Kurdish Studies
Jan 2023
Volume: 11, No: 01, pp. 332-343
ISSN: 2051-4883 (Print) | ISSN 2051-4891 (Online)
www.KurdishStudies.net

Received: May 2023 Accepted: September 2023
DOI: https://doi.org/10.58262/ks.v11i1.1025

Virtual and Augmented Reality in Enhancing the Learning Experience

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Abstract

Traditional teaching methods lead to insufficient motivation of students to learn, in order to solve this problem, this paper combines virtual reality technology and augmented reality technology to design. Firstly, it elaborates the advantageous features of VR as well as AR technology and its application in learning. Then based on the theory of learning experience, VR and AR technology are integrated. Finally, through the spatial transformation of VR and AR technology, the corresponding learning scenes are designed for students to integrate into them. The results show that in the chemistry module, the students' hands-on experience index score through the AR/VR learning model is 9.56, and in the children's art module, the p-value of all the indexes is less than 0.01, which can help the learners acquire knowledge at a deeper level.

Keywords: *virtual reality, augmented reality, learning experience, spatial transformation, learning scene*

Introduction

With the arrival of the digital information age, modern information technology is constantly changing people's production and lifestyle, but also has an important impact on people's way of thinking, learning, etc., which also continues to promote the adjustment and reform of education (Hu, Qu, Xu, Yang, & Yu, 2017). In this context, the realization of education means from text to image, three-dimensional technology to virtual reality change is the way to go. At the same time, due to the rapid development of Internet technology, the information network has gradually penetrated into all aspects of human life, and the field of education has also ushered in an era of network education. The combination of network and virtual reality technology can better promote the use of high technology in human life, thus accelerating the modernization of education in China (Liang & Shuang, 2017; Meng, 2019).

(Dalman et al., 2020) As far as the field of education is concerned, virtual reality technology, as one of the important modernized teaching means, has continuously promoted the development and innovation of education methods (Wang et al., 2022). Contemporary education advocates the cultivation of students' independent learning ability and active exploration ability, which requires that educational institutions should be taught by students as the main body. However, the teaching form of most schools nowadays still follows the boring traditional mechanical teaching mode, leaving little space for students to explore (Diao, Xu, Jia, & Liu, 2017). Students always lack the initiative in the learning process, resulting in the teacher's teaching efficiency is also reduced. Virtual reality-based educational products can provide great help to alleviate the above problems, the virtual space can provide a more vivid and broad, high teacher teaching effect and effectiveness, so the subject of virtual reality interactive learning forms of research on the development of the field of education also has a certain positive significance (Cui, 2017).

At present, virtual reality technology has a wide range of applications, including military teaching, medical teaching, sports training and other multi-disciplinary teaching, virtual reality technology for educators to develop a broader vision and provide a more effective form of education. Tokarev, a et al. developed a set of educational programs based on the CDIO standards for the learning of skills in the use of VR technology. Providing new opportunities for computer science, mechatronics and robotics education in Russian schools and universities helps to save time, money and other resources (Tokarev, Skobelin, Tolstov, Tsyganov, &

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Pak, 2021). Gargrish, S et al. based on Augmented Reality technology fused virtual information with physical objects and installed on Android and iOS platforms and used it in teaching 3D geometry to high school students. The approach provides a theoretical basis for overcoming the problems faced by students in understanding geometry as well as providing benefits and limitations of the learning environment experience (Gargrish, Mantri, & Kaur, 2020).

Samaniego-Franco et al. developed an AR-based 3D learning object for Legal Medicine and implemented the application in the classroom as well as the Kolb Experiential Learning Cycle. In order to analyze the criteria and perceptions, a university distance learning model was evaluated and the results showed a high level of acceptance by the students and demonstrated that the application was complementary to the teaching and learning process (Samaniego-Franco, Agila-Palacios, Jara-Roa, & Sarango-Lapo, 2019). Yang, S. H et al. constructed an e-learning system by combining a serious game in the Unity3D game engine with augmented reality. Students can acquire knowledge and develop logic skills through this game-based e-learning system. The game-based e-learning system was evaluated and compared with traditional learning and other e-learning systems based on its effectiveness and usefulness (Yang et al., 2020).

