Research on the teaching mode of improving the learning efficiency of university students based on VR technology

Ying Chen

School of Tourism and Geographical Sciences,
Yunnan Normal University,
Kunming 650500, China
Email: 332541086@qq.com

Lede Niu*

School of Tourism and Geographical Sciences,
Yunnan Normal University,
Kunming 650500, China
and
Teaching Affairs Office,
Yunnan Normal University,
Kunming 650500, China
Email: lede@36haojie.com
*Corresponding author

Abstract: In order to solve the problem of low learning efficiency of students under the traditional teaching mode, this paper proposes a new teaching mode based on VR technology to improve the learning efficiency of university students. This teaching mode is based on VR theory. It constructs VR teaching data background, including teaching organisation information and event system, which together constitute the current classroom VR immersion teaching environment. Relying on VRPC interface and high-performance CPU, it builds VR development platform, constructs WTK, Vega, MR and other teaching tools, enriches VR teaching methods. Finally, according to the characteristics and principles of VR teaching, it designs the basis. In VR teaching platform tools and teaching background appropriate teaching mode, to achieve the improvement of university students' learning efficiency. Experimental data show that the education model can effectively improve the learning efficiency of students, and the highest learning efficiency can be increased by 50%.

Keywords: VR technology; VR teaching; teaching background; creativity.

Reference to this paper should be made as follows: Chen, Y. and Niu, L. (2022) 'Research on the teaching mode of improving the learning efficiency of university students based on VR technology', *Int. J. Continuing Engineering Education and Life-Long Learning*, Vol. 32, No. 1, pp.48–64.

Biographical notes: Ying Chen received his Bachelor's in Management from the School of Tourism Management of the Sanya University in 2019. She is currently studying at the School of Tourism and Geography Sciences, Yunnan Normal University, studying for a Master's in Education. Her research interests include geographical education.

Lede Niu is a Master's tutor and received his Master's degree in the School of Geographical Sciences from the Xi'nan University in 2007. He is currently an Associate Professor in the Teaching Affairs Office, Yunnan Normal University. His research interests include human geography and teaching management.

1 Introduction

With the rapid development of modern electronic science and technology, the traditional teaching methods can no longer meet the needs of teaching, and new multimedia teaching methods are constantly emerging and upgrading. After the last multimedia education upgrading, a new teaching digital technology is applied in the teaching field, which is VR technology. That is, virtual reality technology (Lee and Shvetsova, 2018). Virtual reality technology is a new comprehensive science and technology that was discovered at the end of the last century and gradually emerged in recent years (Butt et al., 2018). In VR technology, there are many kinds of parallel technology, such as image processing technology, computer technology, multimedia teaching technology, information sensing technology and so on (Skedsmo and Huber, 2019). Many information science and technology experts regard VR technology as a branch of information science and technology, because VR technology can generate virtual reality images at any time, and the visualisation and sound effect of the impact have a distinct Cubism feeling, the whole human-computer interaction process depends on the background skills, through VR technology can build a virtual reality teaching environment (Matton et al., 2018).

At present, many scholars have studied the teaching mode to improve the learning efficiency of university students, and have made relevant research results. Zhang et al. (2017) proposes a teaching model based on augmented reality technology to improve the learning efficiency of university students, and establishes a detail learning model to improve students' understanding and memory of learning content. However, the information presentation mode of this teaching mode is relatively single, which is difficult to improve the learning efficiency for a long time. Song et al. (2018) puts forward the teaching mode of improving learning efficiency of university students based on the blockchain technology. According to the requirements of improving learning efficiency and the characteristics of the blockchain, the learning efficiency improvement model based on the blockchain is refined and formed, and a multi-party collaborative learning efficiency improvement standard process is constructed to improve the durability of learning efficiency improvement. However, the overall scheme of the teaching mode is more complex and difficult to be widely accepted by university students. Gao (2017) puts forward the teaching mode of improving the learning efficiency of university students based on the improved ant colony algorithm, establishes the model of improving the learning efficiency of students, formalises the tasks of each link in student learning, completes the setting of task distribution matrix and objective function of each link, so as to improve the learning efficiency of university students, but the effectiveness of the teaching mode is poor.

In order to solve the problems existing in the above teaching mode, from the perspective of education and teaching research, and with the purpose of improving the learning efficiency of university students, this paper puts forward the method of improving the learning efficiency of university students based on VR technology. The overall scheme of the teaching mode is as follows:

1 Based on VR technology, build VR teaching data background model, including teaching organisation information and a variety of teaching systems, to complete the construction of immersive classroom environment.

2 Depending on VRPC interface and high-performance CPU, build VR development platform, construct WTK, Vega, MR and other teaching tools, enrich teaching methods and stimulate students' interest in learning.

3 According to the characteristics and principles of VR teaching, design the teaching mode suitable for VR teaching platform tools and teaching background, and complete the research on the teaching mode of improving learning efficiency based on VR technology.

