	0.321**	1

* p<0.05 ** p<0.01

4.5 Mediating effect analysis

Table 6 and 7 show six regression equations: immediate performance= 4.604–0.062 * cognitive engagement + 0.042 * emotional engagement; whether VR technology is used= 1.941–0.448 * cognitive engagement + 0.070 * emotional engagement; immediate performance = 3.787+0.126 * cognitive engagement + 0.013 * emotional engagement +0.421 *whether the VR technology is used; one-week-later performance = 5.202 + 0.001 * cognitive engagement – 0.190 * emotional engagement; whether the VR technology is used= 1.941–0.448* cognitive engagement + 0.070 * emotional engagement; one-week-later performance 4.532 + 0.156 *cognitive engagement-0.214 * emotional engagement + 0.345 * whether the VR technology is used. The results manifest that whether the VR-based teaching model was used plays a complete mediating role in the influence of cognitive engagement on immediate performance and one-week-later performance. This finding fully proves that the use of VR technology could obviously affect students' cognitive engagement, especially for the curriculum of *Engineering Structure*. This content cultivated operating skills, and students were required to gain a certain understanding of mechanical tests, so under the VR-based teaching model, students could more truthfully experience such knowledge. However, whether the VR-based teaching model was adopted does not play any mediating role in the influence of emotional engagement on the immediate performance and one-week-later performance. This result indicates that that under the VR-based teaching model, teachers relied excessively on VR devices, while students simply used VR devices in learning or appreciated a sense of freshness but failed to fully understand the VR-supported learning resources and contents, affecting their emotional engagement. This finding reflects that teachers should attach importance to students' change in mentality and emotional fluctuation in the VR-aided learning process to comprehensively motivate their emotional engagement and enhance their self-efficacy in learning. Under the VR-based teaching model, some tedious concepts and definitions in the curriculum—*Engineering Structure*—can be transformed into more programmed and contextualized knowledge through good curriculum teaching resources. Thus, the knowledge can be fused with concrete contexts and the knowledge learned by students can be memorized and perceptually cognized for a longer time. On this basis, students can be more interested in such contexts with a higher degree of excitement. The VR environment has provided multiple perception channels and information retrieval tools that help students to transcend transient memory, focus their attention, and integrate their knowledge, enabling them to learn more complicated knowledge concepts faster. The students can apply the knowledge in real life and acquire deeper learning effects.

Table 6. Mediating effect analysis of immediate performance

	Immediate performance	**Whether VR technology is used**	**Immediate performance**
Constant	4.604** (5.909)	1.941** (2.872)	3.787** (4.937)
Cognitive engagement	−0.062 (−0.355)	−0.448** (−2.949)	0.126 (0.730)
Emotional engagement	0.042 (0.207)	0.070 (0.394)	0.013 (0.067)
Whether VR technology is used	-	-	0.421** (3.460)
Sample size	82	82	82
R^2	0.002	0.103	0.135
Adjusted R^2	−0.024	0.08	0.101
F value	F (2,79) = 0.068, p=0.935	F (2,79) = 4.527, p=0.014	F (3,78) =4.041, p=0.010

* p<0.05 ** p<0.01 In the brackets are t values

Table 7. Mediating effect of one-week-later performance

	One-week-later performance	**Whether VR technology is used**	**One-week-later performance**
Constant	5.202** (7.426)	1.941** (2.872)	4.532** (6.487)
Cognitive engagement	0.001 (0.009)	−0.448** (−2.949)	0.156 (0.992)
Emotional engagement	−0.190 (−1.034)	0.070 (0.394)	−0.214 (−1.227)
Whether VR technology is used	-	-	0.345** (3.119)
Sample size	82	82	82
R^2	0.015	0.103	0.124
Adjusted R^2	−0.01	0.08	0.09
F value	F (2,79) =0.594, p=0.554	F (2,79) =4.527, p=0.014	F (3,78) =3.683, p=0.015

* p<0.05 ** p<0.01 In the brackets are t values

5 Conclusions

The VR environment has provided an opportunity for students to gain a deeper understanding of abstract scientific concepts, enhanced the interaction between students and media resources, increased opportunities for collaboration, and promoted the sense of reality. The VR environment is also an effective means of changing learning styles and information processing methods. VR-based learning can keep and even increase the knowledge retention rate of students, helping students to migrate knowledge to new contexts or new problems, thereby improving their learning effect. In this study, the differences generated by the scenario resources under a virtual reality environment to the learning effect and learning engagement were explored. The influences of learning engagement (emotional engagement and cognitive engagement included) on the immediate test performance and one-week-later test performance were tested. The mediating role played by the VR technology in the positive promotion of learning effect by learning engagement was analyzed. Results showed that the emotional engagement (3.366) in the experimental group is higher than that (3.325) in the control group, and the cognitive engagement (3.854) in the experimental group is also higher than that (3.618) in the control group. The immediate performance and one-week-later performance in the control group are significantly different from those in the experimental group at the 0.01 level. The use of the VR-based teaching model plays a complete mediating role in the influences of cognitive engagement on immediate performance and one-week-later performance. The cognitive mechanism of deep learning, the relationship between immersion and engagement of participators, and the relationship between learning engagement and learning performance of students at different ages should be continuously figured out in multi-scenario complex tasks. The acquisition of cognitive process data through AI data tracking technology also should be deeply probed.

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