Based on virtual reality technology and augmented reality technology, this paper designs and develops targeted educational teaching resources or learning experimental platform, which is rich and complementary to the mainstream forms of teaching, and provides diversified means and methods for teaching and learning. This paper firstly introduces the concept of augmented reality technology, the development stage, key technologies and core features, and explains its advantages, characteristics and basic development process (Ubillus, Neira-Montoya, Sedano-Gelvet, & Verona-Cueva, 2022). Then it creates a learning system in the context of virtual reality based on the theory of learning experience, and at the same time integrates the theory of human-computer interaction and the theory of immersion in the design of the system, so that students can obtain the best learning experience in the learning process. Finally, the AR/VR learning model constructed in this paper is practically analyzed, and the effectiveness and robustness of the learning system in this paper are verified through technical performance testing, and learning experience analysis. It proves that the technical characteristics of virtual reality technology and augmented reality can well present realistic rendering in visual effect, making the visual feeling and cognitive effect of learners relatively good (ERGÜDEN, Deniz, ALTUN, ERGÜDEN, & Bayhan, 2019).

Virtual Reality Education Application Value and Technological Advantages

Open up a new learning experience

Virtual Reality, or VR for short, is an immersive interactive environment based on multimedia computer technology, sensing technology, and simulation technology. By placing the learning content in an immersive virtual environment, students can interact with the knowledge in a completely new way, so as to understand and absorb the learned content more deeply (Liu & Pan, 2022; Zhong & Xu, 2021). The most critical technical point in the process of virtual reality technology is to combine the virtual environment, virtual sound effects, and visual information in space to synthesize a multi-dimensional digital informational scene. The use of computer simulation technology to build a virtual environment, so that students can participate in this virtual environment, and get the same feeling and perception as the real world, creating a sense of immersion for students (Maskati et al., 2021; Qin & Tao, 2018; Zhang, 2019). Specifically, as follows:

(1) The application of virtual reality and augmented reality technologies in the field of education has greatly enhanced the learning experience. By placing the learning content in an immersive virtual environment, students can interact with the knowledge in a completely new way, thus understanding and absorbing what they have learned in a deeper way.

(2) Virtual reality technology creates realistic virtual environments that allow students to participate in historical events, scientific experiments, or other subjects as if they were there. For example, students can roam around an ancient city through virtual reality glasses to feel the environment and atmosphere of the time, thus gaining a deeper understanding of history and culture.

(3) Virtual reality technology can also provide multi-dimensional sensory experiences, including visual, auditory and tactile senses, making learning more vivid and intuitive. For example, when learning biology, students can observe the structure and function of cells through virtual reality technology, and even simulate

biological activities within cells, thus deepening their understanding of biological concepts.

(4) Virtual reality technology can also provide a highly free space for manipulation, allowing students to learn according to their own interests and learning pace. Students are free to explore various resources and information in the virtual environment, thus promoting the implementation of independent and discovery learning.

Core elements for expanding learning spaces

Space and time and space have always been factors that constrain learning, in learning, people are often only able to intuitively see what is around them, what is now, and the rest can only be understood through information, other people's introductions or imaginations, which makes people's footsteps in recognizing the world be greatly bound (Klingenberg et al., 2020). And through virtual reality technology, learners can visualize, feel and even touch distant things. Ideally, this virtual reality should be to such an extent that it is difficult for the user to distinguish between the real and the fake, and may even be more real than what really exists in the real world.

Figure 1 shows the core elements of virtual reality technology for learning, and there are three core elements in the process of using virtual reality technology for learning, which are VR pedagogy, resources and VR equipment, and learner experience. Among them, the learner experience is the most direct factor affecting whether virtual reality technology can effectively promote learning, including the students' immersive feeling in the virtual reality learning environment, their identification with the virtual identity, and their interaction with the equipment, the environment and other avatars. The immersive feeling and natural and rich interactive experience not only greatly stimulate students' learning motivation, but also provide students with a large number of opportunities for hands-on observation, operation, and cooperative learning with others, which promotes students' cognitive processing and knowledge construction process, and is conducive to the realization of deep-level understanding.

