Design and Development of User-Centered Virtual Reality Teaching Information System

Junming Chang(✉), Kun Luo, Qiong Ren, and Lu Xu

School of Artificial Intelligence, Jianghan University, Wuhan, China
409466559@qq.com

Abstract. User-centered design is a key part of the design and development of VR teaching information systems. The practical reasons why virtual reality teaching system is difficult to promote and popularize in practical teaching were discussed; the conditions for effective learning activities to occur were summarized; technology acceptance model was extended and mapped to learning activity conditions. On the basis of these two theories, detailed analysis was conducted from two aspects: system requirements analysis and system design, the typical process of user-centered design and evaluation was described. Taking user as the center, the paper gives effective availability design methods for VR system environment navigation, object movement, and user experience, etc.

Keywords: virtual reality · system development · teaching information system · human-computer interaction

1 Introduction

Virtual reality (VR) has been greeted with an avalanche of publicity of the education circles for its unique technological superiority and educational value in recent years. The deep integration of VR and education brought innovation of educational technologies, and caused profound changes in educational sense, teaching ways and talent development and so on. With the coming of the 5G era, there will be even broader prospects for "5G + VR" to enhance the educational quality [1]. VR + education meets with various practical barriers and difficulties in practical teaching while other industries are enjoying the benefits of advanced technology, and the main reasons can be attributed to two aspects: on the one hand, technical factors, virtual reality has high requirements for hardware equipment and software technology; on the other hand, it is more important to forget the essence of VR in serving education, and is used to applying technology mechanically, which not only fails to achieve good positive results in practical teaching, but sometimes also brings a lot of negative effects [2].

Virtual reality technology plays an important role in improving teaching and learning, but it is out of all proportion to people's expectations. The promotion and popularization of virtual reality technology meets with various practical difficulties in practical teaching, which is worth our reflection on and discussion in depth. First, this paper discussed

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the conditions under which effective teaching and learning activities occur and the technology acceptance model, and then focused on system need analysis, system design and human-computer interaction, and explored the key factors affecting the effectiveness of virtual reality teaching system.

2 Theoretical Support for VR Teaching System Design

2.1 Conditions for Effective Learning to Occur

The fundamental change in teaching lies in focusing on students' learning, and the key to effective teaching is the effectiveness of students' learning. Effective learning is not a strictly academic term; it is relative to inefficient learning and inefficient learning. Therefore, this paper defines it as whether the learner completes the learning task and reaches the learning goal within the expected time. The criterion of good and bad points of VR teaching system is not whether the technology is advanced or not, but whether it promotes the occurrence of effective learning activities.

Randy Hinrichs pointed out five indexes of any success in any education: motivation, time on task, collaboration, critical thinking, and feedback [3]. This paper further extends the above five indexes and summarizes effective teaching activities in VR+ education as follows: taking willingness to learn as motivation; taking learning readiness as starting point; taking learning experience under effective environment as an overt behavior; taking analytical thinking as covert behavior; and positive feedback as external support, as detailed in Fig. 1.

From the perspective of teaching system design, feedback is the activity of providing information on the results (correctness, appropriateness) of learning activities to learners, which is and essential link for effective learning, it can not only test and adjust learning activities, but also strengthen or weaken learning motivation. An effective learning environment is a necessary condition for learning to occur, is an external environment that influences learners' learning, and is an effective integration of the physical learning environment, resource learning environment, technological learning environment, emotional learning environment, etc. To a certain extent, an effective learning environment can increase learners' a sense of achievement and belonging, and reduces anxiety and cognitive load [4].

2.2 Extended Technology Acceptance Model

Technology Acceptance Model (TAM) was proposed by American scholar DAVIS, it is based on rational behavior theory and combined with self-efficacy, input-output theory, etc., it was originally used to explain the factors of computer being commonly used, and now it is widely used to analyze the reasons for users to accept a certain information technology product [5]. Later, Venkatesh and Davis continuously revised the TAM model, combined the motivation model, social cognitive theory and other models, and proposed Unified Theory of Acceptance and Use of Technology (UTAUT) [6].