4 Experimental verification, with classroom feedback and teaching time as comparative indicators, this method is compared with Zhang et al. (2017) and Song et al. (2018), and the experimental results are analysed.

Through the above teaching mode research program, it is to achieve the rapid and effective improvement of university students' learning efficiency.

2 Research on the teaching mode of improving the learning efficiency of college students

So far, there is no completely agreed concept of VR in the academic circles of science and technology, because many experts think that if a clear definition of VR is given, its development will be limited. The understanding of VR technology in design includes the following research on education, which focuses on VR virtual computer and environment sensing, and constructs the unique 'immersion' simulation environment of VR technology. In short, it is to construct the immersion world with the software and hardware included in VR technology, improve the visual, auditory, tactile and other information channels of university students, so that they can feel the advanced teaching and education ideas provided by the designers, and apply an interactive virtual environment. Students and instructors enter the simulation environment through the computer interface, and realise the visual interaction between students and teachers, as shown in Figure 1.

The design takes VR technology as the core, and the proposed learning efficiency improvement method needs to focus on the application of 'three characteristics' of VR technology. The three characteristics are interaction, immersion and imagination. The above three characteristics together build the three parts that people feel most strongly in VR environment, to ensure the interaction between VR system and people. From the design point of view, we must first ensure that university students have a 'real' teaching experience (Jagušt and So, 2018). This kind of reality is 'immersion' and 'devotion'. That is to say, we need to devote ourselves to the illusion of virtual reality construction. Ideally, it is better to achieve a certain degree of fidelity, even more true than 'true'. This sense of immersion can fully mobilise students' attention, so to achieve this goal, three basic technical elements need to be guaranteed, as shown in Figure 2 (Hang et al., 2018; Hao et al., 2018).

1 Imagery: In the construction of virtual environment, in order to ensure that the learning object has three-dimensional structure display, we need to pay attention to the polygon generated by human vision, according to the difference information under the motion vision, to ensure the grandness of the image, so as to ensure that the world observed in the image rather than the world measured by the image appearance (Bower and Kawaguchi, 2018; Ali et al., 2018).

2 Interaction: Three dimensional interactions between virtual objects and users. Students can control teaching objects and objects in virtual environment. Because this interaction remains in a state of perception, users can interact with objects in a natural way.

3 Behaviour: In the movement of virtual world, VR image needs to improve the mutual position information, or ensure the interaction between objects. Its dynamic service needs to conform to the discipline design information law, under the guidance of objective law, ensure the authenticity characteristics of objective information.

Figure 1 VR technology related fields

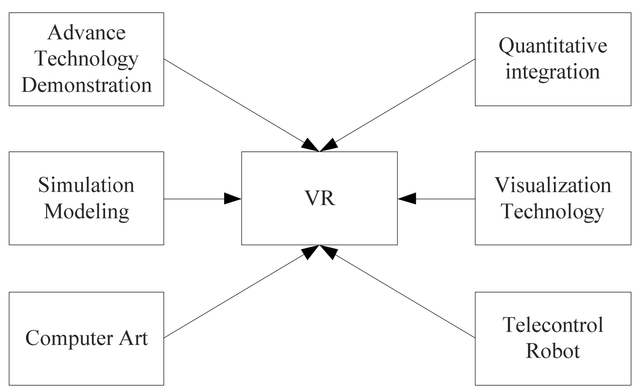
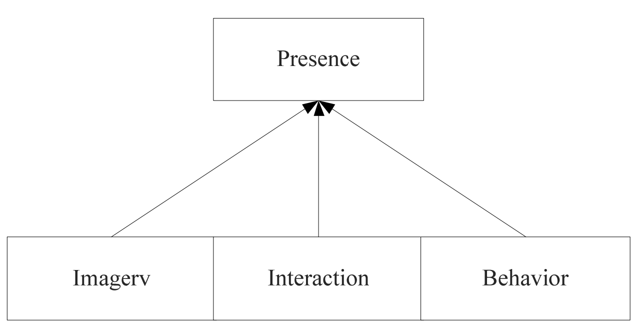


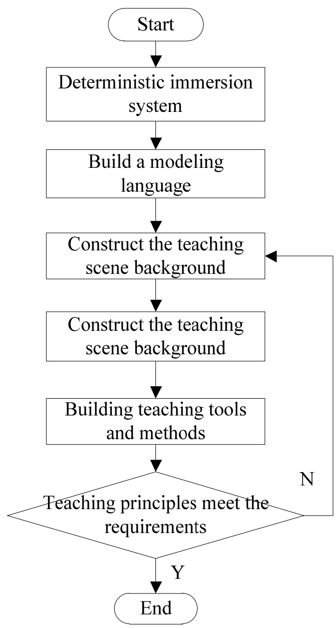
Figure 2 Technical elements of realism



In order to improve the sense of VR system stereoscopic visual effect, CRT display and stereoscopic image technology should be applied to improve the real sense of teaching classroom.