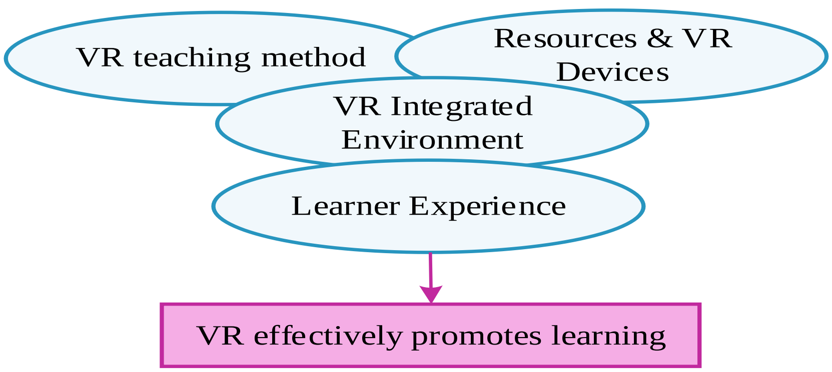

Figure 1: The technical feature structure of virtual reality

Augmented reality in learning

Augmented Reality Expands the Bridge of Perception

Augmented reality (AR) is based on computer display and interaction, network tracking and localization technology, superimposing computer-formed virtual information on real scenes to supplement the real world, so that people can enhance their experience of the real world in terms of vision, hearing, and tactile senses, etc. (Balco, Bajzík, & Škovierová, 2022; Manuaba, 2021; Rigamonti et al., 2021). The most important feature of AR lies in the seamless connection and real-time synchronization between the virtual scene and the real scene The most important feature of AR is the seamless connection and real-time synchronization between the virtual scene and the real scene, when the learner's sight and position change, the virtual scene also changes, and this change is natural. What is presented through AR technology is the learning content that meets the needs of learners and constantly changes the angle, which is a perfect combination of reality and virtualization, and learners get a surreal experience from it (Nurbekova & Baigusheva, 2020; Zuo, Birk, van der Spek, & Hu, 2022). Figure 2 shows the relationship between augmented reality technology and the real environment, augmented reality technology expands the way of human cognition of things, it builds a bridge between the virtual environment and the real world, the augmented content allows users to understand the background, access to information and expand knowledge, and enhances the user's ability to perceive the real world. In the learning process, this expanded cognitive pathway provides students with a unique learning experience, making the digestion and absorption of knowledge more efficient and profound (Parenti, 2019).

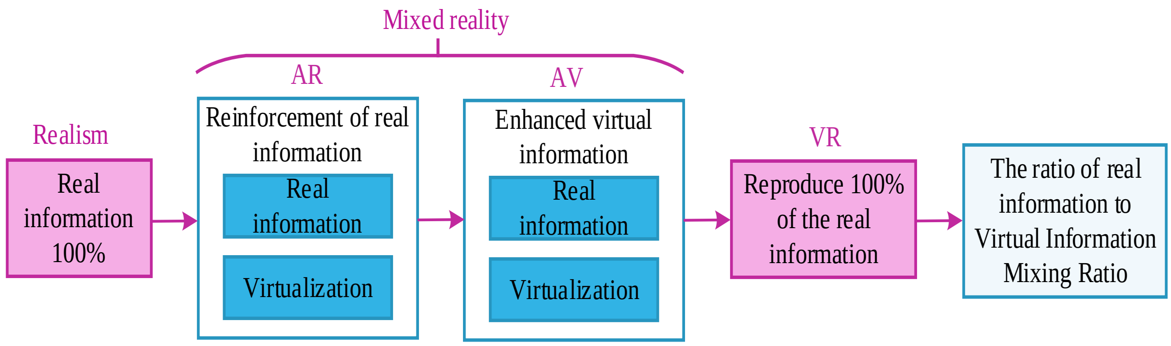

Figure 2: AR in relation to the real world

Learning scenario enhancement

AR is able to enhance the real scene in which the learner is located, providing the learner with a different way of perceiving information, which applies virtual information to the real world, so that the virtual information and the real environment exist in the same space and time, and the two kinds of information complement each other and are displayed on top of each other. The working principle of AR is shown in Fig. 3. In an augmented reality system, it mainly relies on two types of hardware, a kind of hardware that can capture the real world information, the information collected includes location data, image data, orientation data, and other forms of data. The other type of hardware is the hardware where the media can be incorporated into the virtual content at the time of the augmented reality and to be able to incorporate the virtual content in a meaningful and useful way. A complete augmented reality system contains signifiers, computers, cameras, display terminal devices, and augmented reality software systems. The first step is to obtain information about the real scene, followed by comparing and analyzing the real scene and the position information read by the camera. Then comes the production and generation of the virtual information to be augmented. Finally, there is the presentation and display of the virtual information in the real environment, which provides a powerful support for the enhancement of the learning experience.