This paper extends the theory of the technology acceptance model to the VR teaching field in combination with the conditions under which effective learning activities occur,

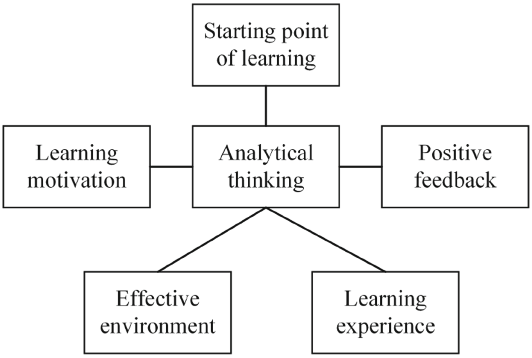

Fig. 1. Conditions for effective learning to occur

and increase the interpretability of the model, as shown in Fig. 2. Perceived usefulness and perceived ease of use are still the two most critical factors in the model and are influenced by external variables. Perceived usefulness is the extent to which learners believe their ability will be improved after using VR technology; perceived ease of use is level of difficulty for learners to use VR technology. External variables are defined as some measurable factors, which mainly contain VR teaching contents, design structure, organizational structure, task type, and individual features, etc. In practical teaching, learners are pressured by the external environments such as teachers, parents and classmates, so the influence of subjective norms cannot be ignored. Studies also confirm that subjective norms can have an indirect impact on learners' attitudes by acting with other variables, and can also have a direct positive effect on their behavioral intention. The unique immersion, interactivity and conception of VR can greatly increase the sense of fun and experience when learning, which also have a strong impact on use attitude and behavioral intention [7].

2.3 Integration of Two Theories

Only by clarifying the relationship among technology, curriculum and learners can we promote the effective integration of VR technology and teaching and truly improve teaching effect. The activity conditions of effective learning and the variables of technology acceptance model are mapped and analyzed, and the learning experience is divided into three dimensions: system environment experience, learning activity experience and learning effect evaluation [8].

1) Experience of System Environment

The experience of system environment is from the technical angle, it mainly is the learners' feelings of multi-system various elements when they are learning VR teaching system, including the feeling of whether the system's functions, design, technology, etc. are usable and effective. This is similar to perceived ease of use.

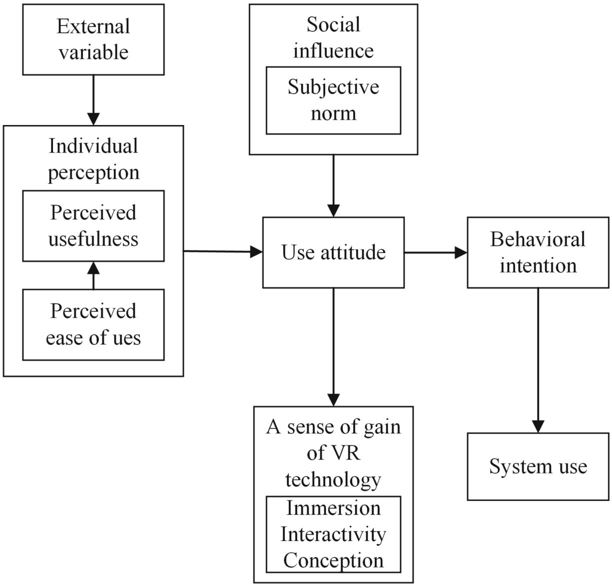

Fig. 2. VR technology acceptance model

2) Experience of Learning Activities

The experience of learning activities is from the angle of course learning, mainly is the learners' experience when participating in VR teaching system, including the cognition and perception of contents, course design, and learning interaction of VR course, etc. This is similar to perceived usefulness.

3) Evaluation of Learning Effect

The evaluation of learning effect is to take learning experience as positive feedback, it is the satisfaction and overall evaluation of the learners after completing the VR course, and is the key to decide whether the learners continue to participate in the VR teaching system or not. This is similar to attitude of wanting to use.