To sum up, the teaching methods proposed in the design take VR environment technology and equipment technology as the core, first determine the modeling language of virtual reality, so as to build the teaching 'immersion' scene, including the teaching scene map and the basic teaching practice system (Selim et al., 2018). Relying on VR development to build software and hardware teaching platform, as a collection of VR materials and virtual reality teaching development tools, and finally according to the practical characteristics of virtual primary school, put forward virtual teaching methods and application principles to achieve the teaching structure innovation under the support of VR technology. The overall process is in Figure 3.

Figure 3 Design process of learning efficiency improvement method under VR technology for university students



2.1 VR teaching background modelling

For VRML file browsing environment and browser, select data version above Netscape Navigator 3.05, and for VRML plug-in, select ns self-contained running version (Aghakarimiha et al., 2017). The development environment depends on the text editor, such as the UltraEdit provided by windows. In the design process, VRML file can be used as a single format file, which includes the following four parts: data file header, file comment, file node part and file value field (Nguyen and Yun, 2018; Sitzmann et al., 2018).

1 File header: Located at the beginning of VRML file, it can provide the development editor with file version information and data information name. Generally, it is

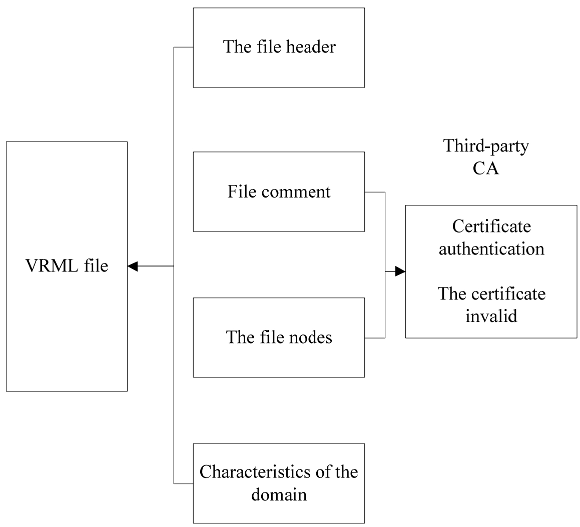
divided into three parts, including '#' part, version number and UTF-8 character part (Telles and Terlevich, 2018).

2 File notes: Generally, the file name starting with #, ending at the end of the line, does not support multi line annotation.

3 File node: Scene information unit, which can be used to edit the current teaching scene modelling, including data file scene animation and so on.

4 File value field: It is used to effectively describe the attributes of file nodes and reflect the value domain transformation.

Figure 4 Features of VRML file



It should be noted that the VRML file used in the design mainly exists as the following interpretation of the program, which can model and colour the background of the current VR text program.

In virtual space, firstly, coordinate parameters B, L and H are constructed, where B and L respectively represent the horizontal and vertical coefficients of the background in virtual environment, and H represents the elevation of the file construction point. On this basis, the three-dimensional coordinate systems of X, Y and Z representing the measured points are constructed, and the conversion formula is as follows:

$$X = (N + H)\cos B \cos L \tag{1}$$

$$Y = (N + H)\cos B \sin L \tag{2}$$

$$Z = \left[N - (1 - e2) + H\right]\sin B \tag{3}$$

In the formula, N is the initial parameter of coordinate system.

The scene graph constructed according to coordinates can abandon the traditional tree structure, but build a kind of data structure similar to the acyclic graph, because the current VR background nodes are constructed by upper nodes. Design the overall application of DEF statement, generate the following file features, and use statement reference, background node generate background copy. The specific method is to insert the background node into the scene map infinitely, so as to ensure that the two nodes share a lower level node, and lay the structural layer of the teaching scene map in the VR scene (Giavridis et al., 2018). Depending on the scene information of the current image node, different data types can be divided. The first is to divide the node level through the rendering strength of the image background.

Figure 5 shows the second-order hierarchical relationship of VRML files forming the scene graph.

Figure 5 Schematic diagram of class II hierarchical relationship

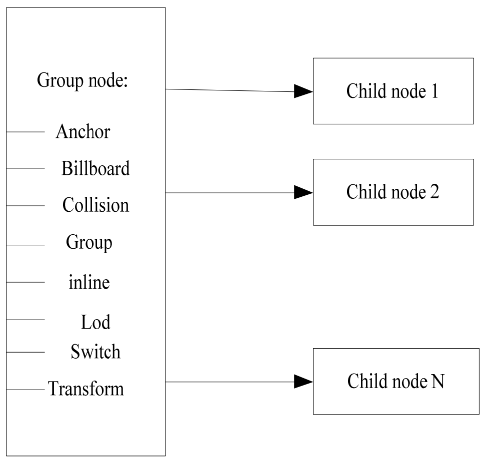
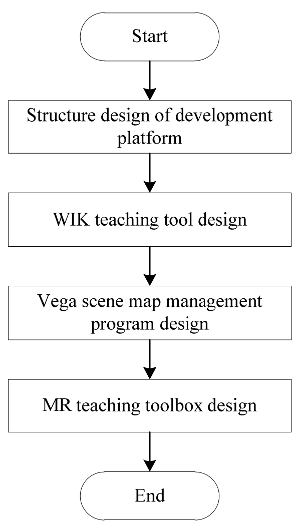