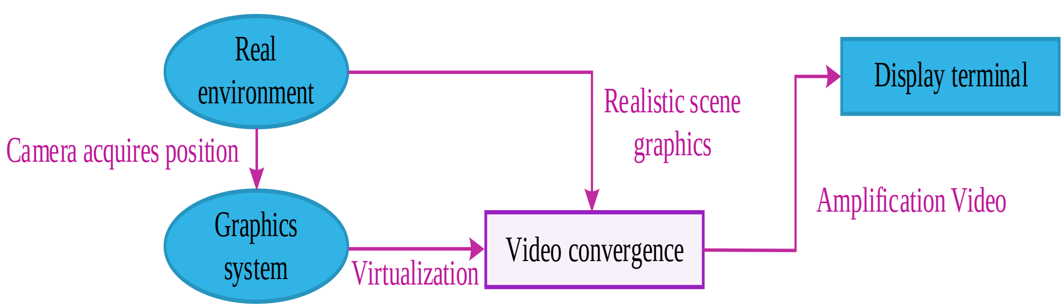

Figure 3: How augmented reality works

Learning system design with joint AR and VR technologies

Key elements of user experience

User experience is the user's experience of using the product household experience is established in the process of the user's use of the product subjective feelings, user-centered, human-centered design has been more and more people's attention, whether it is an Internet product or a traditional software industry product, the user experience has been elevated to a new level. Figure 4 shows the basic elements of user experience, in the design process into the elements of student experience, you can make the product in the operation has not yet been online already have a basic user acceptance, so that the product to take advantage of the first opportunity. Detailed analysis of the product's five user experience elements is from the bottom to the top of the process, from the conceptual framework to the interface visual, gradually oriented to the student interface, and gradually contact with the user's actual experience.

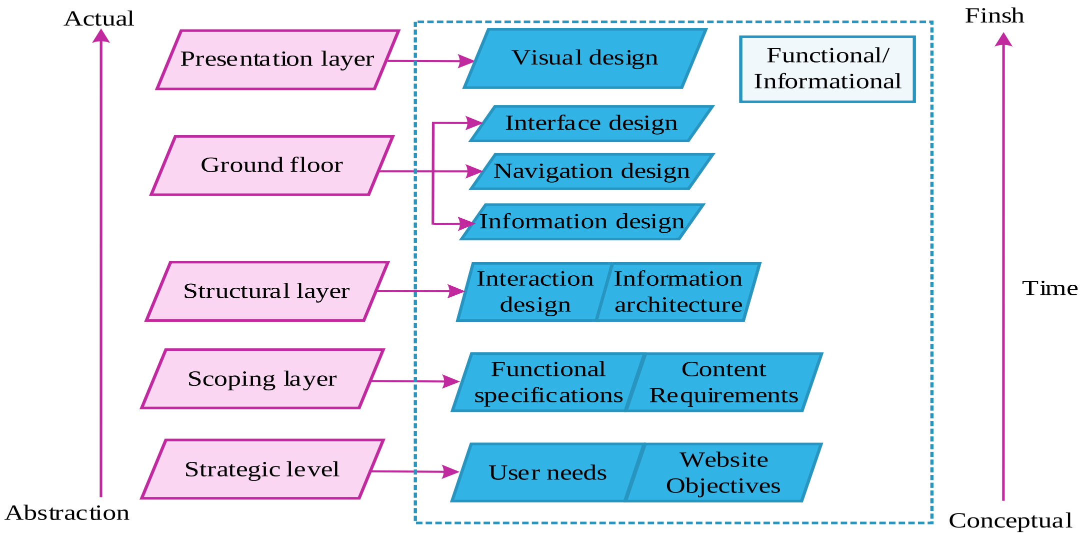

Figure 4: shows the basic elements of user experience

Interactive learning spaces

In this paper, the design of the student interactive learning system in the context of virtual reality is based on student experience and supported by virtual reality technology to build a natural and interesting virtual teaching space. It integrates multiple types of learning contents and scenes to stimulate students' interest in learning, complete natural learning, and achieve learning goals. Figure 5 shows the structure of the interactive learning space; the learner enters the corresponding VR/AR space through VR or AR according to the learning objectives. In the space, according to their own mastery of knowledge, they can choose different learning modes, the system can record all the learning trajectories and learning actions of the learner, and through analyzing the learning behavior of the learner, choose the learning path that is suitable for the learner, so as to generate adaptive learning modes and learning strategies. At the same time, these patterns and strategies are fed back to the learning behavior recording component of the system, which is used to continuously update and expand the corresponding behavior rule base. Through the learning process of continuous training, the system will generate a large number of learning rules, which will provide data support for the generation of adaptive learning control and navigation strategies through data mining techniques.