3 Requirements and Design Reflection of VR Teaching System

3.1 Analysis Dilemma of System Requirements

VR teaching system design is usually presented in the form of software, which requires expertise to develop. VR teaching system is a more complex project in comparison with other industries. Many problems in practical teaching practice are ill-structured problems, which cannot be solved by simple standardization, and their requirements are very difficult to analyze.

Both software engineering theory and practice process of requirement analysis of general software, people think more about the functions or features of the VR system itself, and pay very little attention to the connections between the system and the application domain or other systems. This does not apply to teaching systems. If the teaching system is taken as a reference, the influencing factors can be summarized as two parts: internal factors and external factors. Internal factors are the factors of the software system itself, such as functions, performance and operation methods; external factors, namely environmental factors and user factors, include whether it is suitable for teaching demands, and whether it is suitable for teachers and students to use.

The requirement analysis of VR teaching system is done by people with background in VR technology, and the specific implementations rely on the theories and methods of software engineering. Therefore, it can lead to the following situations [9].

- The collection work of user needs is mainly carried out by analysts in the form of questionnaires and interviews, because they lack systematic understanding of the teaching field, the collected data only stay on the surface, and it is difficult to conduct in-depth analysis of user information. Furthermore, in the follow-up development link, there is a lack of intuitive judgment on whether instructional design can promote effective learning activities.
- The most important subjects in effective learning activities, students and teachers, are replaced by abstracted teachers and students. Their specific need are inferred with teachers and students on theory. The conditions for effective learning to occur are also abstracted into universality. This will lead to a distortion from theory to practice and abstraction to concrete.
- When VR teaching system is understood as constructing an artificial object that meets specific functions, it will be automatically developed and designed towards technical aspects and are deeply branded as industrialized and streamlined operations, while ignoring the basic conditions for effective learning activities.

And when software is put into practice teaching, it must be tied to the related environment and human, etc. These features of VR teaching software determine that its requirement analysis process should not only focus on the software itself, but also focus on the conditions under which effective learning activities occur in practical teaching. It is these factors that determine whether the VR teaching system can be integrated into practical teaching from simple software form.

3.2 Cognitive Load of System Design

VR technology makes a multi-information environment through various media ways, create a highly simulated effect, makes learners immersive and gain an immersive learning experience, an effective method for thinking design, simulated environments, simulated operations, and it is an effective method of thinking design, simulation environment, simulation operation and practical exercise [10]. However, as scholars such as Richards and Taylor found, the application of VR in practical teaching may produce negative results [11, 12]. Compared to other teaching systems, the technological features of VR teaching are obvious, it is prone to design for design and technology for technology in extreme circumstances, forget that the purpose of technology is to promote learners to learn better. The following three points deserve attention.

- The numerous functions and rich scenarios in virtual worlds may distract students, and neglect the goals that really need to learn.

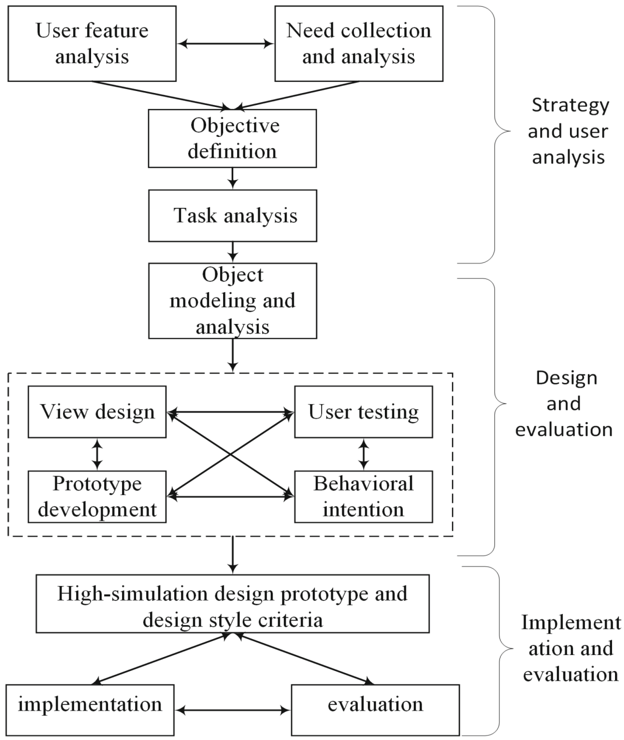

Fig. 3. User centered design process

- Although diverse information delivery ways enhance students' a sense of immediacy, can easily cause information redundancy and take limited cognitive resources.
- Inappropriate design such as content difficulty, scale and presentation mode will easily cause cognitive load and affect learning effect.