Figure 6 VR technology implementation process



In addition to background construction, the generation of event system is also an important part of building teaching environment. VRML2.0 is used as the construction tool in the design to build the time system of the scene map. Compared with the traditional VRML files, the biggest advantage of VRML2.0 is that it can effectively improve the interactive dynamic logic of teaching scenes, which is an important advantage of building urban background events. According to the value of time domain and node value, events are constructed. The value of domain value can locate the current time node. Events can provide the current node with information transfer organisation capability in the external environment (Bandrauk et al., 2018; Leónet al., 2018).

The initial reason for generating educational events according to the background node is the change of VR education environment and background. With the extension of university students' interaction time cycle, VR detection node can clearly perceive the change and initialisation of current background effort. In addition, if it is necessary to propose event definition for the current education environment, it can be constructed according to script node script. Script is a node micro course in the world. It contains a set of unique organisation script description languages, that is, the principles and methods of filtering scenarios written in Java, as shown in Table 1.

Table 1 Syntax of AR/VR scenario principle

The first paragraph	*In the middle*	*Late*
TXTetage	spagicle	Execute solution
TXTetage	spagicle	Execute solution
TXTetage	MFVec2f	Backup solution
TXTetage	MFVec3f	spine
xilerd	spagicle	Execute solution
xilerd	TFCcwoe	TRUE
xilerd	TFCcwoe	Execute solution
xilerd	TFCcwoe	crossSection
xilerd	SFBooI	endCapTRUE
xilerd	spagicle	Backup solution
xilerd	MFVec2f	Backup solution 1
xilerd	TFCcwoe	Always losing
xilerd	SFBooI	Always losing
xilerd	TFCcwoe	Always losing

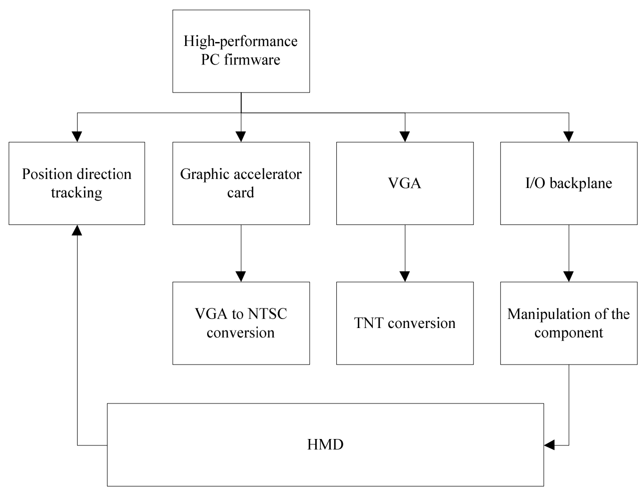
2.2 VR virtual teaching tools

VR technology is based on the technology of building virtual experience environment by computer system. It can generate simulation environment by computer simulation and realise the interaction of various information resources. In the three-dimensional dynamic scene, users can get the maximum immersive experience. Using VR technology to build a new model to improve teaching efficiency can make students fully absorb knowledge in 3D virtual scene. Based on VR technology, this paper constructs a virtual teaching tool development platform, and designs WTK teaching tools, Vega scene map management program, Mr teaching toolbox to complete the construction of teaching model.

The implementation of VR technology teaching depends on not only VR immersion teaching environment, but also the application of VR teaching tools. Therefore, VR development platform is designed and added as a tool component VR classroom supporting teaching tools. Firstly, the development platform is built. In order to meet the current teaching needs, the VR platform designed in this paper is composed of PC, which not only has low cost but also can improve VR performance and meet the teaching environment of domestic universities. The overall implementation process of VR technology is shown in Figure 6.

Figure 7 shows the overall structure of the current PC VR teaching tool development platform.

Figure 7 Structure design of virtual teaching tool development platform

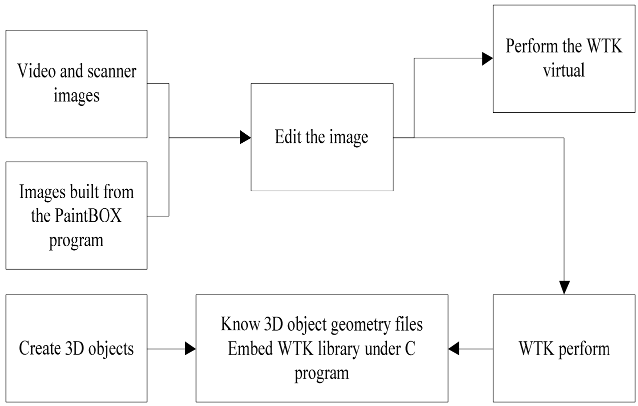


As can be seen in the figure, the design and development platform is based on a high-performance CPU, including the technology of 3D graphics phenomenon. According to the behaviour of PC, the virtual part is generated. The first is to improve the students' sense of the scene; the second is to use VR exclusive image and audio technology to obtain three-dimensional feature images; the third is to use human-computer interface hardware to ensure the output and input of DXF transmission files.