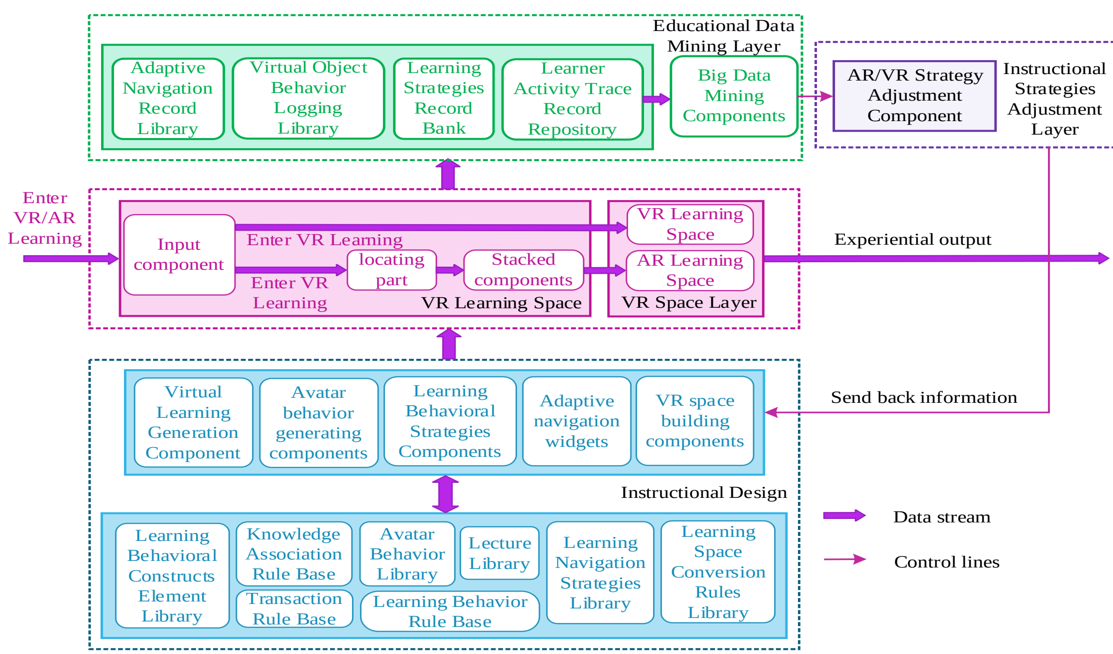

Figure 5: Structure of the interactive learning space

After students enter the interactive learning space, the virtual reality is characterized by putting them in a virtual scene, which are different in the form of combining different knowledge points. Students in the virtual reality environment can automatically walk within a certain range, which is hidden when students enter the environment, and when students arrive at the boundary of the set range in the process of walking, the system will appear in the virtual space with the function of prompting the object block, prompting students that their spatial position is about to arrive at the boundary of the limit.

Virtual learning scenario design

VR/AR spatial transformation

Learning space contains VR learning space, AR learning space and physical learning space. The main role of VR learning space in teaching is to be used to show the teaching process and the internal structure of the teaching object, which is a kind of virtual learning environment. AR learning space, on the other hand, can generate multiple narrative lines and narrative suspense through the superposition of virtual space and physical space. The type of space carried by the virtual space can be nested, i.e., it can be VR space nested in VR space, or VR space can be superimposed and then nested with AR, etc., and the space is integrated (AKYOL, CEYHAN, & CAPAPÉ, 2020).

Virtual teaching space

The three-dimensional virtual simulation environment constructed by virtual reality allows students to be in different learning contents and accomplish learning objectives. Through a variety of forms of operating equipment to allow students to change their own image in the virtual environment, or to design the corresponding learning scenarios to allow students to integrate into it. The way to achieve this goal is to correctly guide students to clarify the virtual reality teaching objectives, so the design of the instructions in the virtual environment is particularly important. For this reason, this paper in the virtual reality environment, combined with the design theory of human-computer interaction teaching system, to build a virtual teaching space as shown in Figure 6, the virtual space consists of a cornerstone, a kernel and three support points.

Students, as the main body of learning activities, are the innermost part of the virtual learning space. Therefore, taking students as the starting point, teachers are the instructors of students' learning and the planners of learning activities, and technicians are the producers of the virtual reality learning system. Virtual learning contexts can be divided into gamified virtual contexts and real contexts according to the way students experience them. The gamified virtual context refers to the experience design, guiding students to interact, perceive and operate with the tasks, images, sounds and objects in the scene with the help of the virtual self-role, so as to create an immersive feeling for students. Real context is a scene that is more consistent with real life, with a high degree of integrity, and the scene is closely linked to real life. Interaction and experience belong to the intermediate components in the virtual learning context, the context needs to stimulate students' experience through interaction, so as to exert an effect on learners' learning behavior.