3.3 User-Centered Availability Design and Evaluation

From the above analysis, it can be seen that VR teaching information system passes through a complex process from initial requirement analysis, overall design to specific design and implementation. It can be generally divided into 3 main stages, as shown in Fig. 3.

- Strategy and user analysis
- Design and evaluation
- Implementation and evaluation

4 Design and Evaluation of Human-Computer Interaction

One of the most topics concerned in the field of human-computer interaction is how to design VR applications. VR increases the depth perception in 3D, which greatly increases the difficulty of interaction design. The research topics mainly include different aspects of design such as navigation in VR environments, user or object movement, and evaluation of VR user experience [13].

4.1 Navigation Design of VR Teaching System

A key challenge for VR navigation design is not only to provide an immersive environment and experience for the users, but also give the user some help clues in the display again. How to strike the balance between the two is one of the design difficulties. Main approaches include:

1) **Adaptive Visual Aided Design**

The basic idea of the design is to analyze the users' eye movements and the users' gaze pattern, which is used to predict whether the users need navigation assistance. If the analysis predicts that the users need navigation aids, then the miniature map or arrow are shown to suggest navigation routes. This adaptive approach can help designers and users decide the frequency of navigation aid display, and reduce the impact on the immersive VR experience.

2) **Navigation Aid of Visual Channel**

The main idea of the design is to implement the navigation of the space location with situational related sounds such as objects or subjects in the VR environment.

3) **Moving Aided Design**

Walk and movement is one of the most basic interactions in VR environments, and the moving auditory feedback generated in VR environments can both help users determine navigation position and significantly enhance users' sense of existence. As the fidelity of VR environments continues to increase, the value of the mobile experience is growing.

4.2 Object Manipulation in VR Teaching System

Object manipulation in VR environments is much more complex than 2D flat interaction design. Object manipulation is a design difficulty in VR environments where objects in 3D space are sheltered from each other. When the target object is partially sheltered by other objects or the environment, the manipulable space to select the target object becomes smaller, moreover, it increases the uncertainty of the selection. At present, this problem is mainly solved through the design of sheltered angles of four different objects: static camera angle, dynamic camera angle, cloned 3D angle, and penetrating view (Klemen Lilija, 2019). Research findings indicate that the design performance of dynamic camera angle is the worst, the penetrating and cloned 3D angle designs had the fastest user task completion times and the best user satisfaction ratings.

4.3 User Experience Evaluation

The lack of effective user experience measurement and evaluation methods is another challenge encountered by developers of VR teaching system. Currently this type of research is the exception rather than the rule. Most VR application designs are still evaluated by using traditional methods, such as questionnaire and video analysis, the indexes analyzed are mostly common usability evaluation indexes such as the success rate of task completion, user satisfaction and learning effect.

The developers of VR teaching system also need to collect special data and user experience indexes specific in the VR environment in comparison with traditional 2D interface design, mainly including the following:

- The place where the user walks.
- The users' posture and movement when interacting. With the space environment and objects.
- Users' vertiginous sensation.
- Users' perception of space navigation.

5 Conclusion

The development of virtual reality technology is extremely rapid, and its support for education is increasingly emerging, helps the application of virtual reality + education in practical teaching. Whatever the teaching method, the fundamental purpose is to improve teaching effect and promote better development of learners. In order to achieve this aim, we need start from the topic of learning activities, based on the conditions for effective learning to occur and the VR technology acceptance model, the three parts: VR teaching system requirements, system design and human-computer interaction, were applied overall in order to achieve the effective integration of virtual reality and education and promote learning.

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