2.2.1 WTK teaching tool design

In order to effectively improve the learning efficiency of university students and build a complete VR technology teaching system, it must be based on teaching flexibility, portability, teaching interaction and so on. Based on the above development platform, the design method of WTK teaching tool is proposed. WTK uses a VR teaching object naming method to complete teaching organisation, including teaching scene, teaching object, teaching polygon, teaching fixed point, teaching path, teaching sensor, educational visual point, teaching entrance, teaching light source, etc. WTK teaching tools can be used to construct multiple teaching scenes, and all teaching activities and scenes include various teaching objects, such as sensor devices, light sources, animation sequences, teaching entrances, teaching application points, etc. The schematic diagram of WTK simulation process is shown in Figure 8.

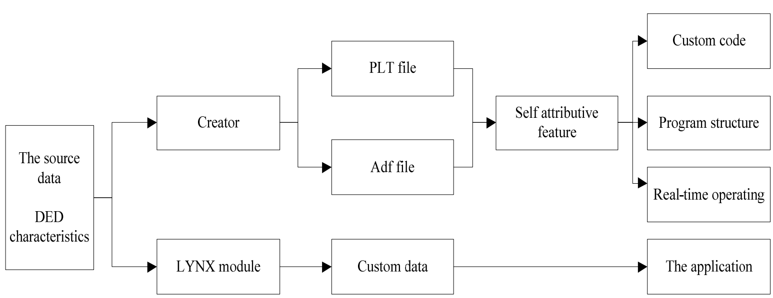
Figure 8 WTK virtual environment creations



2.2.2 Vega scene map management program design

In addition, the original scene management program of WTK is reorganised and Vega scene map management program is designed. Vega library is located at the top level of scene map management system, which functions like OpenGL. Vega on WTK tool can render windows scene graph. Using NT multi thread and multi CPU scene, the current VR teaching background data can be divided into three layers, including low-level database of tool function, OpenGL rendering part and scene management part. The three can jointly build a complete teaching application tool layer. Its overall structure is in Figure 9.

Figure 9 Vega teaching application creation process

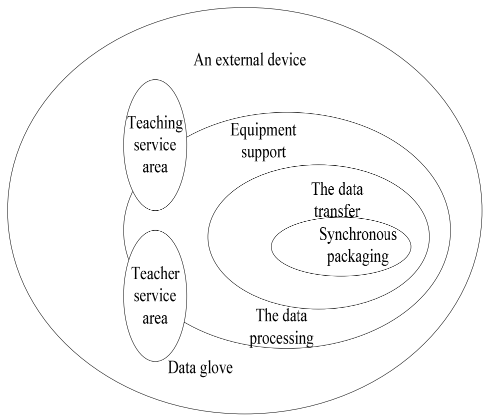


In terms of application, the original feature of Vega application is multi CPU, which uses the teaching background created by VR to construct a single frame degree background program sequence and composition tasks. Because Win57 thread technology realises the demand of large-scale teaching application development, the design uses ADF tool as the initial configuration, and then uses the API dynamic modification program to change the data process service at any time, so as to ensure the teaching task complex education requirements.

2.2.3 Mr teaching toolbox design

MR teaching toolbox is a kind of auxiliary VR teaching tool, which is mainly developed by using virtual development program library files. It supports Polhemus space tracking, VPL data glove and voice device synthesis virtual tracking, etc. In practical application summary, MR also supports distributed user experience interface, including resource sharing of data users, data teaching technology, course data analysis, etc. MR toolbox can use SGI and DEC tool station of PC to call data directly. The basic principle of the toolbox is in Figure 10.

Figure 10 MR teaching toolbox software environment



According to the information in the figure, MR teaching tool software includes a three-tier structure of the library structure.

The lowest layer is the function data package supported by the device. Each data package corresponds to a VR teaching device, which is called the external function structure of the teaching part group server as a whole. The server part adopts a kind of continuous sampling fast filtering underlying operation process structure. When the server device transmits update data, the device interface can be unified.