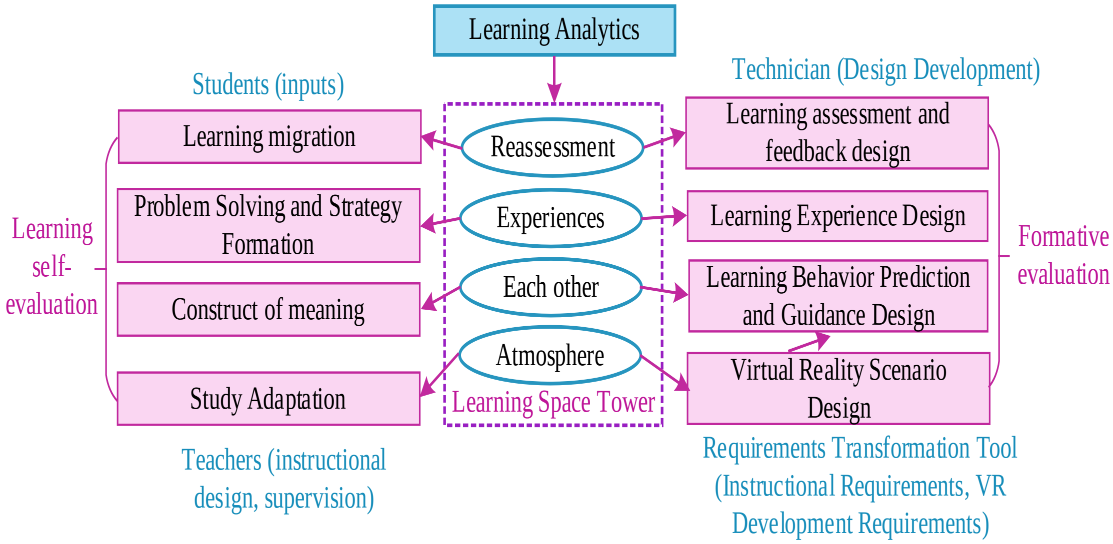

Figure 6: Virtual teaching space

Virtual Reality and Augmented Reality System Performance Verification

In order to verify the effectiveness and robustness of the teaching system in this paper, a series of experiments are conducted to optimize the learning methods through the modeling method of the image with a single point of view in Method 1, the texture-constraint-free method in Method 2, the a priori feature-constraint-free method in Method 3, and the VR/AR technology in this paper, respectively. In the learning experience analysis, qualitative and quantitative analyses are performed by capturing different poses of the students as well as facial feature pixel information.

Table 1 shows the results of the error comparison of the model, compared with the average error of 2.8292mm for the single viewpoint bilinear model, the model error in the VR/AR technology method is 2.4121, which indicates that the technology improves the accuracy by 14% compared to other methods.

Table 1 Error comparison results of four method models

Method	Model error
Image modeling from a single viewpoint	2.8292
No texture constraint method	3.3465
No prior feature constraint method	2.7566
VR/AR technology	2.4121

Table 2 shows the results of the similarity analysis with pose capture. The method based on the single viewpoint bilinear model presents a significant decrease in accuracy from pose3 to pose5 due to the inability to handle occlusion. However, the method proposed in this paper can obtain satisfactory results by considering the feature information from the viewpoint image with similarities all around 0.85, which shows the robustness of the method against occlusion.

Table 2 Pose capture similarity analysis results

	Image modeling from a single viewpoint	No texture constraint method	No prior feature constraint method	VR/AR technology
Pose1	0.8914	0.8435	0.9151	0.9574
Pose2	0.8548	0.8118	0.8847	0.9239
Pose3	0.7913	0.7332	0.8329	0.8563
Pose4	0.7531	0.6947	0.7821	0.8226
Pose5	0.8047	0.7252	0.8245	0.8696
Pose6	0.8275	0.7861	0.8621	0.9195
Pose7	0.8352	0.8033	0.8678	0.9203

Analysis of the effect of learning experience enhancement

Analysis of student engagement

The experience resulting from VR/AR instruction should not be limited to the enhancement of task solving skills, but should also increase the enjoyment of the learner. A learner's experience of a VR/AR instructional activity is personalized, embedded with the learner's skills, knowledge, and prior similar experiences, and is the emotions and feelings that arise when the learner interacts with the VR/AR system. In this paper, the experience design is categorized into four types from the degree of student engagement, which are entertainment, education, aesthetics, and escapism.

Figure 7 shows the results of the analysis of student engagement, in which the entertainment experience is mainly divided into watching performances and listening to music, etc. The activity has a high degree of student engagement, starting from the 4th activity, the degree of student engagement is more than 80%, and in the last activity, the degree of engagement is as high as 98%. The next activity was Escape Experience, which had the highest level of participation at 95% as long as the content was a realistic immersion experience such as the main park and casino.

Lastly, teaching and art, the highest level of participation reached over 90% in both cases. It can be seen that VR/AR teaching activities to enhance the dramatization of the experience, through suspense and dramatic tension to enhance the immersion and engagement of learning, so that learners get the maximum emotional satisfaction and cognitive benefits.

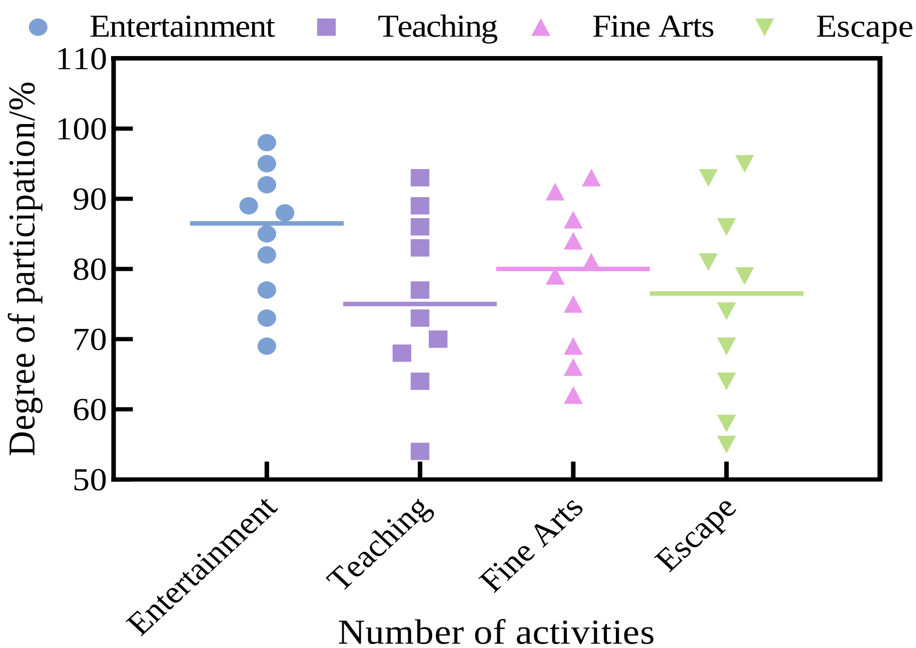

Figure 7: Results of student engagement analysis

Classroom Behavior Evaluation

The ultimate goal of AR/VR learning model is to improve students' learning effect, and the measurement of learning effect is an important way to test the degree of achievement of learning objectives, and different types of knowledge have different ways of measurement. In this paper, we choose A middle school and B high school in an urban area among the schools in the scope of application of teaching media, and select a class in the ninth grade and the first year of high school of the two schools to carry out classroom research, and carry out teaching with traditional teaching, physical teaching, video teaching and augmented reality technology-assisted teaching, and the level of the students in the selected class is regarded as similar, and the degree of students' understanding of the content of the teaching before teaching is regarded as similar (Sun & Choi, 2023).

In this experiment, ninth grade students were selected as subjects, and the teaching process was divided into four phases, totaling 100 minutes, with each phase lasting 25 minutes. The first stage was board teaching, in which the teacher used the board to teach and explain the concepts of the elements. The second stage is physical teaching, which explains the physical properties of chemical elements, and the third stage is video teaching. The fourth stage was AR teaching, in which students were divided into 10 groups and each group was assigned a cell phone with AR software installed, and group discussions were conducted. Teachers observed and recorded students' behaviors during the process of each stage and evaluated students' classroom behaviors through various indicators. Table 3 shows the record table of students' classroom behavior.

(1) Using AR technology to assist teaching, students' classroom behavior scores higher on all indicators, compared with physical teaching, augmented reality technology teaching scores a difference of 0.54 on the indicators of operating experience, and scores 8.84 on the indicators of observational experience. it shows that augmented reality technology tends to be perfect in the rendering of physical objects, and is able to provide the learners with a sense of real experience that approximates the real object, coupled with augmented reality's technology features can well present realistic rendering in visual effects, making the learners' visual experience and cognitive effects relatively good.

(2) From the mean value of cognitive effect index data, augmented reality technology assisted teaching is more conducive to helping students recognize the essence through the phenomenon, and the score of the essence index reaches 6.72, which indicates that in the process of teaching activities, the physical model embodies the characteristics of incomplete types and inconvenient to be carried, while the augmented reality teaching media are relatively easy to be carried and simple to be operated, and the augmented reality technology is able to provide a better understanding of the characteristics of the physical model and complex substances which are inconvenient to be constructed. Convenient to build physical models, complex substances, using 3D simulation rendering to the real situation, to help learners acquire knowledge at a deeper level, which is difficult to achieve the experience and cognitive effect of using other teaching methods, reflecting the value of the application of augmented reality technology-assisted teaching.