The second layer of MR teaching toolbox is the device processing layer, which can be transformed into the format functions preferred by programmers. The function of this layer also provides the quality module relations, including the quality conversion comparison of the control panel of the teaching object, the momentum comparison of the execution object, the difference value of the conversion of the teaching data and the total source of the comparison. The formula is as follows:

Control panel quality conversion comparison formula:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i) = S_m \tag{4}$$

In the formula, S_m represents the proportion of the internal decentralised quality of the current assembly teaching element and the VR two connected space quality; ρ is the current network domain volume space density; t is the current control time; u_i represents spatial density function. Because in the virtual space, it needs to integrate different positioning data:

$$\frac{\partial}{\partial t}\iiint_{vol}^{1} \rho dxdydz + \iint_{A}^{1} \rho dA = 0 \tag{5}$$

Execution object momentum comparison:

$$\delta_F = \delta_m \frac{dv}{dt} \tag{6}$$

In the formula, δ_m means to guarantee the overall quality of the execution object data.

Data conversion difference expression formula:

$$\frac{\partial t}{\partial l} + u\frac{\partial t}{\partial x} + v\frac{\partial t}{\partial y} + w\frac{\partial t}{\partial z} = \frac{\lambda}{\rho c}\left(\frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2} + \frac{\partial^2 t}{\partial z^2}\right) \tag{7}$$

In the above formula, l, x, y and z represent the scores at all levels in the current VR space domain, and λ represents the ratio of teaching data source values. In addition, in the process of completing MR data processing, in order not to affect the northbound of VR structure, it is necessary to introduce VR module mathematical expression based on the above formula results:

$$-\rho u_i u_j = \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) \tag{8}$$

where i and j are the current spatial data density.

The top level of MR is teaching package services. These teaching services are based on the VR requirements of the system. Their library function values need to clearly handle the real data structure relationship.

2.3 VR virtual teaching model design

VR virtual teaching is a practical teaching activity, which needs to implement reasonable teaching tasks and build reasonable teaching content according to the specific teaching system. Applying the VR teaching platform and background data designed above, the corresponding concrete teaching scheme is designed.

In the process of using VR technology for teaching, relevant instructors can use the above development tools and reasonable teaching model in the VR teaching background, so that students can intuitively understand the connectivity between teaching knowledge. The teaching model is mainly divided into VR entity model and VR mathematical model. Entity model can directly show the form and operation mode of teaching object. As an efficient and highly integrated teaching tool, mathematical model needs to construct teaching structure according to current educational logic thinking and mathematical concept. Its content and teaching objects need to be consistent. According to the teaching model, the instructor can analyse the classroom knowledge and improve the awareness. On the one hand, immerse in the interaction of VR virtual environment, on the other hand, improve their learning skills.

3 Verification of teaching mode

In order to verify the overall performance of the VR technology-based college students' learning efficiency improvement model, a comparative verification experiment was carried out. The overall scheme of the experiment is: Taking the classroom feedback and teaching time as the experimental comparison index, the proposed model is compared with the Zhang et al. (2017) and Song et al. (2018) teaching model for verification. 100 teachers from 1,000 students of the same grade in a higher education institution in this city were selected as the experimental subjects.

3.1 Data collection

The experimental researchers combined the current students' self-evaluation, teachers' evaluation and classroom observation data to evaluate the effect of VR technology in university students' learning and life. The data collection and collation of the study mainly includes the following three dimensions: Students' listening dimension, teachers' listening dimension and guidance teachers' dimension. Data collection in different dimensions adopts different ways.

3.1.1 Data collection in student dimension

The experimental students collected data from the perspective of effect test, virtual reality device self-evaluation and face-to-face interview. Prepare the test questions of students' learning effect, and collect the questionnaire of students' self-evaluation data. The student interview is a record of the teacher's after-school interview with individual students. Because in the specific teaching process summary, each round of students completed the VR immersion teaching content experience in the classroom time, so students can freely select the interested parts when filling in the effect test questionnaire.

3.1.2 Data collection in the dimension of teachers and instructors

Researchers can be regarded as not only researchers of VR teaching mode actions, but also data receptors. Through listening to the relevant teachers in class, the researchers observe and record the students' classroom from the perspective of other teachers, and combine the data with their own from the perspective of the teachers to sort out an evaluation and reflection data.

3.2 Classroom feedback comparison

According to the feedback of the classroom survey data, the specific data of three classes of ABC under the experimental evaluation are calculated by using Excel table. The dimensions include the average scores of classroom comfort, adaptability, interaction, interest and immersion. And compare it with the regular classroom feedback data. The results are in Figures 11 and 12.

It can be seen from the comprehensive selection of student evaluation data and class data that VR teaching mode can greatly mobilise students' interest in learning, and even some students take the initiative to request to improve the class time, which is a rare phenomenon in traditional classroom. From the data analysis of students' self-evaluation, it can be seen that compared with the traditional teaching mode, students are easier and more willing to accept VR teaching mode. Most of the instructors said that VR technology applied in teaching can effectively improve the utilisation rate of teaching resources and teaching efficiency, and ensure students to devote themselves to teaching knowledge. From the dimensions of comfort, adaptability, interaction, interest and immersion, it also fully shows that this teaching method can effectively improve students' learning efficiency, which is worthy of further promotion and application.

Figure 11 Comparison of VR classroom feedback among three classes of ABC (see online version for colours)

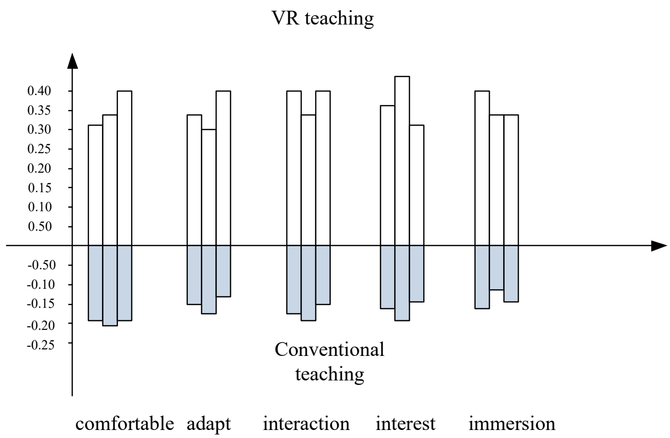
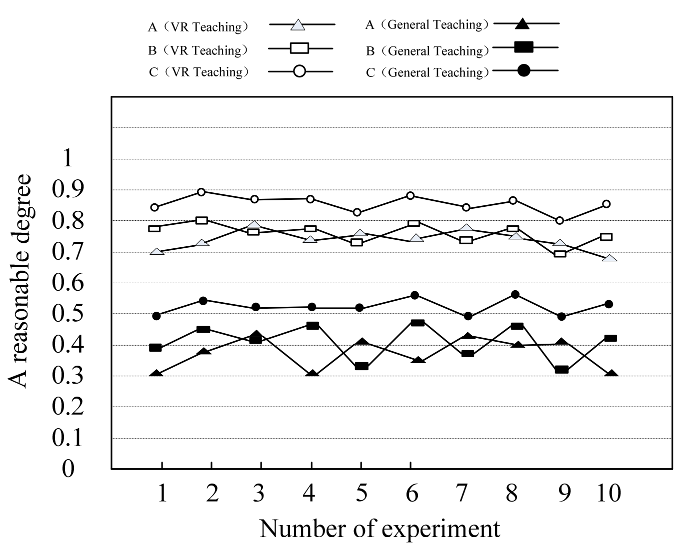


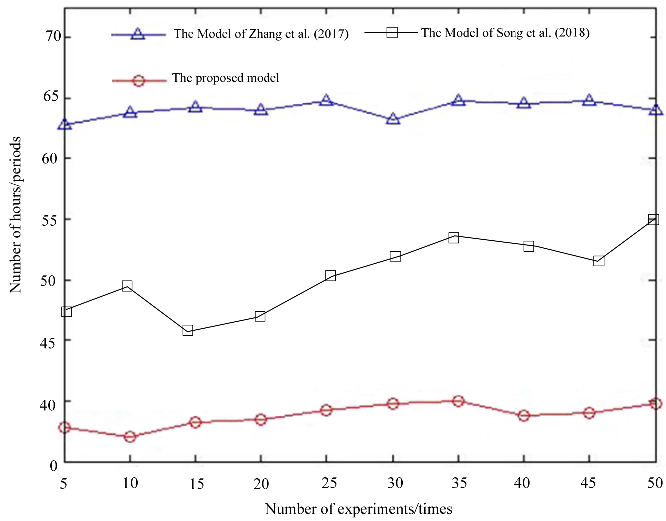
Figure 12 Line chart of evaluation dimension



3.3 Comparison of teaching hours

In order to further verify the effectiveness of the method in this paper, the teaching mode in this paper is compared with the teaching mode in Zhang et al. (2017) and Song et al. (2018) with the teaching duration of a single subject as the comparative index. The comparative results are shown in Figure 13.

Figure 13 Comparisons of teaching hours (see online version for colours)



It can be seen from the analysis of Figure 13 that with the increasing number of experiments, under the proposed teaching mode, the average class hours of a single course are 36, while under the Zhang et al. (2017) and Song et al. (2018) teaching modes, the average class hours of a single course are 64 and 52, which fully proves that the proposed teaching mode can improve the learning efficiency of university students sustainably and effectively. Because this model uses VR technology to build, on the basis of stimulating students' interest in learning, improve students' learning efficiency, and achieve the effect of twice the result with half the effort.

4 Conclusions

In order to continuously and stably improve the learning efficiency of students, this paper studies the teaching mode of improving the learning efficiency of university students based on VR technology, designs the teaching background and teaching tools according to VR teaching framework, formulates appropriate teaching strategies, and implements VR teaching innovation. The core work is as follows. Based on VR teaching theory and teaching data, a set of effective teaching mode is sorted out, and corresponding teaching platform and software and hardware tools are designed to form a complete teaching system. The experimental data show that the teaching mode can improve students' interest and efficiency. In the future further research, we should focus on improving students' interest in learning, and fundamentally improve students' learning efficiency.