Table 3 Student Classroom Behavior Record Sheet

Experiences	**Hands-on experience**		**Observational experience**		**Abstract experience**	
Teaching methods	Manipulate	Immersion	Heed	Space structure	Cognitive effect	
					Phenotype	Hypostasis
Traditional teaching	2.32	2.94	1.82	1.94	7.27	2.75
Object lesson	8.57	8.15	8.66	8.16	7.63	2.39
Video instruction	2.13	5.70	3.48	5.57	6.55	3.65
AR Teaching	9.56	8.69	8.84	8.23	2.32	6.72

Analysis of Teaching Effectiveness

This paper collects data through observation, classroom video, and children's works in the art classrooms of Class A and Class B of an elementary school, in which Class A is taught through AR devices and drawing tools, while Class B is taught through traditional drawing tools, and five observers in each class conduct on-site observation according to an observation scale, which is used to understand the children's specific performance during the activity, including initiative, interest, concentration, independence, and skillfulness in manipulation. The main aspects include initiative, interest, concentration, independence, and skillfulness.

To analyze the differences in classroom observation data of class A and class B, this paper mainly conducts an independent t-test on the observation scores of the two classes, and calculates the average scores of the observation indexes of the two classes as well as the t-value and p-value. Table 4 shows the results of the difference analysis of classroom observation data. In Activity 1, the P-value of Class A and Class B in the difference analysis of coloring and creativity is greater than 0.05, which can be learned that the difference between the two classes in coloring and creativity is not significant, while the P-value of these two indexes in Activity 2, Activity 3, and Activity 4 is less than 0.01, which indicates that there is a significant difference between the two classes in coloring and creativity.

According to the results of classroom observation data analysis, it can be learned that the T-value of the two classes in Case 1 in terms of initiative, interest, concentration, independence, proficiency in the operation of drawing tools, coloring and creativity are all greater than 0.05. From Activity 2 onwards, Class A added the augmented reality device for teaching, while Class B still adopted the traditional way, which shows that the application of augmented reality technology in art activities for young children can significantly improve children's initiative, interest, concentration, coloring and creativity.

Table 4 Results of difference analysis of classroom observation data

Activity	Sports event	Classes	Average score	T-value	P-value	Degree of significance
Activity 1	Color	A	3.28	0.044	0.967	Insignificant
		B	3.27			
	Inventive step	A	1.87	0.071	0.945	Insignificant
		B	1.85			
Activity 2	Color	A	3.69	1.299	0.003	Significant
		B	3.38			
	Inventive step	A	1.65	2.898	0.008	Significant
		B	1.12			
Activity 3	Color	A	3.83	0.938	0.004	Significant
		B	3.64			
	Inventive step	A	2.19	0.523	0.008	Significant
		B	1.88			
Activity 4	Color	A	4.01	1.249	0.001	Significant
		B	3.75			
	Inventive step	A	2.28	2.409	0.002	Significant
		B	1.59			

Conclusion

In this paper, starting from the theory of virtual reality and augmented reality technology, the concept is integrated into the design of the subject and the design of the learning model based on virtual reality context is realized. The chemistry learning module and children's art are used as examples for learning practice, as well as system usability evaluation and testing to verify the usability and applicability of the system in learning. The conclusions are as follows:

(1) Technology Detection and Engagement Analysis. The model error in the VR/AR technology method is 2.4121, and the pose recognition similarity is all around 0.85. This shows the robustness of the method against occlusion. The highest engagement levels of more than 90% were achieved in all the instructional activities for entertainment, education, aesthetics, and escapism to maximize the emotional satisfaction and cognitive benefits for the learners.

(2) For the chemistry learning module, the students' hands-on experience indicator score through the AR/VR learning model is 9.56, and in the indicator of observation experience, the score is 8.84. From the cognitive indicators, the score of the essentiality indicator reaches 6.72. It shows that the VR/AR technology is able to use 3D simulation rendering of substances that are inconvenient to build a physical model and complicated to a real situation, helping learners to acquire knowledge at a deeper level. Deeper level of knowledge acquisition.

(3) In the art learning module, the P-value of coloring and creative ability of the class that added the VR/AR learning model is less than 0.01, and the T-value of all indicators is greater than 0.05. It shows that the model can significantly improve the initiative, interest, concentration, coloring and creative ability of young children.

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