References

Aghakarimiha, M., Raisi, A. and Pazuki, G. (2017) 'A compositional model based on SAFT-VR and Maxwell-Stefan equations for pervaporative separation of aroma compounds from aqueous solutions', *Journal of Molecular Liquids*, Vol. 250, No. 78, pp.212–222.

Ali, S., Uppal, M.A. and Gulliver, S.R.A. (2018) 'Conceptual framework highlighting e-learning implementation barriers', *Information Technology & People*, Vol. 31, No. 1, pp.156–180.

Bandrauk, A.D., Manz, J. and Vrakking, M.J.J. (2018) 'Attosecond molecular dynamics', *Chemical Physics*, Vol. 366, No. 1, p.1.

Bower, J. and Kawaguchi, S. (2018) 'Negotiation of meaning and corrective feedback in Japanese/English eTandem', *Language Learning & Technology*, Vol. 15, No. 1, pp.1094–3501.

Butt, A.L, Kardong-Edgren, S. and Ellertson, A. (2018) 'Using game-based virtual reality with haptics for skill acquisition', *Clinical Simulation in Nursing*, Vol. 16, No. 7, pp.25–32.

Gao, Y. (2017) 'The research of complex software to ensure the quality and efficiency of fast test simulation', *Computer Simulation*, Vol. 34, No. 11, pp.300–303.

Giavridis, T., Van, S.D.S., Eyquem, J., Hamieh, M., Piersigilli, A. and Sadelain, M. (2018) 'CAR T cell-induced cytokine release syndrome is mediated by macrophages and abated by IL-1 blockade', *Nature Medicine*, Vol. 24, No. 6, pp.731–738.

Hang, W.Y., Chen, H.R., Chen, N.S. and Lin, L.K. (2018) 'Learning behavior analysis of a ubiquitous situated reflective learning system with application to life science and technology teaching', *Educational Technology & Society*, Vol. 21, No. 2, pp.137–149.

Hao, H., Padman, R., Sun, B. and Telang, R. (2018) 'Modeling social learning on consumers' long-term usage of a mobile technology: a Bayesian estimation of a Bayesian learning model', *Electronic Commerce Research*, Vol. 19, No. 1, pp.1–21.

Jagušt, B.T. and So, I. (2018) 'A review of research on bridging the gap between formal and informal learning with technology in primary school contexts', *Journal of Computer Assisted Learning*, Vol. 34, No. 4, pp.417–428.

Lee, J.H. and Shvetsova, O.A. (2018) 'The impact of VR application on student's competency development: a comparative study of regular and VR engineering classes with similar competency scopes', *Sustainability*, Vol. 1, No. 9, pp.18–41.

León, J., Medina-Garrido, E. and Ortega-Vier, M. (2018) 'Teaching quality: high school students' autonomy and competence', *Psicothema*, Vol. 30, No. 2, pp.218–223.

Matton, N., Vrignaud, C., Rouillard, Y. and Lemarié, J. (2018) 'Learning flight procedures by enacting and receiving feedback', *Applied Ergonomics*, Vol. 70, No. 12, pp.253–259.

Nguyen, T.C. and Yun, J.H. (2018) 'Predictive tile selection for 360-degree VR video streaming in bandwidth-limited networks', *IEEE Communications Letters*, Vol. 1, No. 99, p.1.

Selim, A., Rogers, W., Qian, S. and Rothendler, J.A. (2018) 'A new algorithm to build bridges between two patient-reported health outcome instruments: the MOS SF-36® and the VR-12 health survey', *Quality of Life Research*, Vol. 27, No. 8, pp.1–12.

Sitzmann, V., Serrano, A., Pavel, A, and Agrawala, M. (2018) 'Saliency in VR: how do people explore virtual environments?', *IEEE Transactions on Visualization and Computer Graphics*, Vol. 24, No. 4, pp.1633–1642.

Skedsmo, G. and Huber, S.G. (2019) 'Measuring teaching quality: some key issues', *Educational Assessment Evaluation and Accountability*, Vol. 31, No. 2, pp.1–3.

Song, J.D., Dai, B.R., Jiang, L.W., Zhao, Y., Li, C. and Wang, X.Q. (2018) 'Data governance collaborative method based on blockchain', *Journal of Computer Applications*, Vol. 38, No. 9, pp.2500–2506.

Telles, E. and Terlevich, R. (2018) 'The VRI colours of H ii galaxies', *Monthly Notices of the Royal Astronomical Society*, Vol. 286, No. 1, pp.183–208.

Zhang, S.P., Hou, W.J. and Wang, X.M. (2017) 'An AR way for pop-science knowledge learning based on virtual & real interaction', *Packaging Engineering*, Vol. 38, No. 20, pp.48–55.